December 1995

Symposium Proceedings—Coyotes in the Southwest: A Compendium of Our Knowledge [complete work, 185 pp.]

Dale Rollins
Texas Agricultural Extension Service

Calvin Richardson
Texas Parks and Wildlife Department

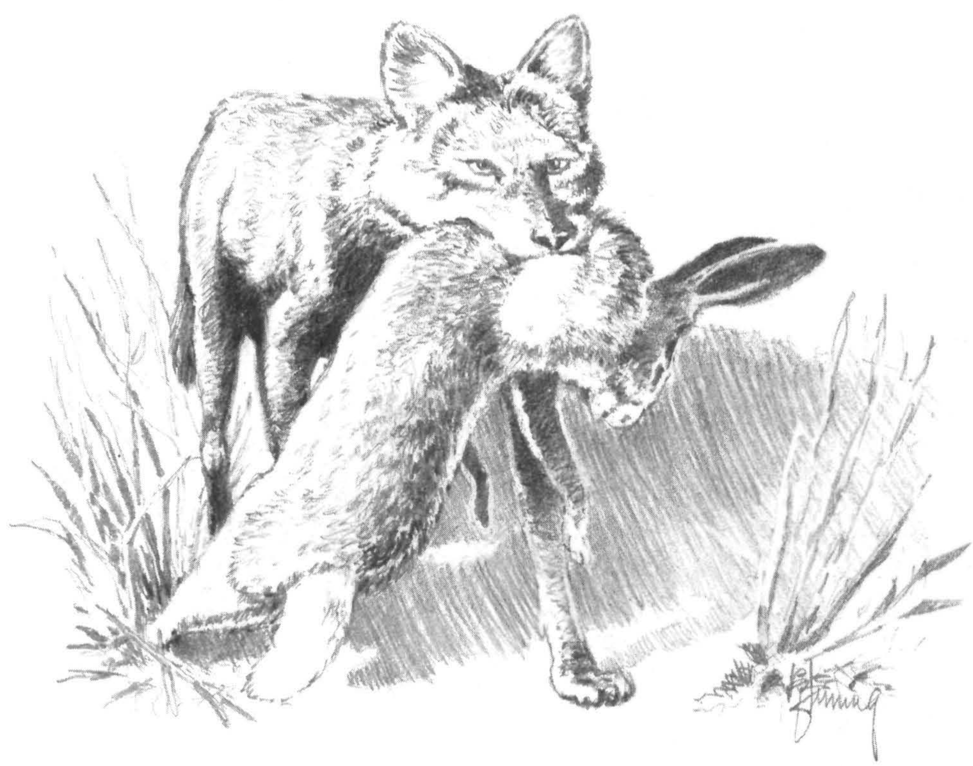
Terry Blankenship
Welder Wildlife Foundation

Kem Canon
Sul Ross State University

Scott Henke
Texas A&M University–Kingsville

Symposium Proceedings

Coyotes in the Southwest:



A Compendium of Our Knowledge

December 13-14, 1995
San Angelo, TX

Editors:

Dale Rollins, Texas Agricultural Extension Service
Calvin Richardson, Texas Parks and Wildlife Department
Terry Blankenship, Welder Wildlife Foundation
Kem Canon, Sul Ross State University
Scott Henke, Texas A&M University - Kingsville

Sponsors:

Jack H. Berryman Institute, Utah State University
Texas Agricultural Extension Service
Texas A&M University System
Texas Animal Damage Control Service
Texas Chapter, The Wildlife Society
Texas Department of Agriculture
Texas Parks and Wildlife Department
Texas Sheep and Goat Commodity Board
Welder Wildlife Foundation

Acknowledgements: The Steering Committee wishes to express their sincere appreciation to Karen Spoo and Steve Byrns of the Texas Agricultural Extension Service and Minnie Savage of the Texas Sheep and Goat Commodity Board for their assistance in developing, promoting and conducting this symposium and these proceedings. Funding for this symposium was provided by the Texas Sheep and Goat Commodity Board, Jack H. Berryman Institute, and Texas Chapter, The Wildlife Society Texas Parks and Wildlife Department provided in-kind support in printing the proceedings

Printing by:

