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***Abstract*:** Coyotes (*Canis latrans*) are often removed from an area because of their predatory nature, regardless of the effect such removal may have on the ecosystem. Research results concerning ecosystem changes due to coyote removal appear ambiguous; however, differing lengths of coyote control can produce different results. Short-term coyote removal efforts ($\leq$ 6 months) typically have not resulted in increases in the prey base; however, long-term, intensive coyote removal reportedly has altered to alter species composition within the ecosystem.

A dichotomy of views exists concerning the role of coyotes in ecosystems. Ranchers, wildlife biologists, environmentalists, and urbanites have different views concerning the same animal Historically, livestock managers have been the group most concerned with coyotes because of their depredation However, with the advent of game ranching, lost wildlife revenues resulting from coyote predation have increased the competition between human interests and coyotes (Scrivner et al. 1985).

Coyotes have been linked to the decline of white-tailed deer (*Odocoileus virginianus*) (Cook et al. 1971, Hamlin and Schweitzer 1979, Hamlin et al. 1984), mule deer (*O. hemionus*) (Truett 1979), and pronghorn (*Antilocapra americana*) (Neff et al. 1985) through predation on fawns. Coyotes were responsible for 86% of annual white-tailed deer fawn mortality in Oklahoma (Garner et al. 1978). Although rarely observed, coyotes have been reported to prey upon adult deer (Hamlin and Schweitzer 1979, Truett 1979). To resolve the problem of predation on domestic livestock and wildlife, various coyote control programs have been initiated; however, most techniques have resulted in limited success (Connolly 1978).

To further enhance the problem of disparate views, coyote control is not a widely accepted practice by the populace at present. A growing concern for animal welfare has caused the American public to re-assess its attitude toward coyote control All lethal methods, and most nonlethal methods, of coyote control receive little acceptance from the general public (Arthur 1981)

Various animal activist groups have questioned the accuracy of the number of livestock reported lost to predators and contend that ranchers exaggerate their losses to justify the need for predator control (Baker 1985). Defenders of Wildlife (1978) contended that not all coyotes prey on livestock, and that mass eradication is like "randomly killing large numbers of people when a murder is committed in the hopes of killing the murderer "

Animal Damage Control (ADC) personnel argue that coyote eradication is not their intended goal and that they only kill about 18-29% of the coyote population in 13 cooperating western states (U S. Fish and Wildlife Service 1978) Connolly and Longhurst (1975) examined the effect of control on coyote populations using a simulation model and determined that a minimum annual removal of 75% of the breeding population was needed to consistently lower the coyote density.

Wayne Pacelle, national director of The Fund for Animals, has used this information as an argument against ADC, stating that because ADC only removes 18-29% of the coyote population, the entire coyote removal program is not only doomed to fail, but is also a waste of tax dollars. Defenders of Wildlife (1978) estimated that the average cost of killing coyote is approximately $1,000. Consequently, in their view, it would be less of an economic burden on the taxpayers to pay ranchers for livestock killed by coyotes.

Certain animal activist groups argue that the coyote is a valuable part of the ecosystem and should not be persecuted by man (Defenders of Wildlife 1978, Humane Society 1978, Sierra Club 1978). Such groups contend that even if coyote control programs were successful, it would increase over-grazing and ultimately decrease livestock productivity (Defenders of Wildlife 1982). Their reasoning is that reduced coyote populations allow rodent and rabbit populations to increase, which in turn, will increase competition with livestock for available forage, decrease livestock productivity, and promote rangeland degradation.

Ranchers have countered this argument by stating that coyote control has no effect on ecosystems. Coyotes are resilient; they respond to control efforts with greater litter sizes (Knowlton 1972). Therefore, coyote removal could never reach eradication levels which would affect the ecosystem

Failure of ranchers to accept coyote predation as a natural process within a healthy ecosystem, and failure of environmentalists to realize that coyote predation can be an economic burden to some ranchers has polarized these 2 groups (O'Gara 1982). This dichotomy is detrimental to solving the issue of coyote control because efforts of each group are directed at countering the other group's opinion, rather than at a cooperative effort to solve this environmental problem

Few studies have been designed to investigate the effects of coyote removal on the remaining ecosystem It is the objective of this paper to give a review of the literature concerning coyote-prey interactions and attempt to explain why results from these studies appear ambiguous.

Texas studies

Beasom (1974) conducted predator removal on the coastal plains of South Texas to determine the impact of predation on the productivity of certain game species. Two study areas, approximately 5,000 acres each and separated 5 miles apart, were used as predator removal and control sites, respectively Control efforts included steel traps, M-44 devices, toxic baits, and shooting each month from 1 February - 30 June in 1971 and 1972. The intensity of removal efforts during 1971 and 1972, respectively, for each method was 11,554 and 15,892 steel trap-nights, 7,400 and 5,433 M-44 set-nights; 5,500 and 6,500 toxic bait-nights; and 200 and 50 man-hours of hunting.

