Effects of Predator Control on Angora Goat Survival in South Texas

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Highlight: Predator control was conducted in South Texas during January–July 1975 and 1976 to determine its effects on productivity and survival of Angora goats. The control effort, when compared to an area receiving no treatment, reduced activity of coyotes and bobcats by 80%. Predators, mainly coyotes, killed 33 and 16% of the known kid crop on untreated and treated pastures, respectively. Because predators apparently were responsible for most unknown losses, the true predation loss was as high as 95 and 59%, respectively, of the known kid crop. The net kid crop under intense predator control was 27 times greater than that under no control, but the crop under treatment was only 13.5% because predation losses were still high. Coyotes killed 49 of 204 nannies (91% of losses) in an untreated pasture. They killed none in a treated pasture, but 10% of 205 nannies succumbed to nonpredator mortality. The data indicate that, in regions of high coyote density, intense localized predator control with traps, snares, and M-44's could curtail predation on adult goats, but would be insufficient to prevent heavy losses of kids.

Cain et al. (1972) stressed the need for objective quantification of predation losses in domestic livestock, particularly sheep. Sanyal (1975) reported predators killed 0.4 to 1.4% of the ewes and 1.4 to 2.5% of the lambs on two ranches in South Texas. In California, coyotes (*Canis latrans*) and other predators killed an estimated 40,400 sheep in 1973–74 (Nesse et al. 1976). Dorrance and Roy (1976) found sheep losses to predation averaged 1.6% of ewes and 2.8% of lambs in Alberta. On a ranch without predator control in New Mexico, predators (mainly coyotes) killed 15.6 and 12.1% of the lamb crop in 1974 and 1975, respectively (DeLorenzo and Howard 1976). A similar study in Montana reported predation losses of 8% of ewes and 29% of lambs during a 1-year period in which predator control was practiced during the first 7 months (Henne 1975). Klebenow and McAdoo (1976) verified a predation loss of 4% for sheep in Nevada. It is now clear that coyote predation presents an economic problem in the United States (Connolly et al. 1976).

Cain et al. (1972:47) also noted "there has been essentially no research aimed at determining the effectiveness of control methods in affecting the magnitude of predation losses." Data interpreted by Wagner (1972) suggested that predation losses of sheep might be compensatory, to some extent, with other types of losses on western ranges. If nonpredator mortality increases in the absence of predation, predator control would be of questionable utility in enhancing survival of these animals. Experimental analysis of the efficacy of predator control has yet to be done.

Although predation on sheep is clearly a problem, no studies have quantified the importance of predation in mortality of Angora goats, which was the first objective of the present work. The second was to determine the efficacy of predator control in reducing Angora mortality.

Study Area and Methods

The study was conducted during January-July 1975 and 1976 in northern Zavala County, Tex., in the South Texas Plains. Gould (1975) described the vegetation of this region and Tanner (1976) detailed the physical environment near the study area. Guthery (1977) described the study area, which supported dense stands of whitebrush (*Aloysia lycioides*), blackbrush acacia (*Acacia rigidula*), guajillo (*A. berlandieri*), and other species. Predominant grasses were threeawns (*Aristida* spp.), common curlymesquite (*Hilaria belangeri*), red grama (*Bouteloua trifida*), buffalograss (*Buchloe dactyloides*), and pink pappus (*Pappophorum bicolor*).

Survival and productivity of Angora goats were compared between a 225-ha treated (predator conrol) and a 201-ha untreated (no predator control) pasture. The untreated pasture was separated from treated portions of the study area by 7 km.

Mammalian predators were killed on a 1,550-ha area which included the treated pasture and a 1.6-km buffer zone on three sides of it. Trespass restrictions prevented establishment of a buffer zone on the fourth side. Steel leg-hold traps, M-44's, and snares were deployed at an average intensity of 20.4 device days/ha/month in 1975, where a device day is one device operative for 24 hours. In 1976 the intensity of mechanical control was 12.5 device days/ha/month. About 1 hour of helicopter gunning was also conducted in February each year, and 6.2 hours of predator calling was done in 1975. Guthery and Beasom (1977a) described the predator control in greater detail.

