Responses of Game and Nongame Wildlife to Predator Control in South Texas

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Highlight: One hundred thirty-two coyotes, 27 opossums, 22 skunks, 18 bobcats, 15 raccoons, 12 badgers, and one gray fox were killed on a 1,550-ha area of mixed brush rangeland in South Texas during January–July 1975 and 1976 to determine the responses of herbivore and quail populations to predator control. When compared to an area without predator control, predator removal at this level had little discernible effect on density trends of bobwhite or scaled quail, rodents, or lagomorphs. However, fawn production per unit area was 70% greater in 1975 on the area with predator control and 43% greater in 1976. These data suggest that intensive short-term predator control on South Texas rangeland results in little or no adverse impact on range forage due to expanding populations of small herbivores. Productivity and populations of white-tailed deer may increase and harvests should be adjusted accordingly, as overuse of range forage could occur.

Several studies have evaluated the efficacy of predator control in increasing the harvestable surplus of game animals (Beasom 1977), but few have concurrently followed the population responses of nongame wildlife. The possibility that predator control could release rodent or lagomorph populations causes concern because of the range management implications. Rodents can maintain less desirable seral states (Norris 1950), remove up to one-third of annual forage production (Fitch and Bentley 1949), and retard weight gain in cattle by forage competition (Howard et al. 1959). The diet of black-tailed jackrabbits (*Lepus californicus*) approximates that of sheep on salt-desert shrub ranges in Utah, and 5.8 jackrabbits consume or waste as much forage as one sheep in the spring (Currie and Goodwin 1966). About 260 black-tailed or 164 antelope jackrabbits (*L. alleni*) consume enough forage to feed one cow in the Southwest (Arnold 1942).

Beasom (1974) found that intensive generalized predator control enhanced reproductive success of white-tailed deer (*Odocoileus virginianus*) and wild turkey (*Meleagris gallopavo*) with no apparent effects on rodent or lagomorph numbers in South Texas. Removal of small mammalian predators from experimental areas in South Dakota resulted in large increases in pheasant (*Phasianus colchicus*) populations, with concurrent moderate increases in jackrabbit and cottontail (*Sylvilagus floridanus*) populations and slight increases in rodent populations (Trautman et al. 1974). To our knowledge, these are the only studies published that have quantitatively monitored the responses of both game and nongame prey to predator control.

The present data resulted from a study to determine the efficacy of predator control in reducing predation on Angora goats. This paper discusses the responses of white-tailed deer, bobwhite quail (*Colinus virginianus*), scaled quail (*Callipepla squamata*), lagomorph, and rodent populations to that predator control.

Study Area

The study was conducted in northern Zavala County, Tex., in the South Texas Plains vegetation region (Gould 1975). Climate of this region is mild. The average annual rainfall (55 cm) is highly erratic yearly and monthly. From August 1974 through June 1975, the study area received about 91.5 cm of rain, and the vegetation responded with lush growth. From August 1975 through June 1976, rainfall totalled 24.8 cm and vegetation growth was retarded, especially during November 1975 through March 1976, when less than 4 cm of rain fell.

Three soil types supported three relatively distinct plant communities on the study area. Fertile clay loams occupied flat lowland sites and supported dense stands of whitebrush (*Aloysia lycioides*). Principal grasses were pink pappus (*Pappophorum bicolor*) and bristlegrasses (*Setaria* spp.) on moister areas and common curlymesquite (*Hilaria belangeri*) and buffalograss (*Buchloe dactyloides*) on drier areas. Lowlands graded into relatively level red sandy loams where honey mesquite (*Prosopis glandulosa*), spiny hackberry (*Celtis pallida*), and blackbrush acacia (*Acacia rigidula*) occurred in low to moderate densities. Threeawns (*Aristida* spp.) and red grama (*Bouteloua trifida*) were important grasses; forbs were sparse. Gravelly ridges with usually moderate slopes and shallow sandy loams were interspersed with the other soil types. These ridges supported dense stands of guajillo (*Acacia berlandieri*) and blackbrush acacia and a sparse ground cover of threeawns and red grama.