Texas Parks and Wildlife Department

Symposium Steering Committee

Terry Blankenship
Welder Wildlife Foundation

Kem Canon
Sul Ross State University

Tommy L. Hailey
Texas Parks and Wildlife Department

Ellis Helmers
Texas Sheep and Goat Commodity Board

Scott Henke
Texas A&M University - Kingsville

Nancy E. Matthews
Texas Cooperative Wildlife Research Unit

Wyman P. Meinzer
Writer/Photographer, Benjamin, TX

Gary L Nunley
Texas Animal Damage Control Service

Calvin L. Richardson
Texas Parks and Wildlife Department

Dale Rollins
Texas Agricultural Extension Service

Matt Wagner
Texas Parks and Wildlife Department

Crystal Wilbanks
Texas Department of Agriculture

Foreword

"A conference is just an admission that you want someone to join you in your troubles."
-- Will Rogers

Long before the recent clamor over endangered species, predators and their management were controversial The coyote (*Canis latrans*) is often at the center of such debates. Cursed by some, revered by others, respected by all, the coyote is an icon of the Southwest.

With the possible exception of its larger cousin, the grey wolf (*C. lupus*), no other carnivore has been studied so extensively in North America as the coyote. Yet, despite the research (or perhaps as a result of it) many ambiguities and contradictions abound regarding coyote biology and management Opponents/proponents of coyotes represent a classical rural versus urban struggle, and the coyote offers a masterful performance of both Dr. Jekyll and Mr. Hyde.

As an educator, I am obliged to maintain an unbiased stance in such debates. Neutrality comes easily for me relative to coyote controversies. I have hunted, called, trapped, photographed, videotaped and enjoyed coyotes on many occasions over the last 25 years. I savor the many evenings in a sleeping bag near a campfire when awakened by a coyote chorus in the witching hour. The rolling hills of western Oklahoma would reveal the locations of all coyotes within a mile radius, each answering his nearest neighbor as if responding to some symbolic roll call. I feel a kinship with J. Frank Dobie and Ernest Thompson Seton as they penned prose and rhyme about such encounters. Yet, as much as I enjoy seeing and hearing the coyote, I respect and appreciate why it is so unwelcome in sheep and goat regions.

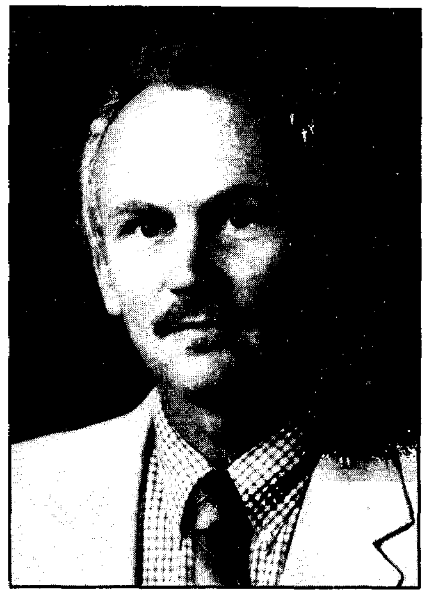
I once saw the following epigram scribbled on a men's room wall: *"where you stand on an issue, usually depends upon where you sit."* Speakers and attendees at this symposium bring with them various perspectives, from the far right to the far left and all points in between. Hopefully the biology involved in these arguments (and reported herein) is unbiased, and can and should be used as the basis to debate the absolute and relative merits of coyotes in this region Such is our challenge.

These proceedings assemble under one title the current state of knowledge about coyotes in the southwestern United States. Hopefully the information presented herein, coupled with the latent potential to network among the various stakeholders present, will further our understanding of coyotes and take us closer to resolving coyote-related conflicts.

-- Dale Rollins
Conference Coordinator

DEDICATION

Samuel L. Beasom
1945-1995



This symposium is dedicated to the life, achievements and memory of Samuel L. Beasom. From the first time that I considered trying to assemble this symposium, Sam Beasom was on my list of key people to include. Sam's professional contributions and his dry wit would surely play a pivotal role in a conference on coyotes in the Southwest, especially one to be conducted in Texas. I never dreamed then that his contributions, and subsequent recognition, would be presented posthumously here today.

Sam was a native of San Antonio and spent most of his professional career in South Texas. After completing his B.S. in Wildlife Biology at Texas A&M University, Sam earned his M.S. in Wildlife Ecology from the University of Wisconsin, Madison. Although conferred in Wisconsin, Sam's research was conducted on the King Ranch studying the ecology of Rio Grande wild turkeys. After serving a stint with the U.S. Army, Sam returned to Texas A&M and completed his Doctorate. Sam went on to hold positions with Texas A&M University, New Mexico Game and Fish Department, U.S. Forest Service and finally as Director of the Caesar Kleberg Wildlife Research Institute at Kingsville.