Scat counts were conducted on 12.8- and 20.0-km routes in treated and untreated portions of the study area, respectively, to determine the effectiveness of the control in reducing predator activity. Scats were cleared from the two routes on 2 successive days, and the routes were run alternately over the next 4 days. In 1975 scats were not counted when the routes were cleared. In 1976 they were counted because rain hampered completion of the work. Only coyote and bobcat (*Lynx rufus*) scats, identified by Murie's (1954) criteria, were used to compute scats/1.6 km, the activity index.

Prior to release onto the experimental pastures, each goat was weighed, measured around the girth, drenched for internal parasites, and tagged with individually numbered punch-through ear tags. Weight in kilograms divided by girth in centimeters times 10 was computed as an index of condition. Goats were examined superficially for physical deformities and general health.

After release the flocks were observed and counted daily except during rainy weather. Data were recorded on morbidity and reproductive condition. Pregnancy was

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determined by the size and tightness of udders, by the size and shape of the abdomen, and by evidence of birth such as blood in the ano-genital region. The ear tag number of does with kids was recorded whenever families were seen together.

The natural diet of the flocks was supplemented at a rate of 0.23 kg corn/goat/day from the early February release through mid-March. Besides enhancing productivity, this gentled the flocks for observations and counts.

Carcass searches on foot and horseback were conducted when counts indicated goats were missing. During 1975 and 1976 combined, 262 and 351 hours were spent searching in the treated and untreated pastures, respectively. The average search intensity was 6 and 12 minutes/ha/month, respectively. These figures understate the effective search intensity because (1) considerable time was spent in the pastures doing other work, (2) searches were not conducted in all months in the treated pasture because no mortality was occurring, and (3) searches were concentrated on portions of the pastures used by goats.

Field necropsies were conducted when carcasses were found. Predation was assigned as the cause of death following criteria described by Anderson (1969), White (1973), and Bowns (1976).

Results and Discussion

Predator Control

Sixty-nine coyotes, 11 bobcats, and 52 smaller mammalian predators were killed on the treatment area in 1975. Comparative figures for 1976 were 63, 7, and 32, respectively.

Predator control apparently reduced the presence of major predators (coyotes and bobcats) because the activity index invariably was lower on the treatment area (Fig. 1). Over the study period, the average activity index on the treatment area was about 80% lower than that of untreated areas. Guthery (1977) calculated that in 1975 late winter density of major predators on the treatment area was about 0.8/km^2, which compared to about 2.0/km^2 on untreated areas. Presence of sign indicated the treatment area was never free of major predators, but density apparently dropped to about 0.4/km^2. Based on catch data, coyotes were roughly six times more abundant than bobcats. Thus the predator control reduced coyote density from high South Texas levels (Knowlton 1972) to levels typical of many portions of the West (Wagner 1975).

Homogeneity of Experimental Flocks

The experimental flocks were tested for homogeneity between pastures because extrinsic sources of variation could affect productivity and survival independent of predation. The productivity of Angora does, for example, tends to vary directly with weight within and among age classes (Shelton and Stewart 1973). Results of *t* tests indicated the mean weight and girth were similar (P>0.05) between treatments within years, suggesting the desired homogeneity was realized.

