Predator Control in Relation to Livestock Losses in Central Texas

ERWIN W. PEARSON AND MILTON CAROLINE

Abstract

Records of the 1971–76 federal-state Animal Damage Control (ADC) program in central Texas reflected 0.27% annual domestic sheep and goat losses to predators despite intensive control efforts. Sheep and goat numbers decreased, but their value, cattle numbers, and cattle values increased. Losses to coyotes and bobcats were proportionately greatest in brushy, uneven terrain on the periphery of the Edwards Plateau. In 1975, cooperative ADC predator control efforts protected 438,649 (40%) of the sheep and goats on 8,912 km² (3,441 mi²), or 15.5% of the total land area in 21 counties studied at an average cost of 46 cents for each sheep or goat protected. Heaviest losses to predators occurred from October to May when small lambs were present; control efforts were most successful during winters. An estimated cost-benefit ratio to measure the effectiveness of the ADC program was 1:4.5 for 1975. We observed that losses to predators were lowest when annual precipitation was highest; high losses coincided with dry years, which were probably the periods of lowest wild prey abundance.

Increasing sociological and political controversy about predator control from local to Congressional levels has increased the need to evaluate the effectiveness of control efforts. This paper analyzes records from a continuing cooperative federal-state program in 21 Texas counties to evaluate the effects of present control methods in this country's largest and most concentrated sheep and goat-raising area. In other parts of the West, detailed loss studies in three no-control situations and several areas with unmeasured controls have provided views (discussed later) of several aspects of predation. We add to that information by providing some insight from the broad view of a control organization as opposed to individual ranch studies of loses to predators.

Methods

The study area included three counties each of seven levels of sheep density as determined by an earlier study (Pearson 1975). The 21 counties included three having the highest sheep densities in the West in 1972, but also included counties lying adjacent to or near the Edwards Plateau with sparse sheep populations (Tables 1 and 2; Fig. 1). The goal of choosing an orderly band of adjacent counties extending across the Edwards Plateau was not achieved because control records of two or more counties were sometimes irreversibly combined; therefore they could not be treated as separate comparable units. Nevertheless, the sample was probably representative of the seven levels of sheep density in Texas and the Southwest.

When records were first examined, rough calculations indicated that, where present, about as many angora goats were killed by predators as were sheep; consequently, data for goats and sheep were combined. Furthermore, since control methods protected both species (nearly one-third were goats), it was not possible to evaluate the program without considering both goats and sheep.

Similarly, because records of predation by bobcats *(Lynx rufus)* and costs to control them could not be separated from similar records for coyotes *(Canis latrans)*, costs of control were combined for the two species. Except in a few areas, control operations were directed primarily at the coyote.

Calendar year 1971 was chosen to represent conditions for the year preceding the presidential ban on use of toxicants for predator control (Executive Order No. 11643, February 8, 1972), and 1973 and 1974 were chosen to reflect conditions after the ban. However, ADC personnel collected the ADC-protected area data for 1975-76 (Table 2) when it became obvious that biased conclusions were being drawn from incomplete data such as unknown numbers of sheep and goats as well as unknown land areas being protected by ADC operations. The ADC-protected area data for 1975-76 present the most complete portrayal of the Texas predator control program.

Records of ADC do not include all livestock losses because ADC operations are not under signed agreements to control predators for all livestock owners. Also, field workers who answer control requests normally apply controls, but usually do not have time to make extensive searches for later losses. Therefore, these data include only a partial listing of losses that occur in spite of controls.

Costs of conducting the cooperative control program in 1975

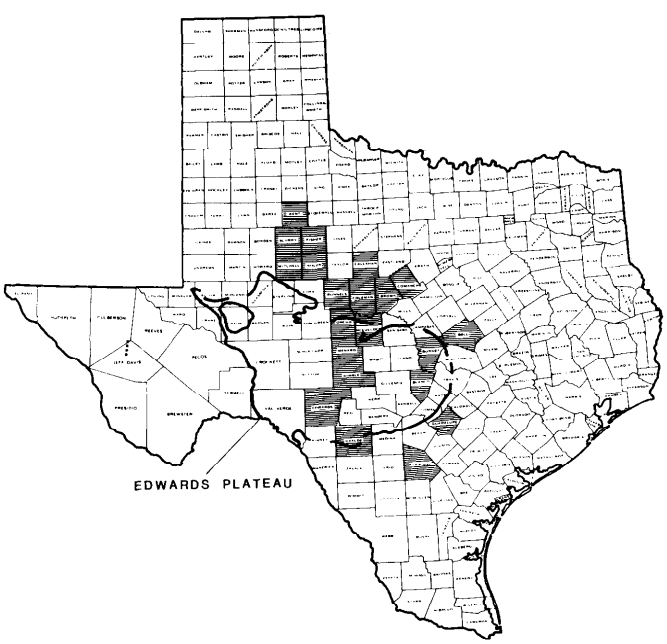

Fig. 1. *The 21 counties in the Edwards Plateau (outlined) study area, Texas (after Teer et al. 1965, p 7).*

Authors are wildlife biologist, U.S. Fish and Wildlife Service, Denver, Colorado; and State supervisor, Animal Damage Control, U.S. Fish and Wildlife Service, San Antonio, Texas. Milton Caroline's present address is 118 Highview Drive, San Antonio, Texas 78228.