Materials and Methods

The project was designed and executed such that predator removal was the major source of variation influencing results. Sampling was conducted concurrently, when possible, on two experimental areas. Density trends of wildlife were compared between a 225-ha treated (predator control) and a 201-ha untreated (no predator control) pasture (Fig. 1).

Mammalian predators were killed in a 1,550-ha area, which included the treated

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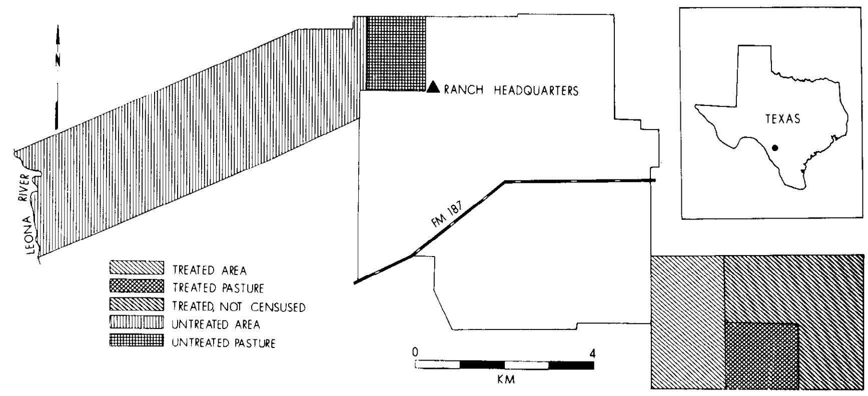

Fig. 1. *The study area in Zavala County, Tex.*

pasture and a 1.6-km buffer zone on three sides of it. Steel traps, snares, and M-44's were deployed at an average intensity of 165 device days/km^2/month, where a device day is one device operative for 24 hours. Also, 1.55 hours of helicopter gunning and 6.2 hours of predator calling were done. Guthery and Beasom (1977) detailed the predator control effort.

Densities of deer, quail, and lagomorphs were estimated with strip census formulas of the King type (Leopold 1933) for comparisons between treatments. Permanent linear transects 0.32 km apart were established in the two pastures and flagged with surveyor's tape. The north-south transects included four 1.8 km long in the untreated pasture and five 1.6 km long in the treated pasture. Counts started at about sunrise and at 2 to 3 hours before sunset. Each transect was walked four times per month. The number, radial flushing distance, and flushing angle were recorded for each individual or group flushed. Distances were paced to the nearest meter, except for long observations of deer where it was estimated visually to the nearest 5 m. Separate analysis (Guthery 1977b) indicated the harmonic mean of radial distances (Hayne 1949) was an acceptable measure of effective transect width for deer and quail, though it likely resulted in underestimates of density. The mode of radial distances was used for cottontails. The harmonic means were stratified by month; this refinement was considered unnecessary for cottontails as there was little seasonal variation in their sighting distance.

Density and fawn:doe ratios of white-tailed deer were determined by helicopter censuses conducted by the Texas Parks and Wildlife Department in October of each year. Systematic flights over about 90% of the study area were designed to give total counts. These data were used to compare deer population response to predator control between a five-pasture block (2,016 ha) that received no treatment and a 698-ha area that received treatment (Fig. 1), because the helicopter censuses were not stratified by individual pastures during both years.

An upland site dominated by blackbrush acacia and guajillo and a lowland site dominated by whitebrush were selected in each pasture to monitor rodent populations. One hundred Sherman live traps, baited with grains, were placed at 15.2-m intervals in a 10 by 10 grid and run for five consecutive days each month of the study period in 1975 and 4 days in 1976. Rodents were marked individually by clipping one or two toes; population size was estimated with the Schumacher-Eschmeyer formula (Overton and Davis 1969). Area trapped was determined by adding the average distance moved between captures to the periphery of the grid (Brant 1962). Because this distance was roughly 30 m for all species (Guthery 1977a), the area trapped was 3.9 ha in each grid.