Predator track count transects were used to measure the effectiveness of predator removal efforts. A total of 129 and 59 coyotes, and 66 and 54 bobcats (*Lynx rufus*) were removed during 1971 and 1972, respectively. Beasom (1974) indicated that predator numbers were similar on both areas prior to removal efforts. Then predator abundance decreased on the removal site after a few months of control, reached a trough in June, and increased once removal efforts ceased.

White-tailed deer counts indicated a fawn:doe ratio of 0.47 and 0.12 for predator removal and control sites, respectively, during 1971, and 0.82 and 0.32 for predator removal and control sites, respectively, during 1972. Similar increases in productivity were observed with Northern bobwhites (*Colinus virginianus*) and turkey (*Meleagris gallopavo*). Significantly greater reproductive success was observed on the area where predator removal was conducted.

Beasom (1974) also indicated a decline in fawn:doe and poult:hen ratios with increasing distance from the removal area He concluded that populations of certain game species could be increased with intensive predator control efforts However, bobwhite numbers, as well as rodent populations, were unaffected by predator removal. Beasom et al. (unpubl data) later reexamined the effect of coyote removal on white-tailed deer and determined that, even though fawn productivity was increased on areas with predator control, white-tailed deer densities and survival of deer >3 months of age were unaffected

Guthery (1977) and Guthery and Beasom (1977) investigated the effects of mammalian predator removal on population trends of various wildlife species in South Texas Their study design involved 2 areas each about 10,000 acres in size. One area received monthly predator control from January-July, 1975 and 1976, the other area was left intact as a control The two areas were separated by a linear distance of 2.5 miles.

Guthery and Beasom (1977) employed an intensive control effort which included 4,042 and 2,811 leghold trap-days, 10,873 and 8,563 snare-days, 7,273 and 1,120 M-44-days, 6.2 and 0 hours of calling, and 1 1 and 0.5 hours of helicopter gunning during 1975 and 1976, respectively. They removed 69 and 63 coyotes, 11 and 7 bobcats, 10 and 5 raccoons (*Procyon lotor*), 11 and 11 striped skunks (*Mephitis mephitis*), 7 and 5 badgers (*Taxidea taxus*), 24 and 3 opossums (*Didelphis marsupialis*), and 0 and 1 gray fox (*Urocyon cinereoargenteus*) in 1975 and 1976, respectively.

Guthery (1977) monitored scat counts as a measure of predator removal success and suggested that this level of control, after a few months, suppressed predator population levels on the removal areas by as much as 70%. Guthery (1977) and Guthery and Beasom (1977) suggested that predator control had no detectable influence on population trends of bobwhite and scaled (*Callipepla squamata*) quail, cottontail rabbits (*Sylvilagus floridanus*), cotton rats (*Sigmodon hispidus*), and woodrats (*Neotoma micropus*). However, they did note that white-tailed deer fawn production was 70% and 43% greater on the predator removal site than on the control site during 1975 and 1976, respectively.

They concluded that short-term, intensive predator removal was not detrimental to the South Texas ecosystem. Microherbivore populations did not increase to cause overuse of range forage while white-tailed deer production improved.

Definitive research concerning the effects of coyote control on white-tailed deer populations was conducted on the Welder Wildlife Refuge during 1972-80 (Teer et al. 1991) A 1,000-acre pasture was enclosed with a mesh net-wire fence extending 6 feet above ground and a 12-inch "apron" buried below ground level to exclude coyotes. The apron was buried perpendicular to the bottom of the fence to prevent coyotes from digging underneath and gaining access to the pasture. The top of the fence was equipped with an electrically charged wire to discourage coyotes from climbing the fence. Deer were capable of crossing the perimeter fence and cattle were stocked inside the enclosed pasture at the same rate as outside to avoid any bias from differential livestock grazing.

Coyotes were removed from the enclosure by leghold traps, snares, M-44s, and aerial and ground shooting. Initially, 5 coyotes were removed from the enclosure, 10 others were taken as soon as their presence was detected over the next 2 years. Therefore, estimated coyote density prior to the removal effort was 2.0 coyotes per square mile, comparable to Andelt's (1985) earlier estimate for the same area.

White-tailed deer fawn survival was 30% higher in the enclosure compared to the rest of the refuge The density of white-tailed deer increased in the enclosure during the next 5 years, but declined sharply thereafter when the food supply was reduced and parasite loads increased. Deer within the enclosure consumed diets lower in crude protein levels, higher in calcium, and with higher calcium/phosphorus ratios than deer outside the enclosure Deer herd "health" within the enclosure recovered as the food supply returned to previous levels. Teer et al (1991) concluded that coyote predation can be an important factor in white-tailed deer herd stability.

A 3-year study in western Texas assessed the effects of coyote removal on semi-arid, short-grass ecosystems (Henke 1992). Four 12,000-acre study sites with similar soil and vegetation composition were assessed seasonally for 1 year prior to coyote removal and for 2 years after the initial removal effort. All sites were similar in coyote abundance, rodent richness, diversity, density, and biomass, and lagomorph densities during each season prior to coyote removal.

