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SHEEP AND GOAT LOSSES TO PREDATORS IN THE UNITED STATES

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Abstract: This paper analyzes and compares 3 recent estimates of the value of sheep, lambs, and goats killed by predators in the United States. The estimates, by Pearson (1986a,b), the General Accounting Office (GAO 1990), and the National Agricultural Statistics Service (MASS 19916), varied from $18 million to $59.7 million annually due to differences in scope, assumptions, data, and estimation methods of the 3 studies. Pearson's and NASS's estimates of the value of sheep and lambs lost to predators in 17 western states totaled $38.3 million and $18.3 million in 1984 and 1990, respectively. The difference between these estimates was attributed to exclusion of predocking lamb losses by NAS S and to higher estimates of sheep and lamb numbers killed as well as higher lamb values in Pearson's study. The GAO estimate of $18 million in sheep and lamb losses in 17 western states excluded losses to predators other than coyotes (Cams latrans), and was based on understated sheep and lamb inventories. Considering both direct and indirect costs, the economic impact of predation on sheep in the 17 western states probably exceeds $50 million annually.

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The magnitude and economic value of livestock losses to predators in the United States is a major concern of livestock producers and wildlife damage control workers. Most governmental activity aimed at reducing these losses, as well as most efforts to evaluate the magnitude and value of livestock loss to predators, have concentrated on the 17 western states that contain approximately 80 percent of sheep and 95 percent of goat inventories in the U.S.

A Denver Wildlife Research Center (DWRC) biologist (Pearson 1986a,b) computed thatpredators killed sheep, lambs, and goats valued at $59.7 million in the 17 western states in 1984. For convenience in this paper, Pearson's work is termed the DWRC study.

The General Accounting Office (GAO 1990) estimated that coyotes alone in the 17 western states killed sheep and lambs valued at $18 million in 1989. Throughout this paper, I refer to this report as the GAO study.

A comprehensive, national estimate of sheep and goat losses to predators was published in 1991 by the U. S. Department of Agriculture (USDA), National Agricultural Statistics Service (MASS 19916). This survey, financed in part by the USDA, Animal and Plant Health Inspection Service (APHIS), Animal Damage Control (ADC) program, indicated that predators in 49 states (excluding Alaska) caused sheep, lamb, and goat losses valued at $27.4 million in 1990. In this paper, I refer to NASS (19916) as the NASS study.

The appearance of 3 apparently contradictory estimates of sheep, lamb, and goatlossestopredators has stimulated inquiries as to which estimate is "best," or most reliable, and why the results differ. Simple and precise answers to these questions cannot be given because the studies differed in scope, assumptions, and procedures. The 3 estimates occurred during different years. The NASS survey covered the entire United States, and the others were limited to 17 western states. The NASS and DWRC surveys included goats, and the GAO study excluded them. The GAO report was also limited to only coyote predation. Moreover, market prices used to compute the value of livestock killed by predators differed widely among the 3 studies.

Such variations obviously preclude simplistic comparisons of these livestock loss estimates, yet comparisons are needed to determine why different studies produced different estimates. In this paper I analyze the DWRC, GAO, and NASS estimates of sheep, lamb, and goat losses to predators and attempt to identify the major reasons for observed differences among their conclusions.

All 3 studies concentrated on direct losses (i.e., numbers of animals killed by predators and the economic value of these animals). Pearson (1986a), however, noted wildlife depredations on livestock also generate indirect costs that should be considered in estimating the economic impact of predation. Some indirect costs of predation are identified and quantified in this paper.

This analysis originated with the need of ADC administrators and researchers for information to answer public inquiries about the DWRC, GAO, and NASS estimates of livestock losses to predators. My review of the DWRC and GAO studies included examination of working papers and information that was excluded from thosereports. Thispaperprovidesadditional, previously unpublished data and analyses that I found necessary for critical evaluation of those studies.

Aside from the 3 studies analyzed at length in this paper, many other estimates of livestock losses to predators have been published. U. S. Department of Interior (USDI) Fish and Wildlife Service biologists estimated the economic loss to sheep producers from coyote predation at $19-38 million in 1977 (USDI 1978). Wade (1982) suggested that economic losses to producers from coyote predation on lambs, ewes, and

calves in 1980 may have been about $75-150 million, plus added costs to consumers of $200-400 million. Terrell (1988) estimated that sheep and lamb losses to predators in the United States in 1987 exceeded $83 million. However, my analysis is limited to the studies of Pearson (1986a,b), GAO (1990), and NASS (1991b).