Jolly (1965:226) derived a method for calculating the "probability that an animal alive at the moment of *release* of the *i*th sample will survive till the time of capture of the $i + 1$st sample (emigration and death being synonymous for this purpose)." To calculate this probability, we considered a monthly trapping period (five days in 1975, four in 1976) as time *i*; data for all species were pooled.

Modified life table analyses were conducted to compare the mortality of cotton rats (*Sigmodon hispidus*) and woodrats (*Neotoma micropus*) between the untreated and treated pastures. Artificial cohorts were created by assigning individuals trapped in February the age of zero. These "cohorts" were comprised, for a given pasture, of animals trapped in both grids during both years to obtain larger samples. Survival was based on trapping records in subsequent months.

Woodrat densities were estimated by spring and summer den counts along the wildlife census transects described earlier. The right-angle distance to dens was paced to the nearest meter, and density was estimated by Leopold et al.'s (1951) formula. Dens were considered active if fresh droppings were nearby, if trails were well defined, if cobwebs were absent from entrances, and/or if there was other evidence of recent use. One adult woodrat per active den (Raun 1966) was assumed.

Results and Discussion

Predator Control

The confirmed kill of coyotes and bobcats (Table 1) apparently reduced the density of these predators to about 0.4 to 0.8/km^2, whereas their density was about 2.0/km^2 on untreated portions of the study area (Guthery 1977a). Guthery speculated that the small kill of badgers (*Taxidea taxus*) and gray foxes (*Urocyon cinereoargenteus*) substantially reduced their numbers because few occurred on the study area. He further noted, based on qualitative appraisal of the abundance of their sign, that raccoon (*Procyon lotor*) and skunk (*Mephitis mephitis*) populations were perhaps reduced by 40 to 60% on the treated area. The fairly large kill of opossums (*Didelphis marsupialis*) did not appear to depress their numbers markedly.

Table 1. Mammalian predators killed on a 1,550-ha area, Zavala County, Tex.

	Number killed	
Species	1975	1976
Coyote	69	63
Bobcat	11	7
Raccoon	10	5
Striped skunk	11	11
Badger	7	5
Opossum	24	3
Gray fox	0	1

White-tailed Deer Responses

Although slightly higher in the untreated pasture, deer numbers were roughly equal in the experimental pastures prior to treatment in August 1974 (Table 2). Fawn:doe ratios were 0.38 (untreated) and 0.48 (treated). The observed number of fawns and does, cross-classed with pastures, indicated homogeneity ($P > 0.05$), however.

Response of the deer population to predator control, which began in Janu-

Table 2. Densities of adult deer on untreated (no predator control) and treated portions of the study area, Zavala County, Tex.

	Number/40 ha	
Time	Untreated	Treated
Aug. 1974	5.8	5.0
Jan. 1975	5.6	5.0
Oct. 1975	4.9	6.5
Oct. 1976	5.5	6.9

ary 1975, was confounded by human disturbance adjacent to the untreated pasture. Density of this pasture apparently declined by about 80% in February (Fig. 2), coinciding with exploratory oil drilling about 2 km from the pasture. Traffic of large trucks on a bordering road was heavy both day and night during this operation. After drilling activities subsided, deer numbers never attained pre-experiment levels in the untreated pasture.

Hood and Inglis (1974) noted the response of white-tailed deer to disturbance associated with intensive cattle roundups in a similar South Texas brushland habitat. They found the main response to be within areas of disturbance rather than between disturbed and relatively undisturbed areas. Rarely did they observe an abandonment of the fidelity for an individual's home range as was indicated in the present study.