I first met Sam while pursuing my Doctorate at Texas Tech University in 1980. Sam served on my graduate committee, and it was then that he gave me subliminal instruction in critical thinking. I can still see him shrugging his shoulders and wrinkling his forehead when someone would confront him with some wildlife-related dogma. "Could be" or "I dunno" he'd say, his expressions intimating that the jury was still out as far as he was concerned. Sam was coyote-like in his basic distrust of the most obvious and seemingly impervious wildlife paradigms. Peering into his Paul Newman-blue eyes, one could see that the wheels were always turning. "Trust everybody, but cut the cards" would have been a fitting creed for Sam.

Sam was as much an icon for predator research, especially coyote research, as anyone in Texas. His 1974 article on the effects of short-term predator removal and its subsequent effects on white-tailed deer productivity was (and continues to be) a benchmark study relative to deer X coyote interactions. Sam coupled a critical eye with an on-the-ground ability to communicate with his colleagues at the time, be they ranchers, Ph.D.'s or front-line trappers. Besides coyotes, he also enhanced our collective knowledge of white-tailed and mule deer, pronghorns, wild turkeys and scaled quail. He was well-published and served a tour of duty as Editor of the Journal of Wildlife Management from 1985-87.

Sam may be gone, but he leaves a legacy among Texas wildlifers. He was recognized as the Outstanding Wildlife Professional by his peers in the Texas Chapter of The Wildlife Society in 1987. I see many of his traits in his former graduate students, some of whom will be on the program here today. Somewhere in my files I have Sam's questions that he challenged me with during my final comprehensive exams at Tech. Short questions, but questions that forced you to challenge dogma and synthesize bits of knowledge that came from both the book and the back forty. He had a knack for confronting your conclusions without threatening your intelligence. I am a better wildlife professional today because of Sam Beasom; perhaps you are too.

Trust everybody, but cut the cards.

-- *Dale Rollins*
Symposium Coordinator

Table of Contents

Table of Contents (con't)

COYOTE POPULATION PROCESSES REVISITED

FREDERICK F. KNOWLTON, Denver Wildlife Research Center, Utah State University, Logan, UT 84322-5295

ERIC M. GESE, Denver Wildlife Research Center, Utah State University, Logan, UT 84322-5295

Abstract: It appears that coyote (*Canis latrans*) abundance is determined primarily by availability of food (prey) as mediated through social dominance hierarchies and a territorial land tenure system. This is reflected in rates of reproduction, dispersal, and mortality, with survival of juveniles a major factor Suggestions for a new generation of simulation models to explore coyote population functions are included

Population manipulation is a prominent component of many coyote management programs. Understanding the factors affecting animal abundance and the mechanisms of population regulation can assist in recognizing the merits and liabilities associated with such management approaches. In turn, this should help identify more flexible management scenarios and result in management programs that are more selective, effective and efficient.

Gier (1968) and Knowlton (1972) provided some initial information on coyote population parameters. Additional information from a variety of authors lead Knowlton and Stoddart (1983) to hypothesize that coyote abundance was governed by interactions between available food (prey) and coyote behavioral characteristics, namely social dominance and territoriality, with the impact expressed through the processes of reproduction, mortality, ingress and egress. Similar conclusions were reached by Packard and Mech (1983) to explain population regulation in grey wolves (*C. lupus*). Herein we review these ideas in light of information acquired in recent years

Evidence concerning food abundance

Knowlton and Stoddart (1983) used 3 lines of evidence to support the contention that food abundance was a major determinant of coyote abundance, namely (1) state by state averages of the indices of coyote abundance calculated from the Westwide Survey of Predator Abundance (Linhart and Knowlton 1975, Roughton and Sweeny 1982), (2) a meager data set concerning coyote and rodent abundance on sites scattered throughout Texas, and (3) a 15-year time series of coyote and jackrabbit (*Lepus californicus*) density estimates in Curlew Valley, Utah

Since the previous paper, the data set for the first has not changed and prior interpretations remain largely intact, i.e., mean coyote abundance varies among the western states and appears to reflect primary productivity Higher densities occur in the Great Plains, a relative scarcity typifies the intermountain region, and moderate abundances are found among the states of the Pacific coast. In addition, an increasing kline in density from northern to southern states seems evident This appears consistent with observations by Weaver (1979) and Todd and Keith (1976) suggesting food supplies in winter may be particularly important in areas where conditions are more harsh Gese (1995) identified available food resources in winter to be particularly important in regulating size of coyote packs in Yellowstone National Park