E. W. Pearson, M. Collinge, R. Robinson, and L. Simpson provided unpublished information about the DWRC, GAO, and NASS studies. These workers, G. Larson, and M. Fall also provided constructive reviews of manuscript drafts. G. Nunley provided helpful advice and information about predocking lamb losses.

METHODS

General

The DWRC, GAO, and NASS reports of livestock loss to predators have several features in common. Each dealt with losses for a single, but different, calendar year. In each study, the percentages (DWRC and GAO) or numbers (MASS) of animals lostin limited studies orby selected livestock producers were estimated. These percentages or sample estimates were then expanded state by state to the geographic region selected for analysis. Each study estimated numbers of animals of each class lost to predators, then multiplied these numbers by the value per head to get total value of animals lost to predators. Loss computations for each state were summed to produce western or national (NASS) estimates of livestock lost to predators. All 3 studies relied upon USDA Statistical Reporting Service (SRS) or NASS publications as sources of statistics on livestock inventories and values (note SRS and NASS are the same agency as the name was changed in 1986).

The DWRC Estimate

Pearson (1986x) compiled all known, published studies of livestock loss to predators by state to determine average loss percentages for adult sheep, lambs, and goats. This compilation, based on 136 publications and reports completed between 1939 and 1985, yielded annual average predation loss rates of 2.4% of adult sheep and 9.0% of lambs in the 17 western states, and 26% of the goats in Texas. These averages were the unweighted means of all loss percentages found by Pearson (1986x) for each class of livestock. Despite the obvious bias incorporated in this approach, Pearson believed that this was the best way to derive current estimates of sheep, lamb, and goat losses west-wide from available data.

To estimate total losses to predators, Pearson applied his average loss percentages to SRS (1985) inventories for stock sheep, lambs, and goats in each of the 17 western states. From the variety of inventory statistics presented by the SRS, Pearson selected those that best represented the numbers of adult sheep, lambs, and goats exposed to predators in the West (goats in Texas only) during 1984.

Dollar values for livestock lost to predators were derived by multiplying estimated numbers of animals killed by average values per head, also from SRS (1985). Numbers and v al animals killed in each state were summed to produce to the 17 western states. The computations (Table 1) did appear in Pearson (1986a,b).

The GAO Estimate

The GAO approach to estimation of livestock losses coyotes was similar to that of Pearson (1986x). General counting Office investigators relied on Pearson's compil of loss percentages, and applied them to published sheep lamb inventory statistics and values per head (NASS 1989 determine the numbers and value of sheep and lambs killed However, GAO selected different inventory statistics tore sheep and lamb populations. Pearson had used "stock she and lambs - total" on 1 January 1984 as the number of sheep exposed to predation in 1984, and the 1984 "lamb c as the number of lambs exposed to predation in that year (Tab 1). General Accounting Office, in contrast, used "stock she 1 year and older" (sum of ewes + rams and wethers) on January to represent the numbers of adult sheep exposed predation, and "stock sheep - lambs" (sum of ewes + rams weathers) on 1 January to represent the numbers of lam exposed to predation in 1989 (Table 2). The impact of the inventory differences on the resulting loss estimates will discussed later.

Yet another difference between the Pearson and GAO computations appeared in the selection of percentage loss values applied to sheep and lamb inventories. Pearson (1986x) applied average, west-wide predator loss percentages to sheep and lamb inventories in each state (Table 1), whereas GAO used different percentages for each state. These details were not presented by GAO (1990), but through the courtesy of GAO personnel were made available for inclusion in this report (Table 2).

The NASS Estimate

Unlike the low-cost DWRC and GAO projections, the NASS study was a nationwide survey. The project was partially funded by an ADC program contribution of $106,000. National Agricultural Statistics Service investigators collectedinformation on livestock losses to predators by mail, telephone, and personal interviews with producers. This study was part of a larger NASS survey on meat animal inventories, production, disposition, and income.

Primary data for sheep and lamb loss estimates were obtained from a sample of agricultural producers across the United States including all states except Alaska. The surveys included information from a list of about 57,300 agricultural producers, plus additional information from operators of about 7,500 small tracts of land. In addition to data on sheep and lamb losses, the 5 major goat-producing states (Ariz., Mich., N. M., Okla., and Tex.) also collected losses for Angora, Spanish, and other goats (NASS 1991b).