Authors thank Martin Popelka of the Denver Wildlife Research Center, while stationed in Uvalde, Texas, for copying the detailed figures from the 1971, 1973, and 1974 ADC records, and district supervisors and field assistants who gathered additional 1975-76 data. All information in this paper was obtained from ADC records unless indicated otherwise. Authors also thank D.S. Balser, Patricia A. Chamberlain, G.E. Connolly, S.B. Linhart, and R.D. Nass for their editorial assistance.

Manuscript received November 23, 1979.

Table 1. Combined numbers of sheep and goats in 1971, 1974, and 1976, cattle numbers, percent changes from 1971 in 1974 and 1976 (in parenthesis), and values in seven selected sheep density areas of the Edwards Plateau region, Texas,[1] on January 1 in 1971 and 1976.

Counties in density category (1972 sheep/km²)[1]	Sheep and goats[2]			Cattle[2]		1976 values[2]	
	1971	1974	1976	1971	1976	Sheep and goats	All cattle
Concho, McCulloch, Menard (62.8)	502,000	487,000 (-3.0)	410,000 (-18.3)	92,000	117,000 (27.2)	$12,352,500	$ 18,135,000
Coleman, Kimble, Runnels (27.9)	403,000	281,570 (-30.1)	243,950 (-39.5)	138,000	158,000 (14.5)	6,897,550	24,490,000
Blanco, Edwards, Nolan (14.0)	380,000	297,000 (-21.8)	223,600 (-41.2)	86,000	125,000 (45.3)	5,435,900	19,375,000
Brown, Burnet Uvalde (18.2)	363,000	237,000 (-34.7)	168,900 (-53.5)	162,000	171,000 (5.6)	4,321,600	26,505,000
Bell, Comanche, Mitchell (5.8)	84,315	38,200 (-54.7)	33,630 (-60.1)	144,000	221,000 (53.5)	963,970	34,255,000
Callahan, Guadalupe, Scurry (1.1)	11,365	5,000[3] (-56.0)	5,270[3] (-53.6)	137,000	168,000 (22.6)	155,130	26,040,000
Atascosa, Fisher, Kent (0.3)	2,985[3]	910[3] (-69.5)	770[3] (-74.2)	141,000	187,000 (32.6)	23,130	28,985,000
TOTALS (19.1)	1,746,665	1,346,680 (-22.9)	1,086,120 (-37.8)	900,000	1,147,000 (27.4)	$30,149,780	$177,785,000

[1]From Pearson, 1975.
[2]From *Texas Livestock Statistics;* average values in 1976 were $31.50 for each sheep, $19 per goat, and $155 for cattle.
[3]Numbers under 1,000 per county not given, so estimated from weights of wool or mohair given, or obtained from county Extension agents by M. Popelka.

included only salaries and expenses of the professional field control workers. An estimate of additional supervisory and state office costs is presented later to offer a tentative economic portrayal of all costs compared with the benefits derived from the predator control program.

Results and Discussion

Emphasis on predator research at the Denver Wildlife Research Center has been placed on the study of coyote-sheep relationships because interactions between these two species have included the greatest economic and sociological considerations and controversies in animal damage control. Tables 1–5 contain most of the applicable facts and calculated data on which this paper is based; an understanding of them is necessary for an objective understanding of the Texas ADC program.

The 21-county study area included 30.5% of the Texas sheep and goat population in 1971 and 31.1% in January 1976 (Texas Livestock Statistics 1971 and 1975). Following a national trend (Pearson 1975, Gee and Magleby 1976), the sheep and goat population dropped 39.0% from 1971 to 1976 in the total state, and 37.8% in the 21-county study area (Table 1). The value of all sheep and goats in the study area increased more than 31% despite the decrease in numbers between 1971 and 1976.

Cattle numbers and values are listed in Table 1 because information from several states in the West indicates that calf losses to coyotes have been increasing. In addition, other studies have

Table 2. Comparisons of tri-county region and ADC-protected area data in seven selected sheep density areas of the Edwards Plateau region, Texas, 1972 and 1976.

Counties in density category (1972 shee/km²)	Tri-county region data		ADC-protected area data, 1975–76					
	Area in km²	Sheep and goats/km² 1976	Sheep and goat numbers	Sheep and goats/km²	% of sheep and goats protected[1]	% loss to predators 1975	Square kilometers protected	% of counties protected
Concho, McCulloch, Menard (62.8)	7,729	53.0	143,335	79.8	35	0.02	1,796	23.2
Coleman, Kimble, Runnels (27.9)	9,352	26.1	86,290	42.8	35	0.29	2,016	21.6
Blanco, Edwards, Nolan (14.0)	9,627	23.2	89,930	38.8	40	0.26	2,318	24.1
Brown, Burnet, Uvalde (18.2)	9,122	18.5	83,288	37.4	49	0.45	2,224	24.4
Bell, Comanche, Mitchell (5.8)	7,539	4.5	29,197	75.4	87	0.84	387	5.1
Callahan, Guadalupe, Scurry (1.1)	6,408	0.8	6,254	38.4	100	0.66	163	2.5
Atascosa, Fisher, Kent (0.3)	7,744	0.1	355	50.7	46	0.28	7	0.1
Totals or averages	57,521	18.9	438,649	49.2	40	0.27	8,911	15.5

[1]Approximate; January 1 county figures (Table 1) do not always agree with ADC figures that may include herd changes during the fiscal year.

Table 3. Combined numbers of sheep and goats killed by coyotes and bobcats seasonally, 1971 and 1973–75.