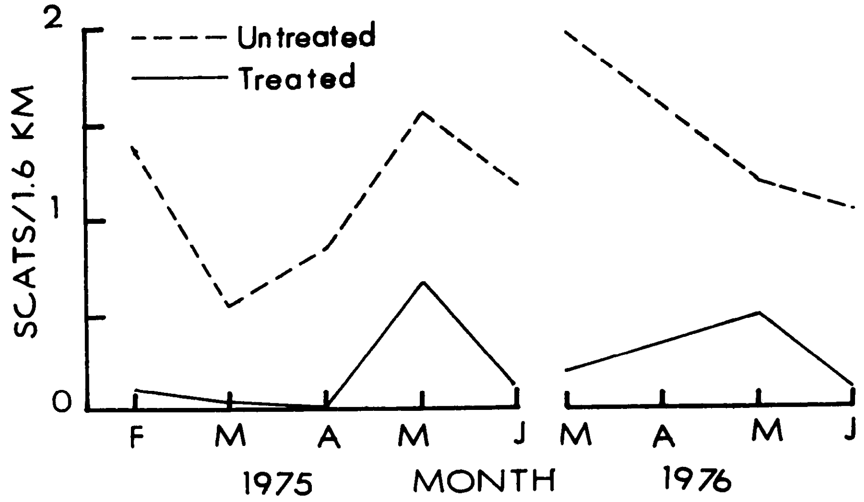

Fig. 1. *Comparative activity of major predators (coyotes and bobcats) on untreated (no predator control) and treated areas, Zavala County, Texas.*

Different pregnancy rates or different parturition periods associated with different weather patterns also could influence comparative kid survival independent of predation. Contingency tables were therefore constructed to examine frequency distributions of reproductive parameters. The nannies, by pastures, were cross-classed with pregnancy status (pregnant, barren, unknown), live kid status (one, two, none), and weight class of adults in 2.27-kg intervals. None of the resulting Chi-square values was significant (P>0.05), again suggesting homogeneity.

Productivity and Survival

Barren nannies were an important cause of lowered productivity. In 1975, 84% of the untreated nannies were pregnant, 5% were barren, and 11% were of undetermined pregnancy. Respective figures for the treated flock were 93, 4, and 3%. In 1976 50% of the untreated nannies were pregnant, 41% were barren, and 9% were of undetermined pregnancy. Respective figures for the treated flock were 54, 29, and 17%. The lower fertility rates of 1976 possibly were due to drouth conditions for 5 months preceding kidding. Because we made special efforts to identify nannies with tight udders or signs of parturition, most nannies of undetermined pregnancy likely were barren. Moreover, evidence of the bleeding associated with birth was detectable on hindquarters for up to a month. Combined over both flocks and years, these data suggest a 70% pregnancy rate in the experimental flocks.

A second factor that decreased productivity, independent of predation, was enlarged teats or otherwise deformed udders. If a nanny's teats were too large (some were 15 cm long and 3 cm in diameter at the tip) the kid could not suckle and usually starved 3 to 4 days after birth. Deformed udders were present on 17% of 410 goats examined in this experiment. Ten (11%) of the nannies that bore live kids on the untreated pasture and 16 (16%) of those on the treated pasture had deformed or "broken" udders. Thus 12 and18% of the kids born in the untreated and treated pastures, respectively, including three sets of twins, doubtless would have died in the absence of predation. Combined losses in productivity from failure to conceive and from inability to nourish newborn kids indicate the maximum potential kid crop in the absence of other losses would have been about 60 to 70%.

Predation was the major source of known losses to the known live kid crop in both experimental pastures (Table 1). All nonpredator losses, excluding unknown and undetermined, accounted for 3% of the untreated kids and 11% of the treated kids. This indicates a slight but numerically unimportant tendency towards intercompensation of losses. Under proper husbandry, it is likely that predation losses of livestock would

Table 1. Partitioned losses of the known Angora kid crop on untreated (no predator control) and treated pastures during February-July, Zavala County, Tex.

