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Contents:

Economic Impact of Sheep Predation in the United States

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Abstract

Though accounting for less than 1 percent of U.S. livestock industry receipts, sheep and goat operations are still important to the economies of several states in the Southern Plains, Mountain States and Pacific regions. Revenues from sales of lambs and culled ewes amount to more than three-fourths of the total receipts in the sheep industry. However, nearly 4 percent of the animals in the sheep industry are lost each year. Most of this loss is from predation. Predators include coyotes, domestic dogs, big cats, foxes and bears, and eagles. Predator losses are concentrated in the Southern Plains, Pacific States and Mountain regions, due to a high concentration of both sheep and predators in these regions.

Most previous studies have looked at the direct loss from predation. We used the Impact Analysis for Planning (IMPLAN) procedure to construct an input-output (I-O) model of the 10 USDA farm production regions to look at some of the indirect effects associated with predation. The direct value of all sheep and lambs lost due to predation for 1999 was simulated using this I-O model and the regional economic impact evaluated. The simulated impact of predator losses on the U.S. sheep industry showed that a $16 million direct loss in sheep and lambs due to predation results in a more than $12 million additional income loss over the rest of the economy. The economies of the Mountain States, Southern Plains and Pacific were most affected.

Keywords: sheep, lamb, predators, economic impact

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Introduction

In 1999, the U.S. sheep and goat sector employed 14 thousand people (Bureau of Labor Statistics, Covered Employment and Wages) and generated $495 million in gross income.[1] Although accounting for less than 1 percent of U.S. livestock industry receipts[2], sheep and goat operations are important to the economies of several states in the Southern Plains, Mountain States and Pacific regions. Revenues from sales of lambs and culled ewes amount to more than three-fourths of the total receipts in the sheep industry.

Predation is an important management decision for ranchers. Knowlton, F., E.M. Gese and M.M. Jaeger note that when organized depredation controls exist, losses to coyotes typically range between 1.0 and 6.0 percent for lambs and 0.1 and 2.0 percent for ewes. When producers were reimbursed for their losses in lieu of predator-control efforts, losses to coyotes were typically higher, ranging from 12 to 29 percent in lambs and 1 to 8 percent in ewes. Similar magnitudes were reported by Bodenchuk, M.J., J.R. Mason and W.C. Pitt, (2002). The General Accounting Office (GAO) reports a benefit cost ratio of 3:1 to 27:1 for the range of Wildlife Service activities analyzed (GAO, 2001). The range management literature reviewed by the GAO focuses primarily on the direct costs and benefits of predation-control options.

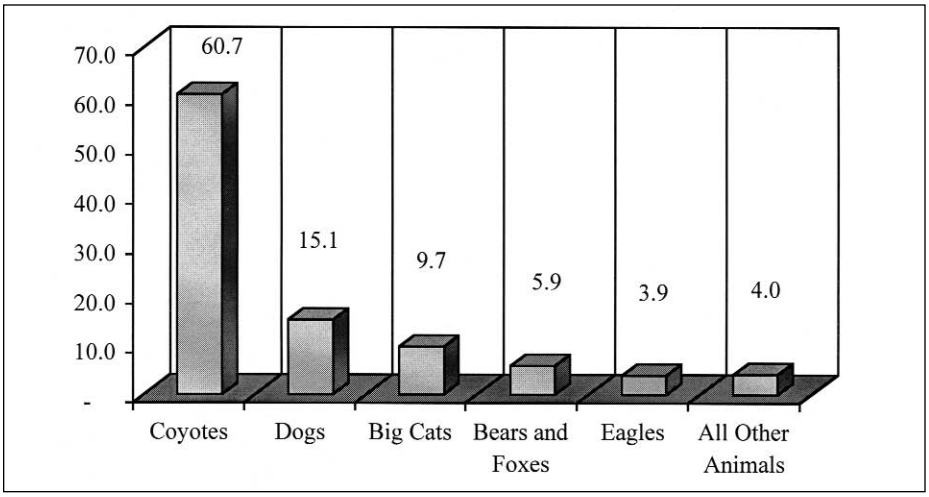
The primary objective of this study is to examine sheep predation and assess its economic impact on regional economies in the United States by examining the *indirect* as well as the direct effects. I discuss the effects of predation on sheep production in section 2. The measurement techniques, assumptions and data are described in section 3. I present the simulation and results in section 4. The conclusions are presented in the last section.