Table 1 DWRC estimates of sheep lambs and goats lost in 1984 to predators in 17 western states.a

	Inventoriesb		Losses to Coyotesc				value		Value of
	Sheep Lambs		She o Lambs		Sheep Lambs		Total	per Headd	Loss to o ote
	1000s 1000s		%	%	No.		No.	No.	$
	$1,000s								
Ariz.261	125	2.4	9.0	6,264	11,250		17,514	52.10	912
Calif.900	720	2.4	9.0	21,600	64,800		86,400	52.10	4,501
Colo.430	375	2.4	9.0	10,320	33,750		44,070	52.10	2,296
Id 355	365	2.4	9.0	8,520	32,850		41,370	52.10	2,155
Kos.165	165	2.4	9.0	3,960	14,850		18,810	52.10	980
Mont.530	455	2.4	9.0	12,720	40,950		53,670	52.10	2,796
Nebr.115	110	2.4	9.0	2,760	9,900		12,660	52.10	660
Nev. 92	83	2.4	9.0	2,208	7,470		9,678	52.10	504
N.M.525	340	2.4	9.0	12,600	30,600		43,200	52.10	2,251
N.D.165	180	2.4	9.0	3,960	16,200		20,160	52.10	1,050
Okla.75	60	2.4	9.0	1,800	5,400		7,200	52.10	375
Oreg.350	315	2.4	9.0	8,400	28,350		36,750	52.10	1,915
S.D.660	610	2.4	9.0	15,840	54,900		70,740	52.10	3,686
Tex.1,800	1,120	2.4			9.0		43,200100,800144,000	52.10	7,502
Ut. 540	430	2.4			9.0		12,960 38,700 51,660	52.10	2,691
Wash.62	50	2.4		9.0	1,488	4,500	5,988	52.10	312
Wyo._9M	_ 54	2.4			9.0		23.040 48.600 71.640	52.10	3.732
SUB TOTALS7,985	6,043	-			-		191,640 543,870 735,510	-	38,318
GOATS (TX) 21,376	1,450e		26.0e	-			-	377,000	56.70
TOTALS (SHEEP, LAMBS, AND GOATS)					1,112,510			59,694	

a These calculations provide details of Pearson's (1986a,b) $59.7 million loss estimate. b "Sheep" are stock sheep and lambs-total on 1 January 1984 (SRS 1985:5). "Lambs" are the 1984 lamb crop (SRS 1985:7). c Loss percentages from Pearson (1986a); loss numbers computed as percentage times inventory. Total is sum of sheep + lambs. d All sheep and lambs, value per head on 1 January 1984 (SRS 1985:2). e Goat inventory and value per head on 1 January 1984 (SRS 1985:2). Loss percentage from Pearson (1986a).

Table 2. GAO estimates of sheep and lambs lost in 1989 to coyotes in 17 western states .a

state	Inventoriesb Sheep Lambs		Losses to Coyotesc Sheep		Lambs	Value per Sheep Lambs	Total	Value of Loss to Headd
Coyotes	1,000s 1,OOOs	%	%	No.	No.	No.	$	$1,000s
Ariz. 194 473	45		0.6076	9.0706	1,179	4,082	5,261	90.00
Calif.656	124	1.1606	4.6424	7,614	5,757	13,371	87.00	1,163
Colo. 368 1,377	77		2.5664	7.6190	9,444	5,867	15,311	90.00
Id. 226 444	51		1.6850	3.0330	3,808	1,547	5,355	83.00
Kans. 143 247	21		2.0604	2.3180	2,946	487	3,433	72.00
Mom 3,520	424 ' 114		4.4125	18.2802		8,709 20,839 39,548		89.00
Nebr. 101 164		18	1.1954	4.6895	1,207	844	2,051	80.00
Nev. 72 558		13	5.8435	17.5305	4,207	2,279	6,486	86.00
N.M. 405 791		80	1.2294	6.9666	4,979	5,573	10,552	75.00
N.D. 116 193		27	1.1725	2.9313	1,360	791	2,151	89.50
Okla. 99 273		21	1.8192	6.8220	1,801	1,433	3,234	84.50
Oreg. 294 684		56	2.5960	4.4781	7,632	2,508	10,140	67.50
S.D. 442		78	0.2829	1.0373	1,250	809	2,059	85.00

Unlike the DWRC and GAO investigators, NASS statisticians did not apply loss percentages to livestock inventories to estimate numbers of animals lost to predators. Instead, total predator losses were determined as a percentage of death losses from all causes as reported by agricultural producers. Losses to specific predators (coyotes, dogs, mountain lions *[Fells* conidor], bears [Ursus], etc.) were then estimated using percentages of total predator losses as indicated by the survey data (NASS 1991b). State totals were obtained by expanding results from producers sampled in each state.