An alteration of the flushing behavior of the deer in this study also may have influenced the calculated density in the untreated pasture. The average radial flushing distance of deer in this pasture in February increased by 50% over January levels. In dense brush such as occurred on the study area, increased flightiness of deer probably would result in underestimates of density. This would occur because the probability of sighting a deer decreases dramatically with increasing distance from the observer in brushy habitat, where even under average conditions strip censuses may yield underestimates of density because of failure to detect animals (Guthery 1977b). The average radial flushing distance in the treated pasture, conversely, decreased by 20% from January to February in 1975. Regardless of the response of the deer to disturbance near the untreated pasture, the helicopter censuses indicated the density of the five-pasture block, including the untreated pasture (Fig. 1), remained relatively stable during the study (Table 2).

The October 1975 fawn:doe ratio of 0.72 in the treated area was approximately 29% greater than that on the untreated area, whereas in October 1976 that on the treated area was about 6% lower than the 0.32 value on the untreated area. Although the age-ratio data indicated little difference in fawn production between areas in 1976, the number of fawns produced per unit area was approximately 70 and 43% greater on the treated area in 1975 and 1976, respectively.

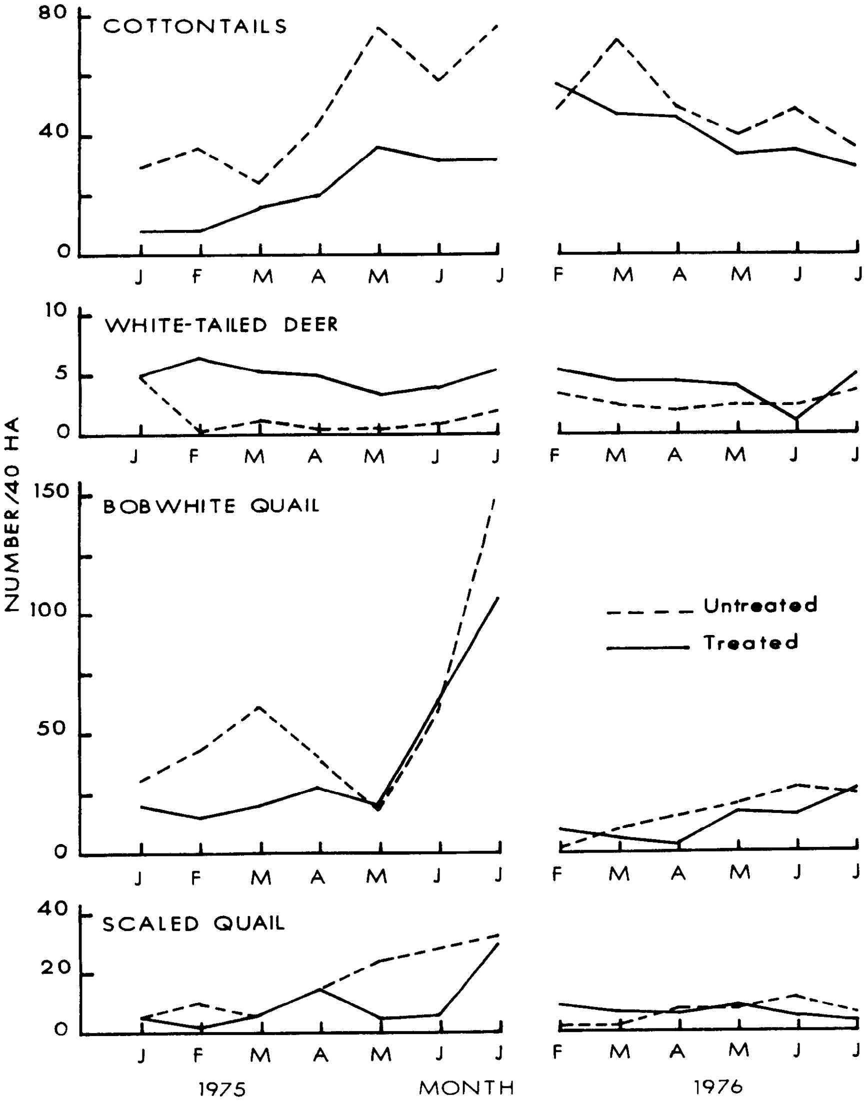

Fig. 2. *Density trends of cottontails, deer, and quails on the untreated (no predator control) and treated pastures, Zavala County, Tex.*