Source of loss	Untreated					Treated				
	1975 (60)[a]	1976 (29)	Total (89)	% of kid crop	% of losses	1975 (63)	1976 (37)	Total (100)	% of kid crop	% of losses
Unknown[b]	35	19	54	62	62	18	25	43	43	59
Predation	21	8	29	33	33	14	2	16	16	22
Starvation or abandonment		1	1	1	1	2	5	7	7	10
Undetermined[c]	2		2	2	2	2	1	3	3	4
Stillborn	1	1	2	2	2	1		1	1	1
Unknown, not predation						1		1	1	1
Infection, trap wound						1		1	1	1
Congenital deformation						1		1	1	1
Subtotals	59	29	88	99		40	33	73	73	
Kids survived	1		1	1		23	4	27	27	

[a] Known minimum number of kids born.
[b] Disappeared without trace.
[c] Carcass fragments too old.

be additive rather than compensatory.

Ninety-seven kids seen alive disappeared without trace, resulting in the preponderance of unknown losses in both pastures (Table 1). Because (1) predation was responsible for over 50% of known losses, (2) survivorship was higher where predators were being destroyed (Fig. 2), and (3) coyote scats composed of mohair appeared on the study area concurrent with the disappearance of kids, it was apparent that kids were disappearing under predator pressure. Predation should be suspected when animals suddenly vanish and leave no trace (Robinson 1952), because, for example, a coyote can kill and consume a white-tailed deer (*Odocoileus virginianus*) fawn in about 5 minutes, leaving virtually no evidence of the interaction (Knowlton 1964). Klebenow and McAdoo (1976) also suspected coyote predation when domestic lambs vanished in their Nevada verification study; they found only the ear of one lamb near a coyote den. Thus predators were probably responsible for most unknown losses in this study, a conclusion strengthened by the fact that disease or other abnormalities rarely were noted among the kids during frequent observations of the flocks. Predator losses therefore accounted for 33 to 95% (33 to 95% of losses) and 16 to 59% (22 to 81% of losses) of the known kid crop on the untreated and treated pastures, respectively. The true predation loss apparently fell on the higher extremes of these ranges.

Intensive predator control increased the kid crop by 2,700% in this study. Because the kid crop was only 13.5% under treatment, the former figure is less impressive. Recognize, however, that predators apparently were responsible for most kids lost in the treated pasture; a more effective control regime would have increased the kid crop there.

The effect of predator control on kid survival was most noticeable 6 to 7 days after birth. During the first week of life, kid mortality was high in both pastures (Fig. 2). This indicates that kidding in well-protected areas, and holding kids in these areas until about 2 weeks of age, is a possible cultural practice for decreasing the severity of predation problems.

Predation on nannies was less severe than that on kids. Coyotes killed three nannies in 1975 while the flocks were being held in a 32-ha pasture prior to release, but none was killed on the