Impact of Predation on Production

Predator losses seriously deplete stock sheep inventory, especially in larger-scale herds that are not intensively managed. Theoretically, if predation reduces the number of lambs and sheep marketed, slaughter prices should be expected to increase. The degree of the price increase will depend on the elasticity of demand. Because of the large market share of imported lamb meat in the U.S. market, the demand for U.S. lamb meat is highly elastic. Nearly half of the lamb sold at retail institutions in the United States is of foreign origin. As such, U.S. suppliers are probably price takers. Thus domestic predation rates are unlikely to influence domestic retail prices. The net effect of predation is a reduction in annual gross sales. Gee et al (1977) report that in 1974 coyote predation alone may have reduced gross U.S. sales of sheep and lamb by 27 million dollars, 9 percent under what sales would otherwise have been. USDA's National Agricultural Statistic Service (NASS) reported that in 1999, sheep and lamb losses from animal predators in

[1] Includes $477.1 million in gross income from sheep, lambs and lamb and mutton and $17.9 million from the value of wool produced.
[2] The Economic Research Service Farm Income Statistics reports 1999 livestock cash receipts of $95.5 billion.

Figure 1. Percent of all sheep and goat losses from predators, 1999.



the United States totaled 273,000 head. This represented 36.7 percent of the total losses from all causes and resulted in a direct loss of $16.5 million, just over 3 percent of gross sales.

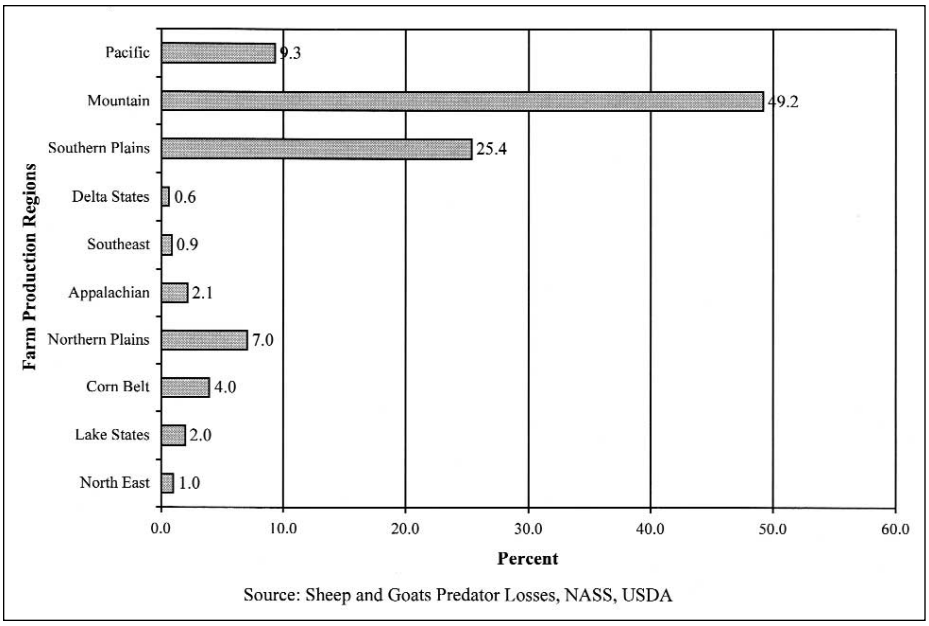
Predators also increase production costs. Gee et al (1977) reports that in 1975, U.S. sheep and lamb producers spent $11 million, or 4 percent of gross sales, on animal damage control measures. In 1999, farmers and ranchers throughout the United States spent $8.8 million on non-lethal methods to prevent predator loss of sheep and lambs, alone — 2 percent of gross sales. Predators include coyotes, domestic dogs, mountain lions, bobcats, foxes and eagles (Fig. 1).