The second data set, concerning the relative abundance of coyotes and rodents on sites throughout Texas has not been elaborated and is unconvincing on its own However, the results are consistent with other sources of information

Since the earlier paper, annual and semi-annual density estimates for coyotes and jackrabbits in Curlew Valley, Utah, were extended to 28 years That data set includes information indicating the irruption in jackrabbit numbers that peaked in 1980 subsided to very low numbers by the mid-1980s and was followed by another irruption in the early 1990s

Coyote numbers, however, did not follow the anticipated patterns. When jackrabbit numbers declined in the mid-1980s, coyote numbers remained high Faced with explaining deviance from the expected, 2 hypotheses were identified The first suggesting this resulted from a marked increase in the abundance of deer and antelope in Curlew Valley, providing an alternate winter food resource. The other hypothesis involved lower mortality rates associated with reduced human exploitation resulting from lower fur prices and a reduction in the intensity of exploitation to protect domestic stock. Although our current preference resides with the first alternative and is consistent with the food abundance hypothesis, no additional data have been assembled to clarify the issues. On the other hand, Hamlin et al (1989) reported that during a population decline of mule deer (*Odocoileus hemionus*) in north-central Montana, coyotes remained abundant. They hypothesized that coyote survival may have increased as a result of increased abundance of microtine rodents as an alternative food source. This was unlikely in Curlew Valley because microtines are not common (Hoffman 1979).

Other studies have added to our understandings A companion study to the Curlew Valley research involved monitoring rodent, lagomorph, and coyote populations over a 12-year period on the Idaho National Engineering Laboratory (INEL), a site some 100 miles north of Curlew Valley and largely immune from public access (Stoddart 1987). Data from this location are similar to those from Curlew Valley, with jackrabbit populations irrupting from extremely low numbers in the late 1970s to over 280 per mi^2 in 1981, and then returning to very low levels by the mid 1980s Coincident with the increase in hares, coyote abundance increased 5-fold, followed by a gradual decline after hares became scarce. This reinforces previous interpretations about the potential role of prey abundance in determining coyote abundance.

One notable aspect of the INEL data is the relatively slow response in coyote abundance to the abrupt decline in a major food resource Two years after the jackrabbit population returned to very low levels, the spring coyote density index was still 3 times pre-irruption levels. Todd et al. (1981) and Todd and Keith (1983) found that winter coyote abundance was directly related to snowshoe hare abundance In their study, all demographic parameters of coyotes measured declined as snowshoe hares became scarce, leading them to believe that low availability of alternate prey in the boreal forest intimately linked the coyote population to fluctuations in snowshoe hare abundance.

Based on an 11-year study in southern Texas, Windberg (1995) provided data indicating coyote population growth was correlated positively with winter prey abundance and correlated negatively with initial coyote abundance Since both prey and coyotes were extremely abundant in the area (spring coyote populations estimated at 4-7 per mi^2), the coyote population may have been approaching the upper limits for density and other constraints may have also been operating This study is particularly notable in that it documents a negative relationship between coyote abundance and population growth.

Although convictions that a relationship between coyote abundance and prey abundance have been reinforced in recent years, more definitive understandings of that relationship have not emerged Improved quantitative assessments of the abundance and availability of prey in relation to coyote density, along with the adoption of standardized methodology among studies are needed to provide more enlightenment. Long-term monitoring of predator and prey populations will be essential to clarify the impacts and mechanism(s) linking predator and prey populations

The social dynamic

Knowledge about coyote sociodemography that was budding at the time of Knowlton and Stoddart's 1983 paper has blossomed. The territorialism initially espoused by Camenzind (1978) and Bowen (1978, 1982), in which packs of coyotes defend areas against intrusions of others has been enhanced by the studies of Andelt (1982, 1985), Crabtree (1988), and Windberg and Knowlton (1988).

Our current understanding indicates that habitat suitable for coyotes is partitioned among territorial social groups of 2-7, frequently related, adult coyotes These territories are typically contiguous and apparently defended against intrusions from coyotes not belonging to the territorial social group (Gese 1995). Non-territorial individuals are a cadre of transient, typically solitary, individuals living among the interstices of the territories. Transients sometimes trespass upon the territories, and occasionally form temporary liaisons with various territorial groups These coyotes appear to be "biding their time", trying to fit into the more stable portion of the population

Data from Andelt (1985), Crabtree (1988), Windberg and Knowlton (1988) and Gese (1995) show that being territorial and socially dominant are common prerequisites for the successful nurture of young. Although subordinate and non-territorial individuals may become reproductively active, their likelihood of reproductive success is very low. There is also a suggestion that territories are inherited from one generation to the next, with territorial boundaries remaining intact well beyond the lives of individual inhabitants.