Compared to the DWRC and GAO studies, NASS investigators also valued sheep and lambs differently. The value for adult sheep in each state was a straight average of the value per head of ewes 1 year old and older in that state on 1 January 1990, and 1 January 1991. The value per head for lambs in each state was the 1990 market year average price applied to an average weight of 60 pounds per lamb. This procedure, which reflects the "opportunity losses" of lambs (MASS 1991b), yielded a relatively low value per head for lambs, compared to values used by Pearson and the GAO. NASS's use of the term "opportunity losses" means that, regardless of when each lamb was killed, it was valued at the price a producer would have received if the lamb had been raised and marketed (L. Simpson, pers. commun., NASS).

As mentioned previously, the NASS survey covered the entire United States except for Alaska. National Agricultural Statistics Service results for the 17 western states are presented in this report (Table 3) to facilitate comparison of NASS, GAO, and DWRC estimates for the same states.

RESULTS

Pearson 1986(a) indicated that in 1984 predators in the 17 western states killed 191,640 sheep and 543,870 lambs with a combined value of $38.3 million, plus 377,000 Texas goats worth $21.4 million (Table 1). General Accounting Office (1990) concluded that in 1989 coyotes in the 17 western states killed 106,772 sheep and 115,011 lambs with a total value of $18.0 million (Table 2).

National Agricultural Statistics Service (1991b) reported that in 1990, predators in 49 states killed 490,000 sheep and lambs valued at $21.7 million, plus 129,400 goats worth $5.7 million in 5 states, for a total loss of $27.4 million to predators. In the 17 western states covered by the DWRC and GAO studies, NASS found that predators in 1990 killed 113,200 sheep and 310,700 Iambs with a combined value of $18.3 million (Table 3). These values considered only the direct value of animals killed.

In order to establish a uniform basis for comparison of the 3 loss studies, this paper concentrates on sheep and lamb loss estimates for the 17 western states listed in Tables 1-3. Subsequent discussion excludes sheep and lamb losses outside those states.

DISCUSSION

Reasons for Differences among the DWRC, GAO, NASS Estimates

Sheep and *Lamblnventories.-In comparing* livestock estimates from different years, it seems logical to consider the numbers of animals exposed to predation could have fered substantially among years. Statistical Reporting S National Agricultural Statistics Service inventories for 1 1989, and 1990 indicate that sheep and lamb numbers in western states did not fluctuate widely among these Lamb crops in these states were estimated at 6.04 million in 1984 (SRS 1985), 5.77 million in 1989 (NASS 1989), 5.78 million head in 1990 (NASS 1991a). These minor fluc tuations obviously could not account for the large differen predator loss estimates produced by the 3 studies.

Even though sheep and lamb numbers did not vary stantially from 1984 to 1990, Pearson and the GAO audi selected different inventory statistics to represent the number of sheep and lambs exposed to predators. The GAO assum much lower inventory values, calculating lamb losses from inventory of 1.33 million lambs (Table 2) even though the 19 lamb crop in the 17 western states was approximately 5. million head (NASS 1989). Likewise the sheep inventory value used by GAO, 5.94 million head, was substantially lower
the 7.27 million stock sheep and lambs estimated by NASS (1989) to have been present on farms and ranches in the 17 western states on 1 January 1989.

Statistical Reporting Service/National Agricultural Statistics Service publications contain a variety of sheep and lamb inventory and production statistics. Of the statistics that were available, Pearson (1986a) decided that the best value to represent numbers of lambs exposed to predation in a given year was the lamb crop for that year. He also selected the 1 January 1984 inventory of stock sheep and lambs as the best available estimate of the numbers of older sheep exposed to predation in 1984.

If the GAO study had used inventory statistics corresponding to those selected by Pearson, the GAO estimates of loss to coyotes would have been much higher-approximately 131,000 sheep and 496,000 lambs, for a total of 627,000 sheep and lambs. These numbers approximate Pearson's total of 736,000 head (Table 1), considering that GAO estimated losses only to coyotes whereas Pearson estimated losses to all predators.

I conclude that most of the difference between the Pearson and GAO estimates of sheep and lamb loss to predators resulted from differences in sheep and lamb inventory figures used in the 2 studies. The GAO estimates of lamb losses, in my opinion, are flawed because they were based on unrealistically low lamb inventory values. The NASS study avoided this *potential* source of error by using different procedures.