Aerial gunning from a helicopter and ground calling were used to remove coyotes from 2 randomly-selected study sites every 3 months for 2 successive years. Intensity of removal efforts per season was 27 helicopter hours and 25 man-hours of hunting. Linear distance between coyote removal and non-removal areas was 12 miles Coyotes also were removed from a 3-mile buffer zone surrounding each site Animal abundance and densities were assessed from the center of the removal and non-removal areas.

A total of 328 coyotes was removed during April, 1990 - January, 1992. Coyote abundance was reduced by 48% on the removal areas, as estimated from scent station lines, vocalization rates, and scat transect counts. After 9 months of removal effort, rodent species richness and diversity declined on removal areas, while rodent density and biomass, percent of kangaroo rats (*Dipodomys ordii*) within the rodent population, and black-tailed jackrabbit (*Lepus californicus*) density increased on the removal areas Abundance and density of species on the non-removal areas remained fairly stable throughout the study. Cottontail rabbit density, and raptor richness, diversity, and density were relatively unaffected by coyote removal

Henke (1992) believed that kangaroo rat populations irrupted on coyote removal areas This appeared to create intense competition among the 12 species of rodents found in the area, and eventually lead to the exclusion of the other rodent species from the area. Henke (1992) also noted that coyote removal appeared to cause a 320% increase in jackrabbit density and suggested that altered jackrabbit behavior due to a lack of coyote predation risk could increase competition with livestock for available forage He speculated that such dramatic changes in the structural composition of the food web would lead to instability within the ecosystem.

Utah studies

Multiple studies have been conducted concerning coyote demographics in the Great Basin area of the western United States (Clark 1972, Knudson 1976, Davison 1980, Stoddart 1987). Although these studies did not intentionally remove coyotes to assess the effects of predator removal on the ecosystem, they have provided nearly 30 years of research concerning predator-prey interactions between coyotes and jackrabbits.

Coyotes were considered the dominant carnivore and black-tailed jackrabbits were the most abundant herbivore in this area (Wagner and Stoddart 1972). Clark (1972) noted that the diet of coyotes from this region consisted mainly of jackrabbits, even when jackrabbit abundance experienced a decline Therefore, coyote densities appeared to respond to changes in jackrabbit abundance and, thus resembled the classical Lotka-Volterra predator-prey oscillations.

Wagner and Stoddart (1972) suggested that coyote predation alone could not produce the observed oscillations because jackrabbits have a higher potential rate of increase than coyotes, and that other mortality sources such as disease, behavioral stress, etc. would be required to reduce jackrabbit abundance to the point where coyotes could again assume dominance over them. However, coyote predation did appear to be a major factor in the 11-year cyclical pattern of jackrabbit abundance.

Knowlton and Stoddart (1992) created a coyote-jackrabbit interaction model that mimicked field observations. Although they acknowledged that model output which resembles field observations does not validate their model, it stands to reason that the inferences they used to build the model were not implausible Researchers of these studies did not speculate about possible effects of reduced coyote predation on jackrabbit abundance; however, indications are that a reduction in coyote density would lead to an increase in jackrabbit abundance

Conclusion

Although the results of these studies appear ambiguous at first glance, differences in methodologies among studies can explain the various outcomes. The Texas studies which involved short-term (≤ 6 months) coyote removal programs did not note differences in rodent and lagomorph populations. However, those studies which consistently removed coyotes throughout the year began to realize population-level changes after a minimum of 9 months of coyote removal.

Although white-tailed deer and bobwhite quail reproductive success increased with coyote removal, overall population densities for both species remained unchanged. This implies that a compensatory mortality mechanism is involved with these populations and that potential population increases of certain game species due to coyote removal are short-lived All studies indicated that coyote control caused an immigration of coyotes into the removal areas Coyote population densities returned to pre-removal levels typically within 3 months after removal efforts ceased

Therefore, short-term coyote removal programs typically are not sufficient in reducing coyote density and, therefore do not alter ecosystem composition. However, intensive, long-term coyote removal has been successful in reducing coyote populations by over 40%, which has resulted in prey-base increases.

The intended goals of coyote control need to be determined prior to the onset of removal efforts. If the management objective is to reduce livestock losses caused by coyotes, then an intensive, short-term removal program may provide immediate relief of depredation just before and after parturition. However, if the coyote removal is practiced year-round, microherbivore populations may potentially increase; increased competition for forage with livestock may result Consequently, a reduced stocking rate then may be required to offset competition, which may negate the number of livestock saved from predation

If the goal is to increase the harvestable surplus of a game species, then it must first be determined that coyote control will increase the numbers of the target species. Next, can the additional animals be supported by the habitat? Finally, will predation as a mortality source be replaced with other mortality factors acting in a compensatory manner? Until these questions can be answered, then coyote removal would not be warranted.

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