Territorial patterns among coyotes in high mountain areas deserve some mention because conventional wisdom frequently suggests coyotes living at high elevations in summer accompany migrating large ungulates to wintering areas at lower elevations. If this occurred, coyotes would seemingly be "off territory" during courtship, breeding, and early post-whelping periods; times when territoriality should convey its greatest advantages. Gantz (1990) specifically studied this aspect and found adult coyotes in the mountains of northern Utah used the same areas in summer and winter, even at altitudes exceeding 7,500 feet. Shivik (1995), working in the Sierra Nevada, similarly reported coyotes maintaining territories at high elevations in winter. This is consistent with Weaver's (1979) interpretations that coyotes live in summer where they can survive in winter

Demography of populations immune from human exploitation

Another significant aspect of coyote population biology is currently emerging, i.e., characteristics of unexploited populations. In retrospect, initial glimpses can be recognized in a Knowlton (1972) as well as unpublished data on coyote population structures in southern New Mexico and Arizona collected by Sam Linhart in the early 1970s. However, the significance of these data were not recognized at the time.

More recent studies (Crabtree 1988, Windberg 1995, Windberg et al. [In draft], Gese et al. 1989) suggest unexploited populations may be functionally and structurally different from information published previously. Although verification is pending, the emerging pattern suggests that in saturated populations, territorial coyotes have relatively long tenures with very low reproductive rates (Gese 1990, Crabtree 1988). There is also a suggestion that coyote territories have a longevity of their own that exceeds that of individual occupants.

Studies of relatively unexploited populations (Crabtree 1988, Gese et al. 1989) suggest 75-90% overall annual survival of adult coyotes in such situations may not be unusual. On age-specific basis, mean annual survival estimates from 3 field studies (Knowlton 1972, Crabtree 1988, Windberg 1995) indicate annual survival rates increase from about 0 40 in year 1 to about 0.70 by age 3, followed by a 2-3 year plateau and a decline thereafter, gradually at first and precipitously around age 10. Coyotes as old as 13, 14, and 15 years (Gese 1990, Knowlton unpubl data) have been reported, but individuals over 11 are rare (Knowlton 1972, Gese 1995).

Recruitment into the adult portion of unexploited populations appears to be relatively low. One unexploited coyote population in eastern Washington had recruitment rates below 10%, with some coyotes apparently maintaining territoriality well into reproductive senescence (Crabtree 1988). Another study (Gese et al. 1989), reported low recruitment into a saturated, unexploited population as a result of low reproduction among yearlings, small litter sizes and high pup dispersal. Windberg et al. (In draft) provide data from a very lightly exploited population in southern New Mexico where juveniles composed only 7% of a population sample (n = 44) 1 year; a sample (n = 38) the next year failed to detect any juveniles. Although these data are meager, they suggest a pattern where reproductive rates among saturated populations fall far short of the biotic potential for the species.

The mechanics of change

While food abundance seems to set the ultimate limits of coyote abundance, and sociality is the driving force for change, proximate effects on density are linked to changes in reproduction, mortality, ingress and egress. A closer look at some of these components is warranted.

Reproductive performance. This component is associated with the fraction of the females breeding, mean litter size of reproductively-active females, and survival of offspring to some specific age. Data are sufficiently sparse and interactions sufficiently complex that unraveling details about factors influencing these parameters is impractical in this discussion. All 3 vary both among coyote populations and within populations over time There is little doubt that prey abundance and population density are major influencing factors. Coyote populations seemingly have the potential to triple or quadruple density on an annual basis On a practical level, however, exponential annual growth in excess of 0.6 appears unusual.

The generality seems to be that being dominant within a territorial social group is a prerequisite to reproductive success, with each territory trying to produce one litter each year. Hence the average size of social groups and the fraction of the population that belongs to territorial groups are important considerations. Some subordinate and non-territorial females may initiate the reproductive process, but most are doomed to fail

Food abundance appears to be an important arbiter of litter size, especially in exploited populations Placental scar count data from Curlew Valley, Utah, indicated that mean litter size varies from less than 4 to over 8 as a function of food abundance (Knowlton, unpubl. data) There was also a hint that mean litter size may be correlated with food conditions under which females are reared, as opposed to conditions leading up to specific reproductive seasons (Knowlton and Stoddart 1983).