Nearly 4 percent of the animals in the sheep industry were lost to predators in 1999 (USDA, Sheep and Goats Predator Loss, 2000). In 1974, 61 percent of all sheep predation losses were from coyotes (Gee et al., 1977). According to NASS, in 1999, the share of all predator losses attributed to coyotes was the same. Predator losses contribute to declines in inventories, leading to declines in total revenues. Losses are concentrated in the Southern Plains, Pacific States and Mountain regions due to overlapping high concentrations of both sheep and predators.

The Mountain States Region registers almost half of all predator losses (Fig. 2). It is the largest sheep-producing region with just over 37 percent of all U.S. sheep. The Southern Plains experiences a higher proportion of predator losses in relation to the number of sheep in that region. This is expected since larger operations are based in these areas, and there is likely more grazing of animals on open range where exposure to predation is greater.

Lambs are often more vulnerable to predators than mature sheep (Fig 3). In the Mountain States and Southern Plains, more than three-quarters of the animals lost to predators are lambs. Since lambs are usually marketed within one year of birth, large predator losses tend to affect producer cash flows.

Figure 2. Regional distribution of sheep and lamb losses due to predation, United States, 1999.



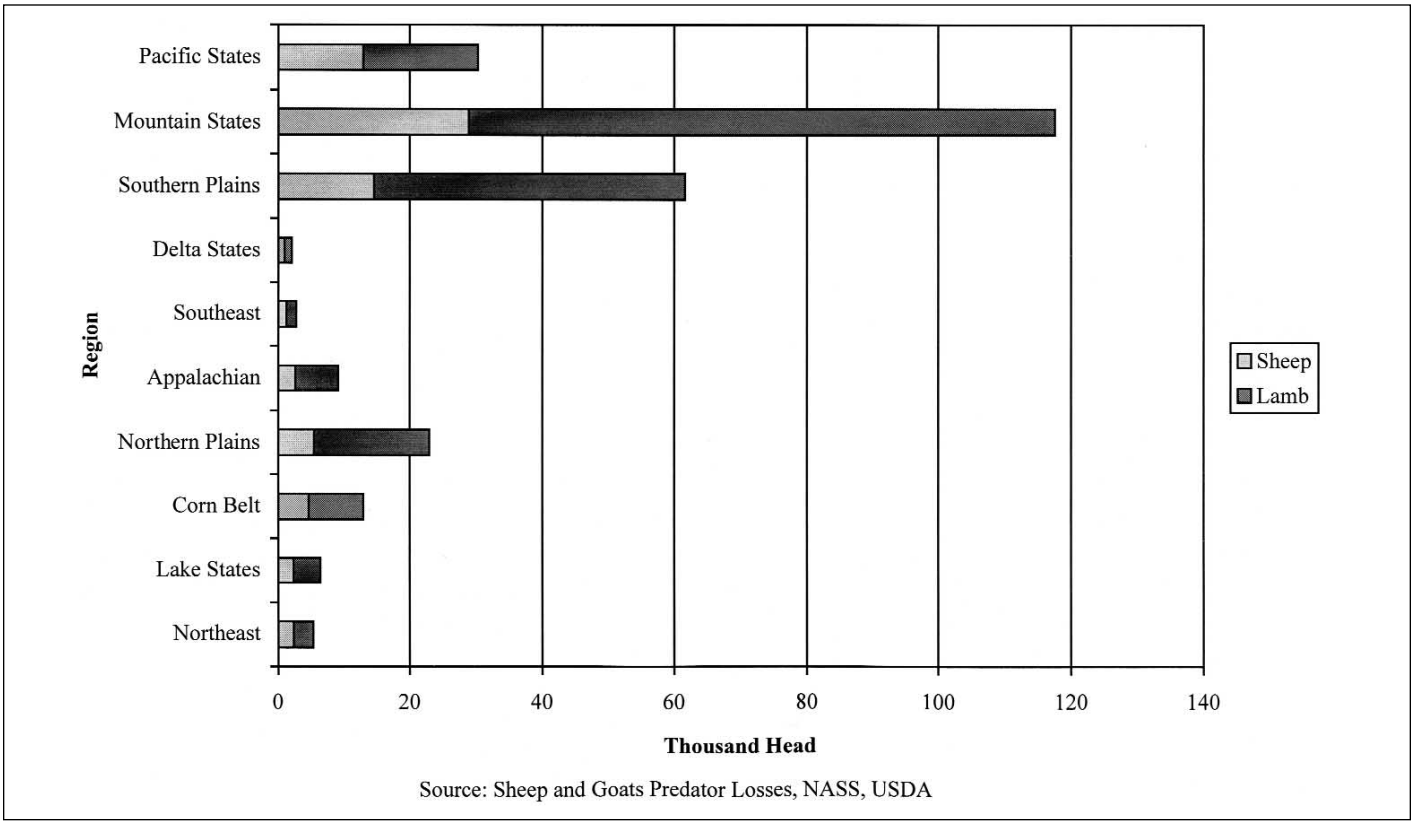
Measurement Techniques, Assumptions and Data