In addition, equal fawn:doe ratios under different deer densities may indicate a positive response to predator control. In central Texas Teer et al. (1965) found that fawn production varied inversely with adult density. If this relationship held in our South Texas area the fawn:doe ratio in the treated area should have been lower because of the roughly 25% greater density. Clearly, age ratios, when interpreted without density estimates, may be an incomplete and sometimes misleading measure of the effects of predator control on game production.

The difference in density of fawns on the experimental areas was a reflection of total numbers of adult does. These females increased on both areas from 1975 to 1976. However, the increase was markedly greater on the treated area (24% above the 5.23 does/40 ha on the treated area compared to 9% above the 3.92 does/40 ha on the untreated area).

Similarly, total numbers of adult deer increased throughout the study period on the treated area and remained relatively stable on the untreated area (Table 2). These data suggest that the approximately 80% reduction in coyote and bobcat activity on the treated area (Guthery and Beasom 1977) resulted in an increased survival of young and/or adult deer and a subsequent increase in the population. That this increase had not become asymptotic was suggested by similar loss rates (1.6/40 ha) in the treated and untreated pastures associated with drought conditions prevailing from November 1975 through March 1976. Most of the carcasses located were too old for unequivocal ascription of cause of death. Two carcasses were assigned to a predator-killed category and several others showed circumstantial evidence of predation, but predation may have represented only proximate mortality, the ultimate agent being nutritional stress. Because deer density was higher, nutrition-induced losses also should have been higher in the treated pasture. The fact that they were not suggests the reduction in predator activity ameliorated, to some extent, total overwinter deer losses on the treated pasture. It is unlikely that this condition could be perpetuated, and the harvest rate of deer in the treated area likely should be increased to prevent the classical habitat destruction associated with unchecked ungulate populations.

Quail Responses

Pre-experiment populations of scaled and bobwhite quail apparently were higher on the untreated pasture (Table 3). This condition held from January through April 1975, with bobwhite densities equalizing in May and scaled quail densities equalizing in January (Fig. 2). Thus the influence of inversity (Errington 1934) on comparative productivity was minimized or cancelled. Reproductive success of bobwhites was excellent in 1975 as density was calculated at over 100/40 ha in July. Scaled quail density trends were similar in the experimental pastures, subject to the inherent variability of counts of flocking species. Both density and productivity of scaled quail were below that of bobwhites.

Table 3. Pre-experiment density indices based on 33.6 and 35.2 km of walking transect in the untreated (no predator control) and treated pastures, respectively, in August 1974, Zavala County, Tex.

	Number/km	
Species	Untreated	Treated
Cottontail	1.04	0.37
Bobwhite quail	6.07	3.32
Scaled quail	0.89	0.51

Whereas little, if any, quail hunting was done on the study area in 1975, it was leased and hunting pressure increased in 1976. It seems unlikely, however, that hunting was solely responsible for a decline in density of about 80% from February of the preceding year (Fig. 2). The droughty period from November 1975 through February 1976 probably played some role in this reduction. Reproductive success of both scaled and bobwhite quail was meager in 1976, as July densities were about 25 and 6/40 ha, respectively. Thus quail populations followed the boom-and-bust cycle typical in South Texas (Lehmann 1953) during the two seasons of study.

The data indicate intensive predator control had but slight influence on quail populations. If there was any effect, it was that the treatment enabled populations on poorer habitat to maintain roughly equivalent numbers with those on better habitat. That the untreated pasture provided better habitat is supported by pre-experiment abundance (Table 3) and by subjective opinion. Similarly, Lehmann (1946) and Beasom (1974) found no significant difference in bobwhite populations or productivity due to predator control in South Texas.