I

Table 3. National Agricultural Statistics Service estimates of sheep and lambs in 17 western states and goats in 5 states lost to predators in 1990.a

i

	Sheep		Value ($)	Lambs		Value ($)	Sheep + Lambs	Total
State	Lost (No.)	Each	Total	Lost (No.)	Each	Total	Lost (No.)	Value ($)
Ariz.	4,000	92	368,000	7,500	37	277,500	11,500	645,500
Calif.	9,900	85	841,500	17,700	36	637,200	27,600	1,478,700
Colo.	9,000	93	837,000	30,500	33	1,006,500	39,500	1,843,500
Id.	3,600	81	291,600	7,600	29	220,400	11,200	512,000
Kans.	2,000	62	124,000	1,800	33	59,400	3,800	183,400
Mont.	7,600	76	577,600	23,000	29	667,000	30,600	1,244,600
Nebr.	1,700	71	120,700	4,600	32	147,200	6,300	267,900
Nev.	4,500	82	369,000	9,200	29	266,800	13,700	635,800
N.M.	10,000	69	690,000	27,000	30	810,000	37,000	1,500,000
N.D.	1,700	77	130,900	5,300	31	164,300	7,000	295,200
Okla.	3,000	65	195,000	4,900	31	151,900	7,900	346,900
Oreg.	5,100	58	295,800	18,800	31	582,800	23,900	878,600
S.D.	8,700	75	652,500	22,700	33	749,100	31,400	1,401,600
Tex.	27,000	59	1,593,000	80,000	35	2,800,000	107,000	4,393,000
Ut.	9,300	80	744,000	22,100	29	640,900	31,400	1,384,900
Wash.	400	79	31,600	1,400	32	44,800	1,800	76,400
Wyo.	5.700	7j	427,500	26.600	IQ	798.000	32.300	1.225.500
SHEEP TOTALS	113,200	73b	8,289,700	310,700	32b	10,023,800	423,900	18,313,500
GOATS (Tex., N.M., Ariz., Okla., & Mich.)	-	-	-	-	-	-	129,400	5,661,300

a Reproduced from NASS (1991b:8-9). b Total dollars divided by number lost.

Table 4. Selected statistics from 3 estimates of sheep and lamb losses to predators in 17 western states.

	DWRC	GAO	NASS
Year of study	1984	1989	1990
Predator species included	All	Coyote	All
Livestock Inventories (January 1)e			
Sheep (millions)	7.98	5.94	7.55
Lamb crop (millions)	6.04	1.33	5.78
Estimated Numbers Lost to Predatorsb			
Sheep (thousands)	191.6	106.8	113.2
Lambs (thousands)	543.9	115.0	310.7
Total (thousands)	735.5	221.8	423.9
Percent of Inventory Lost to Predators			
Sheep	2.4	1.8	1.5
Lambs	9.0	8.6	5.4
Values per Head (for animals killed)b			
Sheep	$52.10	$80.93	$73.00
Lambs	$52.10	$80.93	$32.00
Total Value of Animals Killed ($ million)			
Sheep	9.98	8.64	8.29
Lambs	28.34	9.31	10.02
Sheep and Lambsb	$38.32	$17.95	$18.31

These values did not appear in original reports but were obtained from related notes or calculated for comparative purposes. Data for DWRC and GAO are from Tables 1 and 2. For NASS, "Sheep" are stock sheep and lambs-total on 1 January 1990 and "Lambs" are the 1990 lamb crop, both summed for the 17 western states from NASS 1991 a. If the values for 1989 had been computed on the same basis as those for 1984 and 1990, the resulting inventories would have been 7.27 million sheep and 5.77 million lambs, much higher than the values used by GAO.

b From Tables 1, 2, and 3 for DWRC, GAO, and NASS estimates, respectively.

Predator Species.-The DWRC and NASS studies estimated losses to all predators whereas GAO calculated losses only to coyotes. Assuming that coyotes are responsible for approximately 67 percent of total sheep and lamb losses to predators in the 17 western states as shown by NASS (1991b), the GAO estimates could be adjusted to approximate the values that would have resulted if GAO had considered losses to all predators, rather than losses only to coyotes. Dividing GAO totals (Table 2) by 0.67, the corresponding estimates for sheep and lamb losses to all predators would have been 331,019 animals with total value of $26.8 million.

Loss *Percentages.-Earlier it* was noted that Pearson (1986a) applied average, west-wide predator loss percentages to sheep and lamb inventories in each state (Table 1), whereas the GAO auditors used different percentages for each state (Table 2). The percentages used by GAO came from Pearson (1986a). The GAO approach resulted in unrealistically high lamb-loss percentages for some states. For example, the 18 percent loss rate for Montana lambs (Table 2) came primarily from studies in which damage control measures were purposely withheld (O'Gara et al. 1983). For the western states in total, however, the procedures following by GAO resulted in average loss percentages slightly lower than those of the DWRC study (Table 4).