This analysis focuses on predation in sheep only. The Impact Analysis for Planning (IMPLAN) procedure was used to construct a preliminary Input Output (I-O) model (MIG Inc. 1997) of the United States and the 10 USDA farm production regions (Fig. 4). USDA-NASS sheep predation data is incorporated into the model to assess the regional economic impact of losses from predation on the U.S. sheep industry.

Measurement Techniques

Input-output (I-O) analysis portrays economic linkages deterministically, and requires that a sector use inputs in fixed proportions (Miller and Blair, 1985). The IMPLAN model-building procedure (Alward and Lindall, 1996) is used to construct the I-O models for the U.S. economy and its regional economies. Input-Output analysis is typically demand driven and examines the relationships within an economy, both within sectors and between sectors and final consumers. As such, the resulting simulation output model, from which multipliers are derived, is expressed as: $X = [I–A]^{-1} F$ which shows that output, X, depends on final demand, F. The multiplier matrix, $[I–A]^{-1}$ translates the given level of final demand into direct and indirect outputs for each sector. Similarly, the resulting simulation of value added (TVA) is expressed as $TVA = V[I–A]^{-1} F$ where V is the diagonal (v_i), which is the ratio of value added to industry output. Employment (l) is simulated as $l = L[I–A]^{-1} F$ where L is the diagonal (l_i), which is the ratio of number of people employed to million dollars of industry output.

Figure 3. Regional losses of sheep and lambs to predators, number by regions, 1999.