Counties in category (1976 sheep & goats/km²)	Years	Sheep and goats killed in: Dec.–Feb.	Mar.–May	June–Aug.	Sept.–Nov.	Totals	4-year totals (%)
	1971	13	0	0	0	13	
Concho, McCulloch,	1973	0	0	6	3	9	364
Menard (53.0)	1974	0	289	19	8	316	(5.8)
	1975	26	0	0	0	26	
	1971	45	120	17	15	197	
Coleman, Kimble,	1973	3	8	45	5	61	870
Runnels (26.1)	1974	61	25	98	174	358	(14.0)
	1975	62	1	149	42	254	
	1971	17	6	0	0	23	
Blanco, Edwards,	1973	21	27	67	26	141	745
Nolan (23.2)	1974	5	268	39	36	348	(11.9)
	1975	18	6	150	59	233	
	1971	408	259	90	20	777	
Brown, Burnet,	1973	736	191	69	75	1071	2712
Uvalde (18.5)	1974	91	157	197	46	491	(43.5)
	1975	44	125	62	142	373	
	1971	46	79	36	197	358	
Bell, Comanche,	1973	48	61	2	157	268	1153
Mitchell (4.5)	1974	40	96	89	58	283	(18.5)
	1975	46	8	31	159	244	
	1971	5	8	0	0	13	
Callahan, Guadalupe,	1973	0	0	12	0	12	336
Scurry (0.8)	1974	4	26	236	4	270	(5.4)
	1975	16	0	17	8	41	
	1971	10	17	0	9	36	
Atascosa, Fisher,	1973	0	0	6	0	6	55
Kent (0.1)	1974	0	0	10	2	12	(0.9)
	1975	0	0	0	1	1	
	1971	544	489	143	241	1417	
	1973	808	287	207	266	1568	6235
Totals (18.9)	1974	201	861	688	328	2078	(100)
	1975	212	140	409	411	1172	
Totals of 4 years		1765	1777	1447	1246	6235	
% of 4 year totals		28.3	28.5	23.2	20.0	100.0	

shown that when sheep numbers decreased, many sheep ranchers turned to raising cattle (Stevens 1971; Pearson 1975; Stevens and Hartley 1976). In the 21 counties, cattle numbers increased 27.4% between 1971 and 1976 (Table 1), and calf losses also reportedly increased in 1975 (Table 4).

In 1975 about 15.5% of the land in this area of concentrated sheep and goat-raising was under written agreement with ADC for possible control work to protect about 40% of the sheep and goats in the 21 counties (Table 2). It is unlikely that other sheep and goat ranchers' control efforts would be as intensive as those of the federal cooperative program. A separate study of those ranches would be necessary to determine the extent of their controls and losses. An early draft of a USDA study (Gum et al. 1978) indicated that ranchers using cooperative federal control programs generally had lower predator losses than did other ranchers, but the lack of basic, factual data often prevented clear, well-founded conclusions.

The percent reduction by ranchers of numbers of sheep and goats from 1971 to 1976 was generally far less in counties having high sheep and goat populations than in counties having low populations (Table 1). However, losses to predators (Table 4, Fig. 2) did not follow a similar pattern; largest percent losses to predators occurred in the low- and medium-density sheep- and goat-raising areas, despite more intensive control efforts there. An associated seemingly contradictory finding is that due primarily to intensive control efforts usually more coyotes were taken in counties with few sheep and goats (Table 4, Fig. 2) than in counties with more sheep and goats in which the heavier losses occurred.

Apparent inconsistencies in the seven different livestock density areas are explained by more explicit observations and considerations of geography and habitat. There probably are advantages, such as better predator control, in raising large numbers of sheep and goats near the center of the Edwards Plateau. Sheep and angora goats have been raised for decades in counties with highest sheep and goat densities on and immediately adjacent to the edge of the Edwards Plateau. The concentration of woven wire fencing has impeded the travel of coyotes and has helped maximize control efforts where the centrally located counties "have contained the lowest known densities of coyotes west of the Mississippi" (Anderson et al. 1974). As Anderson et al. (1974) pointed out, however, counties adjacent to the Plateau serve as the first line of defense to prohibit ingress of coyotes into the country most heavily populated with sheep and goats, and coyote controls are used as intensively as funds permit to keep coyote populations as low as possible. The past history of predator control is readily depicted in 1971 when only 13 sheep and goats were killed in the tri-county area with the highest average density of sheep and goats, and only 16 coyotes and 39 bobcats were taken (Table 4) at great expense while about 175,000 animals were being protected.

The counties with highest percentage losses to predators were those with medium- and low-density sheep and goat populations located on the edges and adjacent to the Edwards Plateau. The irregular, brushy terrain is often grazed only by sheep and goats, but it is also good predator habitat; this obviously places livestock in a hazardous position insofar as predation is concerned.

Another reason why large numbers of coyotes were killed in

those counties having few sheep and goats was the reported need to protect increasing numbers of cattle and calves (Table 1). Coyotes taken to protect cattle are not usually distinguishable from those taken to protect sheep and goats in the same area, and despite large coyote kills, calf losses remained the same or increased (Table 4). Calf losses to coyotes were consistently greatest in counties lying near the Edwards Plateau where the annual coyote abundance survey has continually recorded high coyote densities (Roughton 1976), but where cattle numbers have been about the same as in other areas. It should be emphasized that the loss of a cow or calf usually represents several times the economic loss of a sheep or goat (Table 1).