In contrast to the DWRC and GAO studies, NASS estimates were not computed as percentages of sheep and lamb inventories lost to predators. The percentages shown in Table 4 for the NASS study (1.5% of sheep and 5.4% of lambs) did not appear in NASS (1991b), but were derived for comparative purposes. These percentages are lower than those used by Pearson and the GAO. The higher loss percentages used by Pearson account for much of the difference between his estimate and the NASS estimate of sheep and lamb numbers lost to predators.

Sheep *and Lamb* Values.-Of all points of difference among the Pearson, GAO, and NASS studies, the dollar values assigned to animals killed by predators exhibited greatest variation (Table 4). In particular, lamb values varied from $52 per,head (Pearson) to $81 per head (GAO) to a low of $32 per head (NASS). Actual market values did vary from year to year, but not as much as implied by these differences. Different valuation procedures were involved, as described earlier.

Pearson (1986a) and GAO auditors relied on average values per head for all sheep and lambs on 1 January (i.e., $52.10 in 1984 and $82.40 in 1989). If the corresponding value of $79.30for1990(NASS 1991a)hadbeenappliedtotheNASS (1991b) estimate of 423,900 sheep and lambs lost to predators in 17 western states in 1990 (Table 3), NASS's estimated value of animals lost to predators would have been $33.6 million dollars, substantially higher than the published value of $18.3 million. Thus, differences in values per head assumed in the 3 studies account formuch of the observed differences in bottomline estimates of total value of livestock killed by predators.

Some readers may regard the average NASS per head for lambs in the western United States I unrealistically low. The Idaho Agricultural Stati (1991) published an average value of $80 per he lambs in 1990, much higher than the correspor (1991 b) value of $29 per head. On the other hand, fluc Agricultural Statistics Service (1991) concurred (1991b) in a value of $30 per head for Wyoming tai

Determination of fair market values for livesta the scope of this paper. It is sufficient here to point widely divergent per-head values were a major c served differences among the 3 estimates of total livestock lost to predators.

GoatLosses to Predators.-Pearson's (1986a, of sheep and goat losses to predators in 1984 includ mately 377,000 Texas goats valued at $21.4 million whereas NASS (1991b) estimated that predators in 129,400 goats worth $5.66 million in Texas and 4 1 (Table 3). Comparison of the 2 estimates at face value a major decline in goat losses to predators from 1984 Such a decline could have occurred if goat numbers loss rates, or both decreased sharply between 1984 However, such declines did not occur.

Statistical Reporting Service/National Agricu tistics Service inventories show that goat numbers in major goat producing state, actually increased betv and 1990. The DWRC value of $56.70 per head was sum higher than the $43.75 per head shown in NASS (1! most of the difference between the DWRC and NASS resulted from the higher (26% predator loss) figut Pearson (1986a). The NAS S estimate of goat losses to in contrast, amounted to approximately 6% of the 1990 goat inventory (NASS 1991a).

Predation Costs Excluded Prom the DWRC, G NASS Studies

Predocking Losses.-In many western sheep of is not practical to count the lambs at birth. Instead, first counted when they are docked or marked approx 4-6 weeks after birth. Newborn lambs are vulnerable causes of mortality besides predation, **and substantial can** occur before docking. Nevertheless, the NASS c sheep and goat losses to predators excluded predock in the western states. By excluding predocking loss probably underestimated actual lamb losses.

I am aware of predocking, lamb-loss estimate; from 2 western states. The Idaho Agricultural Statisti (1991) indicated that lamb losses to predators in Ida] totalled 10,7001ambs, including 3,1001ambs before i addition to the postdocking loss of 7,600 lambs NASS (1991b). Thus, approximately 71% of the 1 lamb loss to predators occurred after docking.

Similarly, the Wyoming Agricultural Statistics Service (1991) indicated that predators in Wyoming killed 50,800 lambs in 1990, including 24,200 lambs before docking and 26,6001ambs (NASS 1991b) after docking. These data indicate that only 52% of the 1990 lambs lost to predators occurred after docking. On average, the Wyoming and Idaho reports indicate that approximately 62% of the lamb loss to predators in 1990 occurred after docking, and 38% before docking.

In 1974, the USDA Economic Research Service estimated lamb losses before and after docking in 15 western states based on mail-survey responses from 8,910 farmers and ranchers (Gee et al.1977). In all,1,026,100 lambs were reported as lost topredators (398,500 [39%] before docking and 627,600 [61%] afterdocking). These percentages are remarkably similar to the 1990 averages for Wyoming and Idaho.