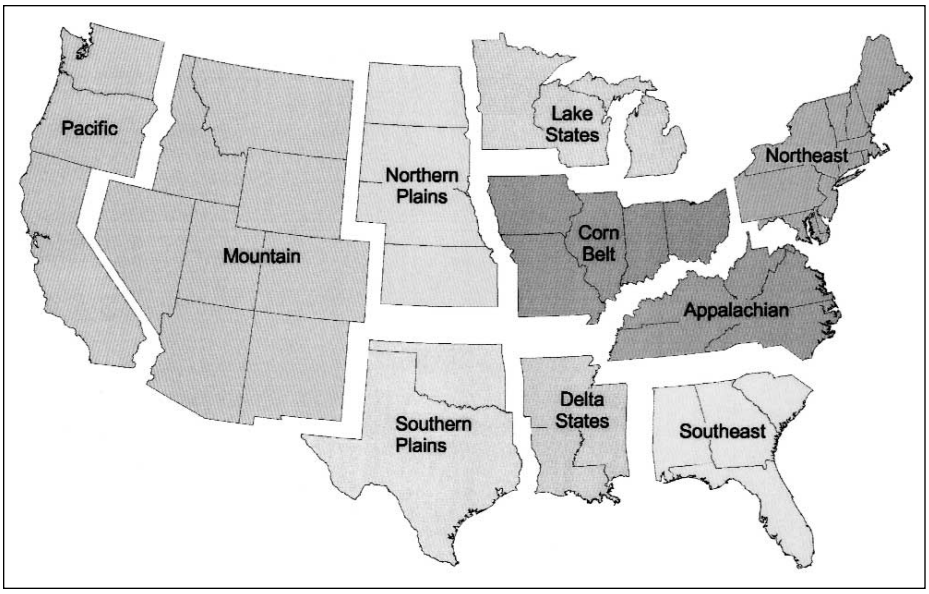


Source: Sheep and Goats Predator Losses, NASS, USDA

The economic contribution of the sheep sector extends far beyond the farm. Because sheep producers buy inputs from other regional producers, and sell their products for further processing, sheep production contributes to the vitality of regional economies. As a result of extensive linkages, fully understanding the impact of sheep predation to the regional economy requires a close examination of its direct and indirect effects of these linkages.

Input-output analysis is a straightforward tool for examining the relationship between the predation in the regional sheep industries and the rest of the regional economies. This can best be analyzed by examining the region-wide loss to the regional economies from sheep predation. Using IMPLAN to construct the regional models, we can approximate how the entire local economy would be affected if the cost associated with predation is subtracted from the sheep sector. The value of losses due to predation for each region for 1999 is used to simulate changes in the sheep industry. The value of sheep losses is deflated to correspond with the 1996 IMPLAN data, then re-inflated, after simulation, to 1999, for reporting of results.

Figure 4. USDA farm production regions.



Input-output multiplier models distribute the impacts of a shock among two components: a direct effect, and indirect effect. The direct effect shows the direct (first round) impact of a change in output due to predation on final demand. The indirect effect shows the indirect impact in subsequent rounds resulting from increased or decreased purchases from other industries in the economy.

Key Assumptions

The relationships forming the I-O analysis are based on a demand-driven modeling framework employing production equations governed by certain simplifying assumptions. First, it is assumed that no errors of aggregation exist in

each of the *n* industries in the I-O model; that industries or firms aggregated to form a particular industrial sector are homogeneous; and that at least some part of the output of industry *A* required by industry *B* will vary with the level of activity in industry *A*.

Second, it is assumed that factors of production of intermediate goods are used in fixed proportions in the production process. This implies that there are no possibilities for input substitution and no economies of scale or, in other words, the production function for each sector is a fixed technical relationship. In practice, depending on the size of the shock and given that production and the economy are dynamic systems, the assumption of constant coefficients may not always be appropriate. But in our case this assumption is justified given the small magnitude of our shock.

Third, in I-O analysis, changes in final demand are not translated into price changes. In such a framework, a perfectly elastic supply response is assumed. Changes in final demand are reflected in changing output levels for all industries and causes supply to adjust to a shift in demand along a horizontal supply curve. As such, an increase in final demand for a given industry results in a rightward shift in the demand function for that industry, meaning that those industries producing inputs will supply additional inputs, that will in turn result in corresponding increases in the output of other sectors. Such increases are as a result of a direct technical relationship with the increase in inputs, and imply changes in output, not changes in price.

Last, in estimating the value of sheep and lamb predation losses, it is assumed that all the animals are lost to predators while on range, and prior to entering the feedlot. While we are aware that lambs may be lost to predators at varying sizes and weights, it is reasonable to estimate the value of these animals at a weight of transferring them to the feedlot. Warnock and Carkner (1995) indicate that feed represents 80 percent of the total annual cash operating cost to raise sheep, but a significant portion of this cost is associated with the feed grain fed during finishing. Animal loss prior to finishing causes negligible change in cost of production associated with any given farm, since the operating costs associated with labor, hay, and grazing will change little with losses due to predators.