Mean litter size, however, can hardly be the defining parameter, because the fraction of placental scars represented by juveniles in fall may vary by a factor of 5 Similarly, Crabtree (1988), Gese et al. (1989), Windberg (1995), and Gese (1995) identified juvenile survival as a major component of coyote demography At the same time, coyote abundance apparently is a major factor regulating juvenile survival rates (Windberg 1995, Knowlton and Stoddart, unpubl. data). Better data related to reproductive performance and juvenile survival are needed

Mortality Mortality of adult coyotes, as determined by population age structures, tends to be higher among younger ages classes (1-2 years of age) and relatively older animals (≥ 8 years of age) Conversely, survival appears to be high among coyote 3 to 7 years of age, especially among individuals that maintain associations with territorial groups Causes of mortality among adult coyotes is closely linked with human activities (Knowlton and Stoddart 1983). This results both from direct exploitation (e g. hunting, trapping, and related activities) and indirectly through collisions with automobiles, encounters with domestic dogs, etc. Recent studies (Windberg et al. 1985, Crabtree 1988, Gese et al 1989, Windberg and Knowlton 1990) reinforced these interpretations

Ingress and egress. Immigration and emigration are part of the dispersal process and occur when individuals enter or leave a population of interest It is probably the least studied demographic aspect of coyote populations.

The relative frequency, as well as the distances moved, tend to be greater in more saturated populations than less saturated populations, resulting in net movements away from the former and toward the latter (Davison 1980) Hypotheses generated by Knight (1978) and Davison (1980) suggesting that low-ranking individuals are more likely to disperse have been validated by Gese (1995)

Dispersal is driven by nutritional and social interactions. Low-ranking individuals leave natal packs while high-ranking individuals are philopatric, biding their time for the dominant, breeding position. When food is abundant, more animals remain in the pack while in years of scarcity, more individuals disperse and pack sizes remain small. During periods of severe food scarcity, territorial behavior may be abandoned, with all members of social groups dispersing (Mills and Knowlton 1991, Grothe, unpubl. data).

Looking toward the future

There is a need to reassess our knowledge of coyote population biology and management through the revision of existing, or the creation of new, simulation models. Simulation models of animal populations help organize our understanding of the way populations function and provide a means for examining and exploring various concepts and ideas related to population management It has been 20 years since Connolly and Longhurst (1975) and Connolly (1978) published and/or reviewed simulation models for coyote populations. These remain the simulation models currently available for coyote populations They rely upon data collected in the late 1960s and published in the early 1970s, and utilize a series of equations linking demographic parameters, namely density, reproduction and mortality as understood at the time

Relative coyote abundance was based upon fall rather than spring (stock) estimates and the impact of social constraints upon demographic parameters were either unknown or excluded from the process. The data were obtained largely from populations subjected to human exploitation. These models were generated in the absence of information about the structural and functional aspects of populations not subjected to human exploitation It is time to review the modeling process

Several considerations should be incorporated into any new population modeling effort. Two important "data gaps" require study; namely (1) the effect of human exploitation (essentially increased mortality rates) on demographic and behavioral parameters; and (2) validation of characteristics of unexploited coyote populations. The latter is essential to provide a natural "endpoint" for a model, which figuratively represents the alternate extreme from the biotic potential of coyotes.

The possibility of using a behavioral, rather than demographic, base should be explored for a new coyote population model. Population models are usually developed to depict, or understand, changes in abundance or density. Incorporating behavioral constraints into a demographic model can be intimidating, especially since many behavioral aspects have not been defined mathematically.

However, population density could use 3 alternate parameters instead mean territory size, mean number of individuals per territory, and percent of the population belonging to territorial groups. This would utilize the units by which coyote populations are structured and involve parameters that are more readily estimated than behavioral interactions with demographic variables. Some newer computer programming languages that involve "objects and attributes" may provide a useful programming medium for such endeavors in place of the equation-based programming techniques used previously. It will be interesting to watch the outcome of such endeavors.

An appropriate simulation model would be a useful tool in assessing merits of various management strategies as well as to help guide research efforts toward developing more effective and efficient depredation control techniques.

Literature Cited

Andelt, W F. 1982. Behavioral ecology of coyotes on the Welder Wildlife Refuge, South Texas. Ph. D. Thesis, Colorado State Univ., Fort Collins. 169pp.

_____. 1985 Behavioral ecology of coyotes in south Texas. Wildl. Monogr. 94. 45pp.

Bowen, D. 1978. Social organization of the coyote in relation to prey size. Ph. D. Thesis, Univ. British Columbia, Vancouver. 230 pp.