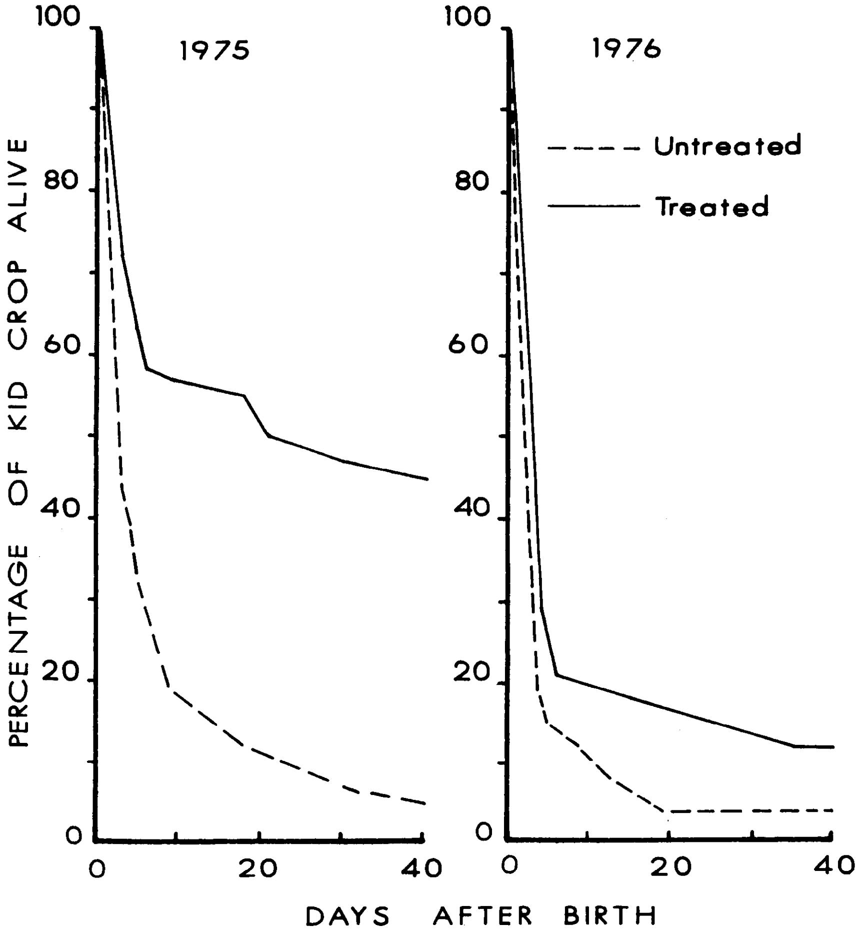

Fig. 2. *Forty-day survivorship of Angora kids in untreated (no predator control) and treated pastures, Zavala County, Texas.*

Table 2. Partitioned losses of adult Angora goats on untreated (no predator control) and treated pastures during January-July, Zavala County, Tex.

Source of loss	Untreated 1975 (102)[a]	Untreated 1976 (102)	Untreated Total (204)	Untreated % of flock	Untreated % of losses	Treated 1975 (103)	Treated 1976 (102)	Treated Total (205)	Treated % of flock	Treated % of losses
Predation		49[b]	49	24	91					
Meningeal worm	1		1	<1	2	16[c]		16	8	76
Unknown, not predation		3	3	1	5	1	1	2	<1	9
Bogged in mud		1	1	1	2					
Ear tumor							1	1	<1	5
Screw worm							1	1	<1	5
Unknown							1	1	<1	5
Subtotals	1	53	54	26		17	4	21	10	
Adults survived	101	49	150	74		86	98	184	90	

[a] Number of goals stocked.
[b] Includes two nannies that died from infection of coyote wounds and five whose carcasses were old, but showed evidence, both direct and circumstantial, of predation.
[c] Includes eight nannies removed for diagnostic examination before death.
[d] Diagnosis not confirmed by laboratory examination of larvae.

experimental pastures (Table 2). In 1976 predation on nannies was heavy in the untreated pasture and was, therefore, the major source of mortality in the flock over the 2 years.

Meningeal worm (*Parelaphostrongylus tenuis*) infection lowered survival of nannies in the treated pasture in 1975 (Fig. 3) and was responsible for most of the 10% overall death loss. The infection should not be regarded as a compensating loss factor, however, because the infection rate in the untreated pasture (4.8%) was lower, rather than equal to, that in the treated pasture (22%).

Over the 2 years, nanny survival under treatment was 122% of that with no treatment. The data indicate that, under relatively intense predator control with mechanical methods, nannies could be pastured in regions of high coyote densities with little mortality from predation.

Factors Influencing Predation Rates

Because predation losses tend to vary directly with coyote density (Wagner 1975), higher coyote numbers in 1976 possibly would explain the heavier predation on both kids and nannies that year. This appears to be an unlikely explanation. The coyote kill in January and February, standardized to number caught per 1,000 snare plus 1,000 trap days, was 21.3 (1975) and 19.3 (1976), which suggests similar densities in the 2 years.