Based on these data, the NASS estimate of 310,700 lambs lostto predators (Table 3) may represent only 61 % of total lamb losses to predators in the 17 western states in 1990. The remaining 39%, attributable to predocking losses, would have amounted to approximately 198,600 Iambs. At $32 per head, these lambs lost before docking would have been worth $6,355,200. In other words, the NASS estimate of lamb losses to predators in 1990 might have been as much as $6 million higher if predocking losses had been included.

Indirect Costs.-The economic impact of predation on livestock includes both direct and indirect costs. Direct cost is usually defined as the loss, at market value, of animals killed by predators (Jahnke et al. 1987). Indirect costs to livestock producers consist of added costs of production, predator control, and monetary gains foregone. Specific examples include expenditures for insurance against predatory loss, construction of extra fencing, hiring extra help at lambing time, shed lambing, penning livestock at night, use of guardian animals, traps or other predator repellent or removal methods, and predatory animal taxes or cash contributions to governmental predator damage control programs.

Comprehensive national estimates of such expenditures do notexist, butJahnke et al. (1987) provided examples for a major sheep producing state (Wyoming). According to these authors, the average out-of-pocket indirect cost of predation to Wyoming sheep producers in 1981 amounted to $1.06 per head, in addition to thepredatoryanimaltaxof$0.28perhead. Assuming that yearling and adult sheep killed by predators were replaced by withholding additional lambs from sale, over and above the number normally retained for replacements, additional costs of replacement were estimated at $0.59 per head of stock sheep. In all, these 3 types of indirect costs totalled $1.93 per head of stock sheep for Wyoming producers.

It is not known how representative these statistics maybe of western sheep producers in general. Assuming that they are representative, however, they can be extrapolated to the adult stock sheep inventory of 6.274 million head on 1 January 1990 (compiled from NASS 1991a) in the 17 western states to project that western sheep producers sustained indirect predation costs totalling approximately $12.1 million in 1990.

Aside from the indirect costs of predation to livestock producers, society at large also incurs indirect costs in the form of governmental wildlife damage control programs supported by tax dollars. In particular, each of the 17 western states has a federal cooperative wildlife damage management program that works to reduce many kinds of wildlife damage including predation on domestic livestock. These programs, supervised at the national level by ADC, spent approximately $18.5 million (total of federal and cooperative funds) to protect livestock (including sheep, lambs, and goats) in 1990.

Yet another indirect cost of predation to society is reduced supplies of lamb and correspondingly higher prices paid by consumers for meat. The annual economic value of this negative impact on consumers of lamb was estimated at $4 million by USDI (1978). No more recent estimate is available.

A thorough analysis of indirect costs of predation is beyond the scope of this paper. The examples presented above are intended only to illustrate some of the more obvious indirect costs that should be considered in assessing the costs to society of livestock losses to predators. This cursory review indicates that the indirect costs are substantial, and may even exceed the direct costs.

CONCLUSIONS

Estimates of the economic value of livestock losses to predators can vary widely depending upon the assumptions, data, and estimation methods used. Observed differences among the DWRC, GAO, and NASS estimates of sheep, lamb, and goat losses to predators resulted from such variations. Sheep and lamb inventories in the 17 western states did not differ substantially among 1984, 1989, and 1990, the years represented by the 3 studies. Differences among the 3 predator loss estimates were not due to differences in numbers of livestock exposed to predators in different years.

The NASS and DWRC estimates of sheep and lambs lost to predators in the 17 western states totaled 423,900 and 735,500 head, respectively. If the NASS estimate is corrected to include predocking lamb losses, it would increase to approximately 622,000 head. The remaining difference between the NAS S and DWRC estimates of numbers lost is attributed to higher predator loss percentages used by Pearson (1986a).

The GAO estimate of 221,800 sheep and lambs lost to coyotes in the 17 western states is not directly comparable to the other estimates that included losses to all predator species. In addition, I believe that the GAO estimate is based on unrealistically low sheep and lamb inventories.

The NASS and DWRC estimates of the value of sheep and lambs lost to predators in the 17 western states totaled $18.3 million and $38.3 million, respectively. If the NASS estimate was corrected to include predocking lamb losses, it would increase to approximately $24.7 million. The remaining differencebetweentheseestimatesisattributedtohigherestimated numbers of sheep and lambs killed, and to higher lamb values in Pearson's analysis. Lambs killed by predators were valued atapproximately $52 per head by Pearson, compared to $32 per head by NASS.