Bowen, D. 1982. Home range and spatial organization of coyotes in Jasper National Park, Alberta. J. Wildl. Manage. 46:201-215.

Camenzind, F. 1978. Behavioral ecology of coyotes on the National Elk Refuge, Jackson, Wyoming. Pages 267-294 *in* M Bekoff (Ed.). Coyotes. biology, behavior, and management Academic Press, New York, N. Y. 384pp.

Crabtree, R. L. 1988. Sociodemography of an unexploited coyote population. Ph. D. Thesis, Univ. Idaho, Moscow. 79pp.

Connolly, G E. 1978. Predator control and coyote populations: a review of simulation models. Pages 327-345 *in* M. Bekoff (Ed.). Coyotes biology, behavior, and management. Academic Press, New York, N. Y. 384pp.

_____., and W. M. Longhurst. 1975. The effects of control on coyote populations: A simulation model. Univ. California, Davis, Div. Agric. Sci. Bull. No. 1872. 32pp.

Davison, R. P. 1980. The effect of exploitation on some parameters of coyote populations. 139pp

Gantz, G. F. 1990. Seasonal movement patterns of coyotes in the Bear River Mountains of Utah and Idaho. M. S. Thesis. Utah State Univ., Logan. 67pp

Gese, E M. 1990. Reproductive activity in an old-age coyote in southeastern Colorado. Nat. 35:101-102.

Gese, E.M. 1995. Foraging ecology of coyotes in Yellowstone National Park. Ph. D. Thesis, Univ. Wisconsin, Madison. 134pp.

_____., O. J. Rongstad, and W. R. Mytton. 1989. Population dynamics of coyotes in southeastern Colorado. J. Wildl. Manage. 53:174-181

Gier, H. T 1968. Coyotes in Kansas. Kansas Agric. Expt. Sta. Bull. 393 (Rev). Kansas State Univ., Manhattan. 118 pp.

Hamlin, K. L., S. J. Riley, D. Pyrah, A. R. Dood, and R. J. Mackie. 1989. Relationships among mule deer fawn mortality, coyotes, and alternative prey species during summer. J. Wildl. Manage. 48:489-499.

Hoffman, S. W 1979 Coyote-prey relationships in Curlew Valley during a period of low jackrabbit density M S Thesis Utah State Univ., Logan. 139 pp.

Knight, S. W. 1978 Dominance hierarchies in captive coyote litters. M. S. Thesis. Utah State Univ., Logan 142 pp.

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

_____., and L. C. Stoddart. 1983 Coyote population mechanics. another look. Pages 93-117 *in* F. L. Bunnell, D. S. Eastman, and J. M. Peek (Eds.) Symp. on natural regulation of wildlife populations. Proc. Northwest Sect. Wildl. Soc. March 10, 1978. Vancouver, B.C., Canada.

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

Mills, L. S. and F. F Knowlton. 1991. Coyote space use in relation to prey abundance. Can. J. Zool. 69:1516-1521.

Packard, J. M., and L. D. Mech. 1983. Population regulation in wolves. Pages 151-174 *in* F. L. Bunnell, D. S. Eastman, and J. M. Peek (Eds.). Symp. on natural regulation of wildlife populations. Proc. Northwest Sect. Wildl. Soc. March 10, 1978. Vancouver, B.C., Canada.

Roughton, R. J., and M. W. Sweeny. 1982. Refinements in scent-station methodology for assessing trends in carnivore populations. J. Wildl. Manage. 46:217-229.

Shivik, J. A. 1995. Factors influencing space use and activity of Sagehen Basin Coyotes. M. S. Thesis. Univ Calif. - Berkeley. 162pp.

Stoddart, L. C. 1987. Relative abundance of coyotes, lagomorphs, and rodents on the Idaho Nat'l. Engineering Lab. Final Rept. Proj. DF-931.07, Denver Wildl. Res. Ctr. 22pp. (typed).

Todd, A. W. and L. B. Keith. 1976. Responses of coyotes to winter reductions in agricultural carrion. Wildl. Tech Bull. No. 5. Alberta Recr., Parks, and Wildl. 32pp.

_____., and _____. 1983. Coyote demography during a snowshoe hare decline in Alberta. J. Wildl. Manage. 47:394-404.

_____., _____., and C. A. Fischer. 1981. Population ecology of coyotes during a fluctuation of snowshoe hares. J. Wildl. Manage. 45:629-640.