Seasonal losses generally reflect the availability of lambs, and in the present study differ in varying degrees from most other western states. Because western range lambs are usually born in the spring, losses in most states are highest in spring and summer (Nass 1977; Tigner and Larson 1977). In Texas (and parts of California, Arizona, and other states), many sheep herds are managed to yield large numbers of lambs for market in spring when lamb prices are high. For example, the Texas early lamb crop (for Easter markets) was listed as 770,000 between October 1, 1974, and March 1, 1975, or about half of the 1,500,000 lambs produced in Texas in all of 1974 (Anonymous 1975). Sheep and goat losses to coyotes and bobcats reflect this winter and spring availability; combined seasonal predator losses for 4 years were 56.8% of the production years' total in December through May (Table 3). A study of losses on seven California ranches, all with early lambing, showed that losses from December through March were 94 and 82% of total predator losses in 2 production years (Nesse et al. 1976).

Seasonally, the loss pattern differed in 1973 and 1975, when, with one county's exception, fewer sheep were lost to predators in the first 6 months (33 and 31%, respectively) than during the same period in other years. Table 5 shows the inverse relationship between precipitation (U.S. Weather Bureau 1971–76) and the proportion of predator kills that occurred during the first 6 months of each year, 1971–75. When first half-year precipitation was about normal (1973 and 1975), only one-third of each year's predator kills occurred in the first half-year, even though that was the period of greatest exposure of lambs and kids to predation. In 1971 and 1974, 61% or more of the year's predator kills occurred in the first half-year periods when precipitation was well below normal. Possibly the average and above-average precipitation in 1973 and 1975 produced abundant vegetation for rodent and rabbit populations, which normally respond quickly to increased food availability. In 1971 and 1974, however, inadequate moisture during the first half-years may have curtailed vegetative growth, which in turn produced deficit wild prey populations, thereby causing predators to turn to livestock for food despite the persistent pressure of the predator control program.

These data can only indirectly relate to studies that link predation with natural prey availability. In Nevada, Kauffeld (1977) found that coyote predation on domestic sheep was highest in a study area with the lowest natural prey:predator ratio. In Texas, Gober (1979) recorded luxuriant vegetative growth in 1975 after abundant precipitation in the fall and winter of 1974–75, but poor growth in 1976 and early 1977 when drought conditions persisted. Concurrently he found rodent biomass estimates on the same areas were substantially lower in 1976 and 1977 than in 1975, and that expanding prey populations in 1975 appeared to enhance lamb survival. In 1977 the rate of lamb loss moderated after spring precipitation allowed vegetative response and indirectly encouraged the expansion of alternative prey populations (Gober 1979, p 98). Also, "in 1974, a year when wild prey populations were probably depressed in the Trans-Pecos, ewes on this ranch produced at least an 80% lamb crop at spring docking (468 lambs) but only a 5% lamb crop (25 lambs) survived the autumn shipping"; most lamb losses were reportedly caused by predators (Gober 1979, p 100–101). During the same period Guthrey (1977), also in Texas, reported plentiful rainfall and good production of grasses and forbs in 1975. This contrasted with a droughty period from November 1975 to March 1976 when (p 23) "The higher level of predation on kids and nannies [angora goats] in the untreated [no predator control] pasture in 1976 roughly correlated with alternate prey availability; . . . rodent densities dropped considerably in 1976, . . . and may have played a role in the increased predation of 1976."

Turkowski and Vahle (1977), with rodent trap-catch data obtained annually in December for 22 years in southern Arizona, showed that, "The total rodent populations of the years following

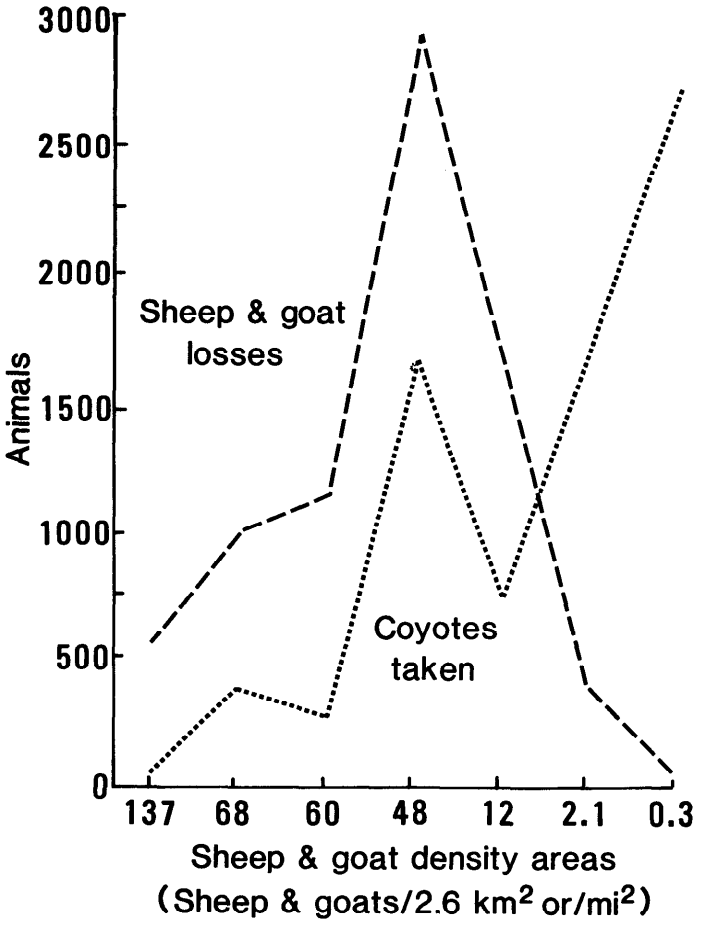

Fig. 2. *Accumulated total numbers of predator losses and coyotes taken in seven sheep density areas, 1971 and 1973 to July 1976.*