Lagomorph Responses

Pre-experiment cottontail numbers were two to three times higher on the untreated than on the treated pasture (Table 3). This condition held in January 1975 when predator control began. Cottontail densities subsequently increased at rates of 8.43 and 5.04/40 ha/month on the untreated and treated pastures, respectively, during 1975. These significantly different ($P < 0.05$) rates are a reversal of the expected condition if predator control is presumed to release cottontail populations.

Cottontail densities apparently were similar on the two pastures in February 1976 (Fig. 2). Subsequently, densities declined at rates of 3.97 and 4.97/40 ha/month in the untreated and treated pastures, respectively, during 1976. These rates were similar ($P > 0.05$).

Because pre-experiment densities were unequal in the two pastures (Table 3), at a time when predator pressure presumably was equal, ecological factors other than mammalian predation probably played a role in observed density trends. This lack of homogeneity confounds an analysis of predation's effects on cottontail populations. However, an apparent correlation ($P < 0.10$) between monthly densities in the experimental pastures suggests that density, though governed by factors common to the two pastures, fluctuated independent of two levels of predator abundance. Clearly, cottontail populations in the treated pasture showed no irruptive tendencies under the conditions obtaining in this study.

Jackrabbit densities never exceeded 2/40 ha on either experimental pasture, probably because the study area provided unsuitable habitat.

Although predation may account for a substantial proportion of annual lagomorph mortality (Trent 1972; Wagner and Stoddart 1972), it by no means follows that predation controls lagomorph populations, or that decreased predation would release lagomorph populations. Because lagomorph fecundity greatly exceeds that of

Table 4. Life table analysis of cotton rats and woodrats in the untreated (no predator control) and treated pastures, during February–July 1975 and 1976, Zavala County, Tex. Animals trapped in February were given an artificial age of zero and survival was based on monthly trapping records.

Artificial age	Untreated				Treated			
(months)	l_x	d_x	q_x	e_x[1]	l_x	d_x	q_x	e_x
Cotton rat								
0	1,000	478	0.478	1.49	1,000	167	0.167	2.14
1	522	283	0.542	1.41	833	403	0.484	1.47
2	239	130	0.552	1.47	430	236	0.549	1.37
3	109	29	0.266	1.64	194	69	0.356	1.44
4	80	37	0.460	1.05	125	69	0.552	0.95
5+	43	43	1.000	0.50	56	56	1.000	0.50
Woodrat								
0	1,000	636	0.636	1.77	1,000	412	0.412	1.85
1	364	92	0.253	2.99	588	294	0.500	1.80
2	272	45	0.165	2.84	294	59	0.201	2.10
3	227	0	0.000	2.30	235	117	0.497	1.51
4	227	45	0.198	1.30	118	0	0.000	1.50
5+	182	182	1.000	0.50	118	118	1.000	0.50

[1] l_x = number of animals alive at start of age interval; d_x = number dying during age interval; q_x = rate of mortality during age interval; and e_x = mean expectation of life (months) for animals alive at start of age interval.

most mammalian predators, and because limits on predator numbers are imposed, to some extent, by energy available at the secondary consumer trophic level, hare and rabbit numbers apparently may wax and wane irrespective of predation. Such has been the case, with few qualifications, for jackrabbits in Utah (Wagner and Stoddart 1972) and snowshoe hares (*Lepus americanus*) in Alberta (Keith 1974).

Considering the diverse predator fauna in South Texas, which includes reptiles, birds, and mammals, it is apparent that the predator control in this study removed only a segment of potential lagomorph predators. The remaining predators, being freed from a certain amount of competition for food, could increase in numbers and compensate decreased predation rates caused by predator control. Breeding efforts of great-horned owls (*Bubo virginianus*), for example, are enhanced by rising food supplies (Rusch et al. 1972), and populations of other rapacious mammals apparently increase in response to coyote control (Robinson 1961). Such ecological adjustments have been largely overlooked by those concerned about the environmental effects of predator control (e.g. Cain et al. 1972).