Decreased buffer prey can induce increased predation on livestock (Gier 1968) and may have played a role in the increased predation rates of 1976. Although lagomorph and deer densities were essentially equal both years, mean rodent densities declined (Table 3) by about 58 and 29% in the untreated and treated pastures, respectively, in 1976. Rodents, especially cotton rats (*Sigmodon hispidus*) and woodrats (*Neotoma micropus*), the most abundant species on the study area (Guthery 1977), are important in the diet of South Texas coyotes (Knowlton 1964; Sanyal 1975; Brown 1977).

An apparent relation between month of birth and kid survival partially explains the difference observed between years. To examine this relation, the percentage of the first 30 days of life survived was determined for each kid. The means over both pastures and years were 17.5 (n=42), 29.7 (n=61), 48.1 (n=58), and 33.9% (n=9) in February, March, April, and May, respectively. A null hypothesis about these means was rejected ($P<0.06$) (Table 4). Whereas the percentages were 10 to 30 points higher on the treated pasture, the trend of increasing survival from February through April and a decline in May was similar in both pastures. In 1975 47, 47, and 6% of the kids were born in March, April, and May, respectively. In 1976, 74, 14, 9, and 3% were born in February, March, April, and May, respectively. Thus in 1975 more births occurred in later months when more predators had been removed from the treated area. Because survival on the untreated pasture showed similar trends, however, other factors were operating. During 1975, densities of rodents and cottontails (*Sylvilagus floridanus*) rose steadily from January through July in the untreated pasture (Guthery and Beasom 1977b). These increasing buffer prey populations may have ameliorated predation on kids as the study progressed. By virtue of greater numbers, 1975 kids had stronger influence on the 2-year mean percentages in this pasture.

Table 3. Densities (number/40 ha) of animal prey and fruit-producing shrubs to compare availability of natural foods for predators between untreated (no predator control) and treated pastures, Zavala County, Tex. The data are from Guthery and Beasom (1977b) and Guthery (1977).

Species	1975[a] Untreated	1975[a] Treated	1976[b] Untreated	1976[b] Treated
All rodents	704	416	296	296
Cottontails (*Sylvilagus floridanus*)	49.7	22.0	49.5	43.0
White-tailed deer (*Odocoileus virginianus*)	1.8	5.1	2.6	4.1
Jackrabbits (*Lepus californicus*)	<2	<2	<2	<2
Mesquite (*Prosopis glandulosa*)	560	13,120		
Pricklypear (*Opuntia* sp.)	2,400	8,320		
Persimmon (*Diospyros texana*)	5,680	2,400		
Condalias (*Condalia* spp.)	3,280	6,440		
Granjeno (*Celtis pallida*)	9,880	8,320		

[a] Animal densities are January-July averages.
[b] Animal densities are February-July averages.

Table 4. Least squares analysis of variance of kid survival, Zavala County, Tex. The classification variables are year (1975, 1976), pasture (untreated, treated), and birth month (February, March, April, May). The dependent variable was the percentage of the first 30 days of life survived.

Source of variation	df	MS	F	P>F
Model	8	7,590.8	5.85	0.0001
Year	1	220.6	0.17	0.6807
Pasture	1	14,024.4	10.81	0.0012
Birth month	3	3,254.3	2.52	0.0592
Birth month by pasture	3	2,000.4	1.54	0.2044
Error	161	1,297.8		

A minimum of 123 kids was born in 1975 compared to 66 in 1976 (Table 1). Death of a kid in 1976 was roughly twice as important, in terms of percentages, thereby influencing portrayed survivorship (Fig. 2) disproportionately. This condition, sometimes called small-sample bias, also should be recognized when interpreting cause of loss as a percent of flock (Tables 1 and 2).

The larger number of kids born in 1975 (Table 1), whose births were more evenly distributed in time, may have buffered predation on nannies in this year. No nannies were killed in the untreated pasture while kids survived.