The Data

The regional IMPLAN database for 1996 was used as the base for analysis. The IMPLAN database provides annual, county-level data for final demand by commodity, sales by sector, transfers to households and other institutional elements and commodity transshipments. Input-output models were constructed for each of the 10 USDA farm production regions. Our simulation models were developed for these regions using the 2-digit standard industry classification (see table 4 for industries included in the analysis). The sheep and goats sector was separated from other livestock and other farm sectors for the purpose of this study. Data for the value of all sheep and lambs lost to predation was obtained from NASS, Sheep and Goats Predator Loss bulletin.

Since 1990, NASS has reported the number of sheep and lambs lost to predators and the total value of these losses. Predator losses are estimated as a percentage of total losses from all causes. Sheep value per head is based on two-year average value of ewes reported in the January 1 sheep survey. The value of lambs per head is based on the average market price. An average lamb weight of 60 to 90 pounds was used. Lambs are taken to the feedlots for finishing at between 60 and 90 pounds. Feeder lambs are fed for approximately 2 to 3 months before attaining a finishing weight of 110 to 120 pounds.

Simulation and Results

The direct value of all sheep and lambs lost due to predation is for 1999 is shown in table 1. Sheep and lambs lost to predators are valued at $16.5 million. Two-thirds of the value of all losses was seen in the Mountain States and Southern Plains combined. The Mountain States realized $7 million in losses and the Southern Plains realized $3.2 million in losses. The Northern Plains and Pacific states were the other regions realizing over $1 million in losses.

The economic impacts presented in table 2 show the effect of predation in the sheep industry on the regional economies. The multiplier model quantifies the additional activity in terms of industry output, value added, and employment generated throughout the economy as a result of direct losses due to predators. Industry output is a measure of the total outlay of the industry as a result of a direct income change in the economy. Value added is a measure of the total payments made to factors of production (labor, land, and capital) used by the industry. Value added consists of employment compensation, other property type income and indirect business taxes. Employment is expressed as the number of full- and part-time jobs needed to produce the new industry output.

Table 2 shows overall economic losses of sheep and lambs due to predation — $28.97 million dollars to the U.S. economy. Large sheep producing regions with high predator losses had less than proportional impacts on industry income, value added, and employment.

Table 1. Direct value of sheep and lambs lost from predation, 1999.

Region	Total Value ($ thousand)	Percent U.S. Losses
Southeast	-272.64	1.7
Appalachian	-611.42	3.7
Northeast	-477.50	2.9
Lake States	-398.12	2.4
Corn Belt	-931.29	5.6
Delta States	-204.48	1.2
Southern Plains	-3,221.00	19.5
Northern Plains	-1,313.00	8.0
Mountain	-7,013.17	42.5
Pacific	-1,995.62	12.1
United States	**-16,438.85**	**100**

Source: Sheep and Goats Predator Losses. NASS-USDA

For example, 49 percent of all U.S. sheep and lambs lost from predation were in the Mountain States (see fig. 2), but only just above 43 percent of the output lost in the United States from predation were lost in the Mountain States regional economy. The movement of goods within and outside the region could explain this. Because more than 7 percent of the intermediate inputs in the sheep industry are imported from outside the Mountain States region, a portion of the regional loss may be felt in other regions, thus causing a less than proportional loss.

A similar situation occurs in the Southern Plains, which imports nearly 19 percent of the intermediate inputs for the sheep industry from other regions. The Southern Plains region had 25 percent of the U.S. sheep and lamb predation losses, but less than 22 percent of the U.S. total-output loss due to predation, 12 percent of the U.S. value-added loss, and 12.3 percent of the U.S. employment loss. By contrast, smaller sheep producing regions with low percentages of the U.S. sheep and lamb predation losses experienced more than proportional losses in industry output, value added, employment due to the fact that they absorb losses from other regions. For example, the Northern Plains had 7 percent of all U.S. sheep and lambs lost from predation but experienced 8.1 percent of the U.S. total income loss due to predation, 9.3 percent of the U.S. value-added loss and 6.2 percent of the U.S. employment loss. Similar scenarios were seen in the Delta States, Appalachian, Southeast and Northeast.

Table 2. Regional economic impact of losses (direct, indirect) due to predation, United States, 1999.