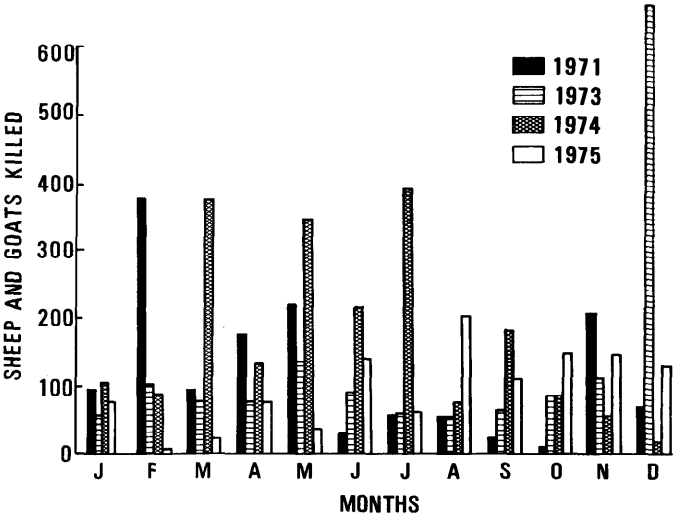

Fig. 3. *Monthly losses to coyotes and bobcats in central Texas, 1971 and 1973-75.*

Table 4. Sheep, goat, and calf losses to coyotes and bobcats, and some predator control costs and results in central Texas.

Counties in density category (1976 sheep & goats/km²)	Years	Losses to coyotes & bobcats: Sheep & goats	Calves	Total	Coyotes & bobcats taken	Coyotes or bobcats taken/sheep, goat, or calf killed	1975 control costs, ADC-protected area[1]	Cost/sheep or goat protected in 1975
Concho, McCulloch, Menard (53.0)	1971	13	0	13	55	4.2		
	1973	9	0	9	29	3.2		
	1974	316	0	316	48	0.2	$ 30,909	$0.22
	1975	26	0	26	49	1.9		
Coleman, Kimble, Runnels (26.1)	1971	197	1	198	208	1.1		
	1973	61	1	62	59	1.0		
	1974	358	2	360	79	0.2	27,159	.31
	1975	254	0	254	57	0.2		
Blanco, Edwards, Nolan (23.2)	1971	23	0	23	88	3.8		
	1973	141	1	142	112	0.8		
	1974	348	1	349	109	0.3	37,119	.41
	1975	233	1	234	146	0.6		
Brown, Burnet, Uvalde (18.5)	1971	777	2	779	532	0.7		
	1973	1071	4	1075	595	0.6		
	1974	491	0	491	447	0.9	52,789	.63
	1975	373	0	373	398	1.1		
Bell, Comanche, Mitchell (4.5)	1971	358	7	365	150	0.4		
	1973	268	4	272	197	0.7		
	1974	283	1	284	246	0.9	27,339	.94
	1975	244	6	250	205	0.8		
Callahan, Guadalupe, Scurry (0.8)	1971	13	1	14	342	24.4		
	1973	12	0	12	324	27.0		
	1974	270	3	273	458	1.7	25,357	4.05
	1975	41	17	58	466	8.0		
Atascosa, Fisher, Kent (0.1)	1971	36	17	53	660	12.5		
	1973	6	13	19	488	25.7		
	1974	12	12	24	747	31.1	1,017	2.86
	1975	1	35	36	707	19.6		
TOTALS (18.9)	1971	1,417	28	1,445	2,035	1.4		
	1973	1,568	23	1,591	1,804	1.1		
	1974	2,078	19	2,097	2,134	1.0	201,689	.46
	1975	1,172	59	1,231	1,924	1.6		
4-year totals		6,235	129	6,364	7,897	1.2		

[1]Obtained for only 1975.

lowest rainfall was about half that following the high rainfall years." Based on the several cited studies, we believe that in 1975, for example, when the previous fall, winter, and spring precipitation was well above average and adequate for the whole year (Table 5), and livestock losses were the lowest of the study (Table 4, Fig. 3), wild prey numbers were probably high and could have produced a buffering effect that reduced sheep and goat losses to predators.

Although there was year-around effort, predator control was generally most successful during winter (Fig. 4) and predators were most difficult to capture during the summer. Of the 6,661 coyotes taken during the main 4 study years, 36, 27, 13, and 24% were taken in the winter, spring, summer, and fall, respectively; this seasonal control was similar for bobcats. Several factors probably contributed to this success pattern, including the fact that naive juveniles normally make up about half of the fall populations (Knowlton 1972). In addition, young coyotes disperse in fall and winter, and are probably more susceptible to capture in strange environments. Also, natural predator foods are becoming scarce, and the predator's wide-ranging, foraging trips come at a time when leafless vegetation makes them more visible to control personnel than in the summer.

Although not shown in tables, costs for reducing coyote populations would be lowest during the winter on areas such as range lambing grounds and early summer grazing pastures where general population reduction is the goal.