A last factor possibly contributing to increased predation rates in 1976 involved historical (Holling 1965) or learned aspects of predation. When introducing goats into a new area, ranchers in South Texas have reported moderate predation losses the first year and substantial losses the second. Although ecological factors such as buffer prey abundance were unknown in these instances, the phenomenon seems general and predictive enough to warrant consideration. Perhaps predators undergo some form of habituation to vulnerable livestock, or perhaps they build traditions by killing kids, subsequently killing adults, and then training the young.

Coyote Predation on Angoras

That coyotes were responsible for most, if not all, of the predation losses was evident from sign at kill sites. Coyote tracks and/or droppings, several composed of mohair, usually were found within a few meters of carcasses. Most killing took place where past observations of tracks indicated heavy coyote use. None of the carcasses was covered with material or brushed together as is characteristic of bobcat predation (Cook et al. 1971). Mature goats were attacked in the larynx region, typical coyote behavior (Bowns 1976; Connolly et al. 1976).

The killing of kids began almost as soon as they were born in 1975. This took place on a ranch where Angoras had not been stocked in nearly a decade, where buffer prey populations were substantial (Table 3), and where the nearest other flock was 16 km away. These observations suggest that Angora kids are readily predated by naive coyotes, as is the case with coyotes and sheep (Connolly et al. 1976), and, by extension, indicate the problem-animal concept of predator control (Cain et al. 1972; Henderson 1972) would have little merit in protecting Angora kids in South Texas.

The location of killing was a function of goat behavior. When a nanny entered labor, the rest of the flock went about normal activities, eventually leaving her (unless the birth occurred on the bedgrounds). She usually stayed with the newborn 2 to 3 days, then left it "lying out" and returned to the flock. There was no apparent pattern for her to return and nurse the kid; one instance was recorded of a nanny leaving her kid for 37 hours before feeding it. After the kid reached 10 to 14 days of age, it was capable of traveling with the flock and often did. Occasionally nannies left a small group of kids unattended during daylight while the flock foraged. Most kids were killed during the critical first few days of life, before they joined the flock. Their location during this time was largely a matter of chance, depending primarily on the habits of the flock and secondarily on where the nanny entered labor.

Adult goats generally were killed on or near the bedgrounds, which were evidenced by an accumulation of fresh droppings and an odor of urine. On one occasion, tracks indicated coyote(s) ran a goat for about 300 m before killing it. Goats move upwind to bed down and usually mass as one flock. Thus they usually bed on the periphery of a pasture, which aided our carcass searches because about 80% of the kills were within 40 m of ranch roads