Rodent Responses

Infrequent captures of pygmy mice (*Baiomys taylori*), harvest mice (*Reithrodontymys fulvescens*), deer mice (*Peromyscus* spp.), grasshopper mice (*Onychomys leucogaster*), pocket mice (*Perognathus hispidus*), and ground squirrels (*Citellus mexicanus*) made monthly estimates of their populations infeasible. To avoid losing these observations, we based the mark-recapture estimates (Fig. 3) on all species. The observed density trends largely reflect the abundance of cotton rats because they represented, averaging over 2 years, 52 to 85% of the catch in any grid. Woodrats, deer mice, and harvest mice were, in descending order, the next most abundant species. Other species accounted for about 3% of the catch.

In 1975 cotton rats apparently irrupted on the untreated whitebrush grid, achieving a peak density in July of about 1,700/40 ha (Fig. 3). Overall rodent density decreased on the treated whitebrush grid from January through May 1975. This decline was due partially to high trap mortality of harvest mice during January and February, when they comprised 34 and 18%, respectively, of the catch in this grid.

Numbers of all species except woodrats declined in 1976. Deer, harvest, grasshopper, pygmy, and pocket mice virtually disappeared from the catch. Combined numbers of cotton rats and woodrats accounted for 91 to 95% of the monthly catch.

Spring and summer counts in 1975 indicated 252 and 192 woodrat dens/40 ha, respectively, on the untreated pasture. Respective figures for the treated pasture were 212 and 204. In 1976 these counts indicated 368 and 160/40 ha, respectively, on the untreated pasture. Respective figures for the treated pasture were 452 and 288. Because the mean perpendicular distance to dens was stratified by seasons to estimate density, differences in visibility do not fully explain the decline in woodrat numbers from spring to summer in both pastures both years. The relative decline was smaller in the treated pasture both years.

The mean probability of an individual rodent surviving from one month to the next, calculated over the two treatments and years, was 0.57 ± 0.035. Whereas this probability was lower in the drier conditions of 1976 ($P < 0.05$), it apparently was unaffected by predator control ($P > 0.25$).

Monthly mortality rates and expected survival of cotton rats were similar in both pastures (Table 4), based on "cohorts" of 138 (untreated) and 72 (treated). Letting $y=\log(l_x)$, the monthly rates of decline of 0.29 (untreated) and 0.24 (treated) were similar ($P > 0.05$), indicating no discernible effect of predator control on cotton rat survival.

Similar regression analysis for woodrats, based on "cohorts" of 22 (untreated) and 17 (treated), indicated woodrats declined at a lower rate ($P < 0.05$) on the untreated (0.16) than on the treated (0.23) pasture. These rates