Bobcat predation on livestock was erratically significant in only a few counties; 13 sheep or goats were lost to bobcats in Uvalde county in 1971 and 20 in Mitchell County in 1974. However, sheep and goat losses to bobcats increased in 1975; 14 sheep or goats were taken by bobcats in Mitchell County, 22 in Coleman, 40 in Uvalde,

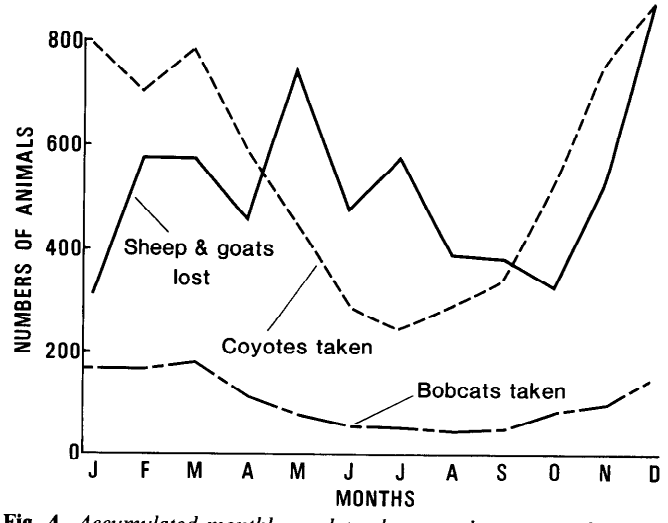

Fig. 4. *Accumulated monthly predator losses and coyotes and bobcats taken in central Texas, 1971 and 1973-75.*

and 100 in Runnels. Of 85 sheep or goats lost to bobcats in the first half of 1976, 77 were taken in Edwards County.

Except in local areas, control operations during the reporting period were seldom directed specifically at the bobcat. It is, however, both easily trapped and usually considered a predator, so it was seldom released. (As recent policy changes have dictated, most bobcats are now being released unless they are causing losses locally.) In addition to predation on lambs and goats, bobcats sometimes take poultry; in 1974, for example, bobcats took 48 chickens and 40 turkeys.

The coyote also destroys more than the sheep, goats, and calves shown in Table 4. For example, in 1974 coyotes reportedly took 714 turkeys, 4 chickens, 15 melons, 1 horse, and 1 deer in the 21 counties.

In 3 of the 4 years of the present study, a proportionally larger number of goats were killed than are represented by their total numbers in the 21 counties. In 1971, 1973, 1974, and 1975, when goats made up 29.3, 33.8, 32.0, and 29.9%, respectively, of the total sheep and goats in the 21 counties, losses to predators were 47.1, 30.6, 33.5, and 52.1% of the total reported sheep and goat losses in those same years. This generally higher percent loss of goats may indicate a preference for goats, or a greater vulnerability of goats because they are smaller than sheep. However, Shelton (1972) indicated that a lower loss of sheep (3.4%) than goats (4.9%) to coyotes might be because sheep were the more valuable species and were given the greater protection. In addition, nannies usually leave their kids behind while they go to water and often while feeding, whereas ewes and lambs remain together most of the time, thereby affording lambs better protection.

Pertinent Information from Other Sources

For most practical purposes, toxicants used for predator control were banned in 1972, and the general belief is that numbers of predators, particularly coyotes, have since been increasing. Some of these are general observations which lack factual evidence of population changes, but ranchers report increasing livestock losses to coyotes as evidence of increasing coyote numbers. In addition, annual reports of the federal ADC program from several states, as well as reports in the *National Wool Grower* magazine (July and December 1974; April, July, November 1975) have indicated that increasing coyote numbers are primarily responsible for increasing livestock losses. Gee et al. (1977), reporting on a survey of about 9,000 sheep producers in 15 western states, indicated that a third of total lamb deaths (728,200) and a fourth of adult sheep deaths (229,400) were attributed to coyotes in 1974; 11.4% of all lambs and 3.4% of all adult sheep were reportedly killed by predators.

Factual evidence of changing coyote numbers come from over 400 (in 1976) coyote survey lines (Linhart and Knowlton 1975) which have been run annually since 1972 in the 17 western states. Roughton (1976) summarized the survey data, which indicated a West-wide 10% increase in coyote numbers between 1972 and 1973, another 10% increase on comparable lines from 1973 to 1974, a 5% decrease from 1974 to 1975, and a 7% decrease from 1975 to 1976. Although there is no clear evidence that valid changes can be detected in areas smaller than entire states, the average coyote index of five comparable lines run in four of the 21 counties in the present study varied greatly. The average index of these five lines increased more than 18% between 1972 and 1973, increased another 20% between 1973 and 1974, decreased nearly 4% from 1974 to 1975, then decreased nearly 21% between 1975 and 1976; in 1976 it was within two points of the beginning (1972) index. The changing coyote population appeared to parallel the losses through 1975, but the 21% decrease in the coyote index between 1975 and 1976 did not reflect the greatly increased losses of 1,544 sheep and goats and 33 calves recorded for the first half of 1976.

Table 5. Inverse relation of precipitation and predator kills as indicated by half-year totals.

Year	Difference from normal precipitation (%)		% of total kill of sheep and goats by coyotes and bobcats	
	Jan.-June	July-Dec.	Jan.-June	July-Dec.
1971	-45	+63	70	30
1972	-24	+ 6	ND[1]	ND[1]
1973	- 4	+12	33	67
1974	-35	+95	61	39
1975	+ 9	- 2	31	69

[1]ND = no data.