The DWRC and GAO estimates of sheep and goats losses to predators were based on projections of Pearson's (1986a) determinations of average loss percentages to sheep and lamb inventory and production statistics. The NASS study, in contrast, was a major, nationwide survey of livestock producers. Neither the Pearson (1986a,b) nor GAO (1990) reports provided loss estimates for specific states. The DWRC study has not been published in detail, and GAO (1990) gave no computations to support its $18 million loss estimate. For these reasons, most persons interested in livestock losses to predators will find the NASS study to be most useful.

The NAS S study was purposely restricted to direct costs of predation, However, indirectcosts also should beconsidered to fully appreciate the economic impact of predation on sheep and goat producers, taxpayers, and consumers. Indirect costs to livestock producers include intensified animal husbandry, guardian animals or other predation controls, added costs of replacing animals killed by predators, predatory animal taxes, and contributions to governmental wildlife damage control programs. Indirect costs to taxpayers and consumers include the costs of governmental programs of wildlife damage control programs, and increased lamb prices resulting from reduced supply. Such indirect costs may equal or even exceed the direct value of animals killed.

Considering both direct and indirect costs, the economic impact of predation on sheep in the 17 western states probably exceeds $50 million annually.

LITERATURE CITED

Gee, C. K., R. S. Magleby, W. R. Bailey, R. L. Gum, and L. M. Arthur. 1977. Sheep and lamb losses to predators and other causes in the western United States. Agric. Econ. Rep. No. 369, Nat. Resour. Econ. Div., Econ. Res. Serv., U. S. Dep. Agric. Washington, D. C. 41pp.

General Accounting Office (GAO). 1990. Wildlife ment effects of Animal Damage Control program predators. GAO/RCED-90-149, U. S. General Ace ing Office, Washington, D. C. 31pp.

Idaho Agricultural Statistics Service. 1991. 1990 ind losses. Idaho Wool Growers Bull. 72:4-5.

Jahnke, L. J., C. Phillips, S. H. Anderson, and L. L. MCDo 1987. A methodology for identifying sources of in ' costs of predation control: a study of Wyoming producers. Pages 159-169 in Shumake, S. A. and R. W Bullard, eds. Vertebr. Pest Control and Manage. als: Vol. ASTM STP 974. Amer. Soc. Testing als, Philadelphia, Pa.

National Agricultural Statistics Service. 1989. Sheep goats. Lv Gn 1 (2-88), U. S. Dep. Agric., Agric. Staffs Board, Washington, D. C. l l pp.

. 1991a. Sheep and goats. Lv Gn 1(2-91), U.S. Dep. Agric., Agric. Statistics Board, Washington, D. C. 8pp,

.1991 b. Sheep and goat predator loss. Lv Gn 1(4.91), U. S. Dep. Agric., Agric. Statistics Board, Washington, D. C. 12pp.

O'Gara, B.W., K. C. Brawley, J. R. Munoz, and D. R. Henne, 1983. Predation on domestic sheep on a western Montata ranch. Wildl. Soc. Bull. 11:253-264.

Pearson, E.W. 1986a. A literature review of livestock losses to predators in western U.S. Unpubl. Rep., U. S. Fish and Wildl. Serv., Denver Wildl. Res. Center, Denver, Colo. 20pp.

. 1986b. Current value of livestock losses to predators. Res. Info. Bull. No. 86-27, U. S. Fish Wildl. Serv., Denver Wildl. Res. Center, Denver, Colo. lp.

Statistical Reporting Service. 1985. Sheep and goats. Lv Gn 1 (1-85), U. S. Dep. of Agric., Crop Reporting Board, Washington, D. C. 7pp.

Ten-ell, C. E. 1988. Predator losses climb nationwide. Nat. Wool Grower 78:32-34.

U. S. Department of the Interior. 1978. Predator damage in the west: a study of coyote management alternatives. U. S. Fish Wildl. Serv., Washington, D. C. 168pp.

. 1979. Mammalian Predator Damage Management for Livestock Protection in the Western United States. Final Environmental Impact Statement. U.S. Fish and Wildl. Serv., Washington, D. C. 789pp.

Wade, D. A. 1982. Impacts, incidence and control of predation on livestock in the United States with particular reference to predation by coyotes. Spec. Publ. No. 10, Counc. for Agric. Sci. Tech., Ames, Ia. 20pp.

Wyoming Agricultural Statistics Service. 1991. Wyoming Agric. Statistics 1991. U. S. Dep. Agric., Natl. Agric. Stat. Serv., Cheyenne, Wyo. pp. 44-46.