	Industry Output		Value Added		Employment	
Region		%		%	**Number**	%
Southeast	-380,845	1.3	-176,466	1.9	-24	2.5
Appalachian	-972,021	3.4	-344,103	3.7	-68	7.2
Northeast	-701,446	2.4	-256,874	2.8	-42	4.4
Lake States	-658,031	2.3	-220,550	2.4	-32	3.4
Corn Belt	-1,514,435	5.2	-610,713	6.5	-56	5.9
Delta States	-286,200	1.0	-123,325	1.3	-14	1.5
Southern Plains	-6,244,828	21.6	-1,133,000	12.1	-114	12.0
Northern Plains	-2,295,446	7.9	-863,491	9.3	-55	5.8
Mountain	-12,679,099	43.8	-4,214,513	45.2	-387	40.7
Pacific	-3,236,911	11.2	-1,390,473	14.9	-159	16.7
United States	**-28,969,262***	**100***	**-9,333,508***	**100***	**-951***	**100**

*Additive and assumes no inter-regional impacts.

Table 3 shows the direct and indirect impact of predator losses in output, value added and employment. Here, I highlight the indirect effects. When the sheep industry purchases inputs from other industries, those purchases, in turn, generate indirect demands for additional inputs for the supplying industries. It was evident that regions with a larger proportion of the sheep industry and larger producers suffered greater indirect losses to output, value added, and employment. Larger farms are more likely to demand inputs in large quantities, thus industries supplying inputs to sheep are likely to be located close to where the sheep are located. The loss of indirect demand for additional inputs varies widely among the regions, from 28 percent to 48 percent of a region's total output. Larger indirect effects imply that more capital-intensive inputs from other regional industries are used by the sheep and will be lost as a result of predation. The largest share of indirect output losses was seen in the Southern Plains.

Since value added is the payment to

Table 3. Regional losses due to predation.

	Southeast	Appalachian	Northeast	Lake States	Corn Belt	Delta States	Southern Plains	Northern Plains	Mountain	Pacific
Output										
Direct	-272,644	-611,609	-477,507	-398,123	-931,289	-204,483	-3,220,997	-1,313,406	-7,013,170	-1,995,617
Indirect	-108,201	-360,412	-223,939	-259,908	-583,146	-81,717	-3,023,831	-982,040	-5,665,929	-1,241,294
Total	**-380,845**	**-972,021**	**-701,446**	**-658,031**	**-1,514,435**	**-286,200**	**-6,244,828**	**-2,295,446**	**-12,679,099**	**-3,236,911**
% Indirect	28.4%	37.1%	31.9%	39.5%	38.5%	28.6%	48.4%	42.8%	44.7%	38.3%
Value Added										
Direct	-116,975	-160,366	-133,972	-94,699	-319,135	-82,999	-337,607	-423,672	-1,631,572	-739,410
Indirect	-59,491	-183,737	-122,902	-125,851	-291,578	-40,326	-795,393	-439,819	-2,582,941	-651,063
Total	**-176,466**	**-344,103**	**-256,874**	**-220,550**	**-610,713**	**-123,325**	**-1,133,000**	**-863,491**	**-4,214,513**	**-1,390,473**
% Indirect	33.7%	53.4%	47.8%	57.1%	47.7%	32.7%	70.2%	50.9%	61.3%	46.8%
Employment										
Direct	-23	-61	-39	-27	-47	-13	-73	-41	-286	-130
Indirect	-1	-7	-3	-5	-9	-1	-41	-14	-101	-29
Total	**-24**	**-68**	**-42**	**-32**	**-56**	**-14**	**-114**	**-55**	**-387**	**-159**
% Indirect	4.2%	10.3%	7.1%	15.6%	16.1%	7.1%	36.0%	25.5%	26.1%	18.2%

Table 4. The 2-digit standard industrial classification industries.