Costs for Control

An estimate of total costs was derived from the 1975-76 data and used to obtain an estimate of the efficiency of the ADC program, sometimes expressed as the cost-benefit ratio. Sources of funds could not be determined at disbursement, but total income for livestock protection in all Texas in fiscal year 1976 ($1,699,255) was one-third federal and two-thirds state and cooperative funding (U.S. Fish and Wildlife Service 1976).

Direct costs for salaries and expenses of ADC field workers in the 21 counties were $201,689 in 1975, or an expenditure of 46 cents for each sheep or goat protected (Table 4). Nass (1977) reported that in Idaho similar predator control funding varied from 60 to 90 cents per adult sheep, plus some additional unknown rancher expenses. His estimates were for adult sheep, whereas those in the present study also include lambs in most instances. A combined total of 1,172 sheep and goats were killed by coyotes and bobcats in 1975 with an estimated average minimum value of $25 each, or a total loss value of about $29,300. These two cost figures—salaries and expenses plus losses—total nearly $231,000, but do not include some likely, but unknown, ranchers' control costs. Some proportional part of the District Supervisors' salaries should also be added, as well as part of the salaries and expenses of the State supervisor's office. Perhaps the 21-county share is $30,000, and the estimated total ADC program cost was about $260,000. This estimate raises the protection cost to 59 cents per sheep.

The benefits are difficult to assess because apparently only 5 years of data (none in Texas) from three studies of sheep herds with no predator control are available (Henne 1975; De Lorenzo and Howard 1976; Munoz 1977; McAdoo and Klebenow 1978) from which base figures can be obtained. These figures may not be completely applicable, but with no better information available, and to have some basis for comparison, we offer the following values: The average annual sheep and lamb loss to predators for 2 complete years of study with no predator control in New Mexico, 2 years in Montana, and 1 summer (113 days) in California was 10.7% (range, 3.8 to 20.8%). In the Montana study (Henne 1975; Munoz 1977), new ewes were added in January of each year which we did not include in figuring total flock numbers because limited predator control was also allowed from October 15–March 14 in the first study year, and more coyote controls were used in the second year. Although coyotes were not taken during the damage season, nine were killed in the first year, and 44 in the second year, so it is likely that the "no-control" designation was not valid for either year. The loss of "new ewes" to predators was low, and would undoubtedly be more than offset by the use of controls in this "no-control" study. Because the New Mexico study area covered only seven sections, neighboring predator control efforts probably biased results downward in that study. The short California study (less than one-third year) undoubtedly also helps to produce a very minimum 10.7% loss figure.

If one applies the 10.7% predator loss to the 438,649 sheep and goats in the ADC-protected areas of the 21 Texas counties, a loss of 46,760 sheep and goats worth about $1,169,000 would be expected if no controls were used. A comparison of this value with the estimate of about $260,000 in control costs plus the value of sheep taken by predators yields benefits equal to about 4.5 times the costs, or a cost-benefit ratio of 1:4.5.

Although no special studies were made to determine the effects of predator losses on the area's economy, Nielsen and Curle (1970),

and Nesse et al. (1976) indicated that in studies in Utah and California, respectively, a chain reaction (multiplier effect) in the area economy could cause an area loss of two to four times the combined value of direct losses and control costs. Nielsen and Curle (1970) estimated a total loss to ranchers of $1,320,098, a loss of $3,538,846 to Utah's economy, and total control costs of $213,569. From these data, we estimated an approximate 1:6.2 cost-benefit ratio to the rancher. Thompson (1976) calculated a cost-benefit ratio of 1:3.9 for fiscal year 1975 in California, using an estimated total predatory animal damage loss of $4.7 million that included the value of lost livestock, costs of the control program, and associated projected losses to related industries of manufacturing, processing, and transportation.

The average value placed on sheep and goats lost in the present study ($25) is probably too low, but it provides a minimum loss figure that converts to a plausible cost-benefit ratio. Even so, the 21-county figure of 1:4.5 fell between the 1:3.9 for the California ADC program (Thompson 1976) and the 1:62. for the Utah study (Nielsen and Curle 1970). These three cost-benefit ratios are undoubtedly not as accurate as those that will be derived from an improved data-gathering system being implemented by ADC. However, inasmuch as the three separate studies in different parts of the West yielded somewhat similar figures, they probably are reasonably representative of the returns that can be expected for each dollar spent in the cooperative predator control program.

It is also possible that cost-benefit ratios may vary from one area to another as much as or more than they did in the three examples, due to several factors. Some differences might be attributable to the effects of differences in vegetative cover and topography on the ease of taking livestock by predators, or on the ease of killing predators. Differences by area are interrelated with differences in livestock management that result in large differences in exposure to predation (particularly of sheep and goats), e.g., shed lambing vs. range lambing, and close herding vs. loose herding vs. nonherding in fenced pastures, for example.

Before a more accurate appraisal of livestock-predator problems is possible, it will be necessary to determine reasons for variations in coyote populations from one place to another and from one year to the next, as well as what variations exist in the coyote's wild food supply in relation to livestock losses. From the research standpoint, other studies in coyote behavior and ecology as well as the development of more efficient and environmentally sound control techniques will also be required before a more satisfactory approach to predator management can be made. From a practical control operations standpoint, there is also a need to establish a more consistent and scientifically based federal predator control policy to replace uncertainties in the future of long-range predator management.