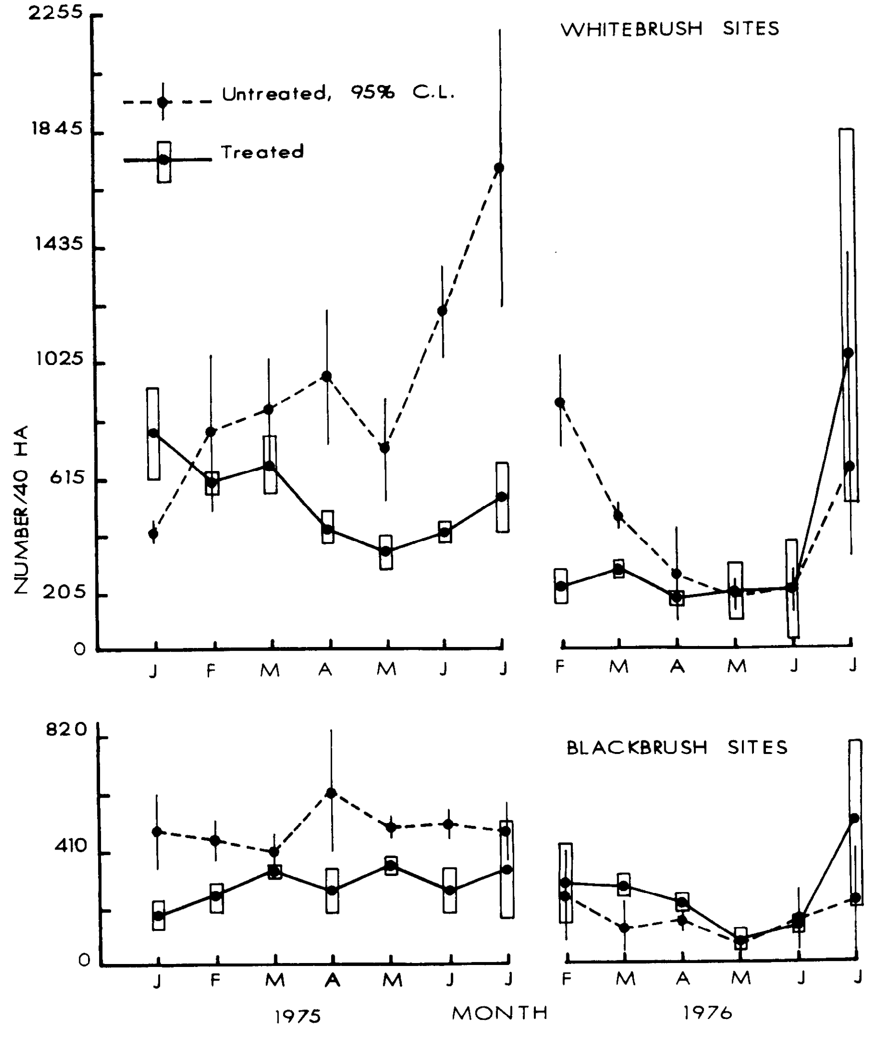

Fig. 3. *Density trends of combined rodent populations on the untreated (no predator control) and treated pastures, Zavala County, Tex.*

are a reversal of the expected condition if predator control is presumed to enhance woodrat survival.

No irruptive tendency of rodent populations in response to mammalian predator control was demonstrated. It therefore follows that intensive short-term predator control in South Texas would not result in adverse impact to range forage due to expanding numbers of rodents.

The present findings support results of Beasom (1974) and Trautman et al. (1974), who also recorded little or no response of rodent populations to predator control. Schnell (1968), however, felt that diverse and highly mobile avian and mammalian predators were more important regulators of cotton rat density than food, weather, or social interactions. He was working with *non-breeding* cotton rats, and while he may have demonstrated that predation is responsible for most mortality, his conclusions about its population regulating effects may well be spurious. Pearson (1964) reported that mammalian predators nearly annihilated a vole (*Microtus* sp.) population in California. However, because house cats were an important component of the predator fauna, suggesting predator density was artificially high, his findings may be valid only under such specialized circumstances.

The present data suggest a possible inversely density-dependent effect (Keith 1974) of predation on rodent populations, assuming that predation on a population is roughly proportional to the number of predators acting on that population. In 1975, a year with plentiful rainfall and good production of grasses and forbs, rodent densities were higher on the untreated grids (Fig. 3). The droughty period from November 1975 to March 1976 probably contributed to decreased rodent densities in 1976 by retarding growth of vegetation. The relative decrease was greater in the untreated grids because the lowest densities were roughly equal in both pastures in 1976. Thus it may be hypothesized that predation caused a greater decline in rodent densities than would be expected under a lower level or absence of predation. Furthermore, predation had possible effect only on declining and relatively low rodent numbers, i.e. it was inversely density-dependent.

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Individual Sustaining Members

We regret our inadvertent omission of the following members from the list of Individual Sustaining Members published in the September 1977 *Journal of Range Management*:

Robert S. Campbell
John D. Freeman