Industry	
Other Livestock	Water Transportation
Sheep, Lambs and Goats	Air Transportation
Other Farms	Pipe Lines, Except Natural Gas
Forestry Products	Transportation Services
Commercial Fishing	Communications
Agricultural Services	Utilities
Metal Mining	Wholesale Trade
Coal Mining	Retail Trade
Oil Mining	Banking
Non-metal Mining	Credit Agencies
Construction	Security and Commodity Brokers
Food Processing	Insurance Carriers
Tobacco Manufacturing	Insurance Agents and Brokers
Textiles	Real Estate
Apparel	Hotels and Lodging Places
Wood Products	Personal Services
Furniture	Business Services
Pulp and Paper	Automotive Services
Printing and Publishing	Repair Services
Chemicals and Allied Products	Motion Pictures
Petroleum Products	Recreation Services
Rubber Products	Health Services
Leather Products	Legal Services
Stone, Glass and Clay	Education Services
Primary Metals	Social Services
Fabricated Metal	Non-profit Organizations
Industrial Machinery	Professional Services
Electrical Equipment	State & Local Non-education Government
Transportation Equipment	Federal Non-military
Scientific Instruments	Special Sectors
Miscellaneous Manufacturing.	Federal Government - Military
Railroads and Related Services	State & Local Government - Education
Local, Interurban Passenger Transit	Domestic Services
Motor Freight Transport and Warehousing	

factors of production, the quality of, and the level of compensation paid to, the inputs used determine the indirect effects. Larger indirect value-added effects imply greater compensation paid to the factors of production. Though the proportion of indirect industry output losses was never more than 50 percent for any of the regions, indirect loss in value added ranges from 33 percent in the Delta States to 70 percent in the Southern Plains with five states having value added over 50 percent.

The indirect effect on employment is much smaller and ranged from 4.2 percent in the Southeast to 36 percent in the Southern Plains. Large direct effects imply more labor intensive industries, while small indirect effects imply that the inputs used from other industries were more capital intensive in nature. Losses were greatest in the processing and wholesale trade sectors.

Conclusions

The losses of sheep and lambs due to predation reduce the number of animals available for market each year, creating secondary effects in regional economies. The extent of the impacts depends largely on the number of sectors within the regional economy that supply the sheep industry with inputs.

However, some caution is in order here. The simulated economic impacts suffer from the general weaknesses of static input-output models. As such, simulated economic impacts of a loss in the sheep industry due to predation results in an unidirectional change in all other sectors affected by this loss. This is not necessarily the case in a dynamic setting, since interactions among agents and substitution among factors of production often results in lower magnitudes of impacts than are obtained from an input-output analysis. Also, in the event of a change in one sector, full and immediate change in all other sectors that may be affected is assumed in the input-output framework. However, all sectors do not adjust at the same rate. As such, situations of temporary underemployment of resources may result. This is particularly true with labor resources. A decrease in workload on the farm may result in a decrease in activity for employees in other sectors, but due to temporary disequilibrium conditions in these sectors, the number of employees may not change. The results, therefore, should be viewed as upper bounds or the maximum loss that can be expected to the economy as a result of predation.

The simulated impact of predator losses on the U.S. sheep industry showed that a $16 million direct loss in sheep and lambs due to predation results in a more than $12 million additional output loss in the rest of the economy. However, due to the overlapping effect of regional losses, where direct losses from one region may result in indirect losses from other regions, the overall impact of the indirect losses from predation may be smaller for the entire United States. Economies of the Mountain States, Southern Plains and Pacific were most impacted, largely because most of the sheep and lambs are concentrated in these regions, and as a result, most of the sheep and lambs lost due to predation are in these regions. Also, industries supplying inputs to the sheep industry would be more likely to be located in regions where there is intensive sheep production — near the source of production. As such these intensive sheep-producing regions are likely to experience a higher proportion of indirect loss, while the less-intensive, sheep-producing states are likely to have a lower proportion of the indirect losses.

Finally, it is important, when interpreting these results, to bear in mind the assumptions of the model and to recall that the costs associated with the removal of predators are not included in the analysis. If the costs were explicitly included in the analysis, the overall economic impact of predator removal would be much less than our modeling results indicate.

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