Literature Cited

Anderson, T.E., M. Caroline, and J.L. Beavers. 1974. An evaluation of aerial hunting as a means of protecting sheep and goats from coyote and bobcat predation in Uvalde and Kinney Counties, Texas. U.S. Dep. Int., Fish Wildl. Serv., Div. Wildl. Serv. Mimeo. 18 p.

Anonymous. 1975. Texas sheep and lambs on feed and early lamb crop. Texas Crop Livestock Rep. Serv., SRS-U.S. Dep. Agr., Austin. Release: March 18. 2 p.

DeLorenzo, D.G., and V.W. Howard, Jr. 1976. Evaluation of sheep losses on a range lambing operation without predator control in southeastern New Mexico. Final Rep. to U.S. Fish Wildl. Serv., Denver Res. Center, New Mexico State Univ., Las Cruces. 34 p.

Gee, C.K., and R.S. Magleby. 1976. Characteristics of sheep production in the western United States. U.S. Dep. Agr., Econ. Res. Serv., Econ. Rep. No. 345. 47 p.

Gee, C.K., R.S. Magleby, W.R. Bailey, R.L. Gum, and Louise M. Arthur. 1977. Sheep and lamb losses to predators and other causes in the Western United States. U.S. Dep. Agr., Econ. Res. Serv., Agr. Econ. Rep. 369. 41 p.

Gober, D.R. 1979. Factors affecting domestic sheep losses to predators in Trans-Pecos Texas. Ph.D. Diss. Texas A&M Univ., College Station. 119 p.

Guthery, F.S. 1977. Efficacy and ecological effects of predator control in south Texas. Ph.D. Diss. Texas A&M Univ., College Station. 50 p.

Gum, R.L., Louise M. Arthur, and R.S. Magleby. 1978. Coyote control: A simulation evaluation of alternative strategies. U.S. Dep. Agr., Econ., Statist., and Coop. Serv., Agr. Econ. Rep. No. 408. 49 p.

Henne, D.R. 1975. Domestic sheep mortality on a western Montana ranch. MS Thesis, Univ. Montana, Missoula. 53 p.

Kauffeld, J.D. 1977. Availability of natural prey and its relationship to coyote predation on domestic sheep. MS Thesis. Univ. Nevada, Reno. 144 p.

Knowlton, F.F. 1972. Preliminary interpretations of coyote population mechanics with some management implications. J. Wildl. Manage. 36:369-382.

Linhart, S.B., and F.F. Knowlton. 1975. Determining the relative abundance of coyotes by scent station lines. Wildl. Soc. Bull. 3:119-124.

McAdoo, J.K., and D.A. Klebenow. 1978. Predation on range sheep with no predator control. J. Range Manage. 31:111-114.

Munoz, J.R. 1977. Causes of sheep mortality at the Cook Ranch, Florence, Montana, 1975-76. MS Thesis, Univ. Montana, Missoula. 55 p.

Nass, R.D. 1977. Mortality associated with sheep operations in Idaho. J. Range Manage. 30:253-258.

Nesse, G.E., W.M. Longhurst, and W.E. Howard. 1976. Predation and the sheep industry in California, 1972-1974. Univ. California, Davis, Div. Agr. Sci. Bull. 1878. 63 p.

Nielson, D., and D. Curle. 1970. Predator costs to Utah's range sheep industry. Nat. Wool Grower 60:14-16, 22.

Pearson, E.W. 1975. Sheep-raising in the 17 western states: populations, distribution, and trends. J. Range Manage. 28:27-31.

Roughton, R.D. (Coordinator). 1976. Indices of predator abundance in the western United States, 1976. Prog. Rep. U.S. Dep. Inter., Fish Wildl. Serv., Denver Wildl. Res. Center, Colo. 123 p.

Shelton, M. 1972. Predator losses in one flock of sheep and goats. Nat. Wool Grower 62:20-22.

Stevens, D.W. 1971. An economic analysis of Wyoming's sheep industry (1960, 1964, 1968). Univ. Wyoming, Laramie. Agr. Exp. Sta. Bull. 564. June. 64 p.

Stevens, D.W., and D.R. Hartley. 1976. Decline in Wyoming's sheep industry—a partial explanation. Univ. Wyoming, Laramie. Agr. Exp. Sta. Res. J. 104. 42 p.

Teer, J.G., J.W. Thomas, and E.A. Walker. 1965. Ecology and management of white-tailed deer in the Llano Basin of Texas. Wildl. Monogr. 15:7.

Texas Livestock Statistics. Reports for 1971, 1974, and 1975. Texas Crop and Livestock Rep. Serv., P.O. Box 70, Austin. 78767.

Thompson, R.A. 1976. The cost of predator damage control using trapping as the primary technique. Proc. 7th Vertebrate Pest Conf., Monterey, Calif. p. 146-153.

Tigner, J.R., and G.E. Larson. 1977. Sheep losses on selected ranches in southern Wyoming. J. Range Manage. 30:244-252.

Turkowski, F.J., and J.R. Vahle. 1977. Desert rodent abundance in southern Arizona in relation to rainfall. U.S. Dep. Agr., Rocky Mountain Forest and Range Exp. Sta., Forest Serv. Res. Note RM-346. 4 p.

U.S. Fish and Wildlife Service. 1976. Annual report, Texas rodent and predatory animal control service. Fiscal year 1976. Mimeo. 57 p.

U.S. Weather Bureau. 1971-76. Climatological data: Texas. Vols. 76-81.