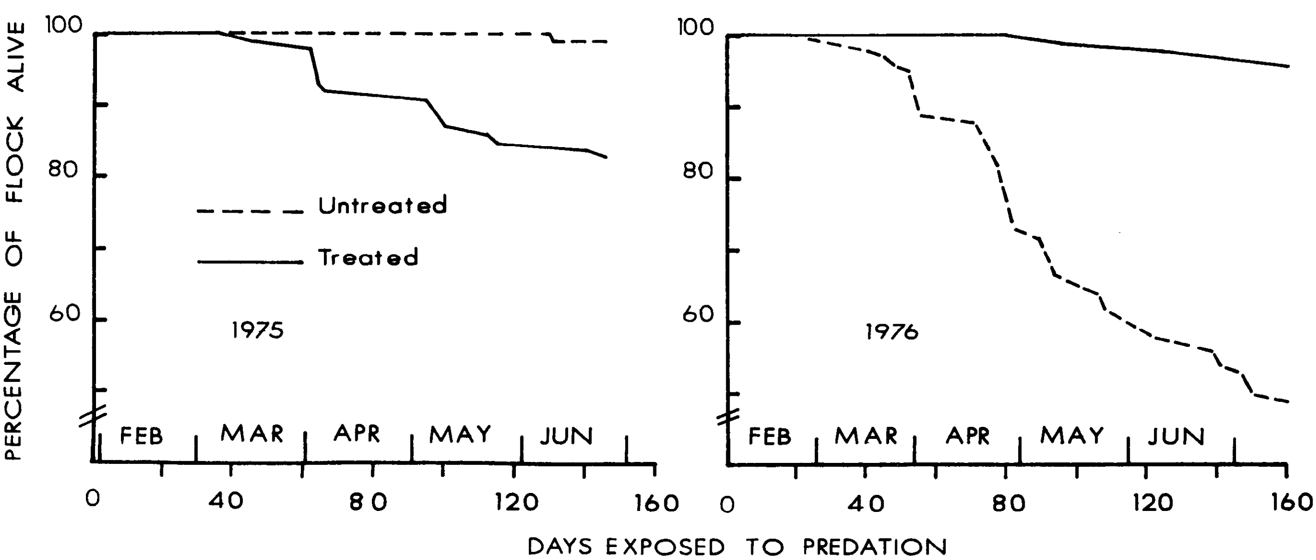

Fig. 3. *Survivorship of adult Angora goats in untreated (no predator control) and treated pastures, Zavala County, Texas.*

surrounding the untreated pasture.

Nine nannies survived apparent coyote attacks during the study. Four were lacerated in the throat, five in the flanks or hams. Four nannies were attacked on a night when three others were killed.

Coyotes selected the youngest, smallest kids before older kids and kids before nannies. Nannies were not killed in 1976 until the last kid was lost and predation on adults began almost immediately.

Whether coyote predation on adult goats was selective for inferior individuals cannot be determined unless the proportions of healthy and debilitated animals in the flock are known. Formal records of these proportions were not maintained. Nonetheless, the kill included five nannies weakened from previous coyote attacks (health prior to attack was unknown), three slightly crippled, one in poor condition and suffering diarrhea, and one with a broken hock (old injury) that impaired her running ability. Thus 20% of the kill was composed of somewhat debilitated animals. Behavioral aberrancies, such as separating from the flock due to illness or injury, apparently made goats highly susceptible to predation because killing occurred in the three known instances of this behavior in 1976. Whereas coyotes took both the healthy and the infirm, some selection for the latter seemed likely. This conclusion is supported by the fact that the pre-experiment condition index of the 49 nannies killed was lower ($P<0.01$) than that of the 49 nannies surviving in the untreated pasture in 1976. Whether the index truly reflects condition is open to speculation, but girth would be more stable than weight and the index should vary directly with a nanny's health and nutritional state, though perhaps not linearly. Regardless of the validity of the index, the mean weight (2.83 kg heavier in survivors) and girth (2.4 cm larger in survivors) were significantly different ($P<0.01$), indicating coyote selection for smaller nannies.

Whereas the condition index was determined from measurements of girth and weight, it may seem redundant to examine each separately. The index, however, is a variable that adjusts for differences in body structure. Had coyotes been selecting solely for smaller animals, the condition indices, according to normal theory, would have been equal. That they were not suggests selection for both large and small animals in poorer condition; smaller animals probably were selected, to some extent, independent of condition.

Conclusions

In the absence of catastrophic losses due to cold rainy weather or similar factors, coyote predation apparently is the major source of mortality to range flocks of Angora goats in South Texas. In addition, the data indicate intensive predator eradication with traps, snares, M-44's, and shooting can substantially increase the survival of kid and adult goats in this region, but is insufficient to curtail large losses of kids to predation, at least when conducted on a small scale and when total eradication of coyotes is not attained. It follows that predation losses of Angoras are, at most, slightly compensatory under low stocking rates and proper husbandry.

We should recognize, however, that Angora goats are inherently subject to a number of problems which tend to decrease their productivity and increase their mortality under range conditions. A weak mothering instinct (Gray and Groff n.d.; this study) a problem with udder deformities (Shelton and Stewart 1973; this study) poor reproductive performance under nutritional stress (Huston et al. 1971), and an intolerance of cold wet weather after shearing make large losses possible in a total absence of predators. Thus predator control emerges as a valuable adjunct to, but certainly no substitute for, proper range management and animal husbandry.

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