Weaver, J. L. 1979. Influence of elk carrion upon coyote populations in Jackson, Hole, Wyoming. Pages 152-157 *in* Boyce, M. S. and L.D. Hayden-Wing (Eds.) Symp. North American elk: ecology, behavior and management. Univ. Wyoming, Laramie.

Windberg, L. A. 1995. Demography of a high-density coyote population. Can J. Zool. 74(5) 942-954.

_____., and F. F. Knowlton. 1988. Management implications of coyote spacing patterns in southern Texas. J. Wildl. Manage. 52:632-640.

_____., and _____ 1990. Relative vulnerability of coyotes to some capture procedures. Wildl. Soc. Bull. 18:282-290

_____., H. L. Anderson, and R. M. Engeman. 1985. Survival of coyotes in southern Texas. J. Wildl. Manage. 49:301-307

_____., F. F. Knowlton, S. M. Ebbert, and B. T. Kelly In draft. Population characteristics of coyotes in the northern Chihuahuan desert

BEHAVIOR OF COYOTES IN TEXAS

WILLIAM F. ANDELT, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523

Abstract: Coyotes (*Canis latrans*) live in social groups with relatively small territories or as single, non-territorial transients with large home ranges in southern Texas. Coyotes communicate and establish territories through auditory, olfactory, and visual means They consume mammals, fruits, and insects with their diets reflecting differences in abundance and vulnerability of prey, effects of plant phenology and weather conditions. Coyotes have adapted to human exploitation by avoiding humans and their control techniques. Because coyotes habituate to nonlethal control techniques (e.g., frightening devices), I suggest apply frightening devices only when coyotes are a problem. Lethal techniques likely will be most effective at resolving coyote depredations if they are applied at depredation sites and immediately before or when losses occur

Coyotes have been studied well enough in Texas to provide a fairly comprehensive picture of their behavior. In this paper, I review social organization, home range, activity patterns, reproduction, communication, predatory behavior and learning by coyotes in Texas and provide implications for their management

Social organization

Seventy percent of the coyotes on the Rob and Bessie Welder Wildlife Refuge (WWR) in southern Texas existed in groups (3-7 coyotes), 17% as mated pairs, and 13% were transients (i.e., coyotes that ranged over large areas, usually alone) (Andelt 1985). Coyote groups also were reported in Jim Wells (Bradley and Fagre 1988*a*) and Webb counties in Texas (Knowlton et al. 1985), but transients composed a greater proportion (34%) of the female population (Windberg and Knowlton 1988) than at the WWR.

Although coyotes existed in groups and interacted occasionally on the WWR, an average of only 1.4 coyotes were observed together per sighting. Each group consisted of a mated pair and associates The mated pairs interacted frequently, maintained pair bonds for at least 3-22 months and were found together most frequently during the breeding season. Male and female associates interacted with other group members less frequently than did individuals of mated pairs The social organization of coyotes in southern Texas was similar to that reported for other unexploited coyote populations (Bowen 1978, Camenzind 1978).

Mated pairs and associates were active around pups, spending about 30% of the time near them on the WWR (Andelt 1995). Males and females of mated pairs spent similar amounts of time near pups; associates spent similar or only slightly less time near pups than did the mated pair Bekoff and Wells (1982) speculated that adult coyotes spend time near pups to protect them, but adults did not alternate in attending pups on the WWR The percentage of time pups were unattended by adults was not related to the size of coyote groups. Pups spent less time together as they matured.

The majority (21 of 25) of coyotes classified as transients on the WWR appeared to be healthy adults; only 2 were <1 year old (Andelt 1985). Knowlton et al. (1985) and Windberg and Knowlton (1988) reported that the majority of transient female coyotes were ≤ 2 years old, whereas the majority of territorial females were >2 years old Two transients on the WWR entered resident groups, paired, and remained in the groups (Andelt 1985).

Larger coyote groups have been reported from more northern regions (Camenzind 1978, Bekoff and Wells 1980, Bowen 1981) presumably as an adaptation in capturing or defending large prey. However, prey size in coyote diets was not related to the number of coyotes interacting within groups or to the average number of coyotes observed together on the WWR (Andelt 1985). The relatively large size of coyote groups on the WWR likely resulted from a lack of human exploitation and saturation of habitat by territorial coyotes

Home range

Adult resident male coyote home ranges averaged 2 to 3 mi^2 (95% polygon method) and adult resident female home ranges averaged 1.8 to 2.9 mi^2 in southern Texas (Andelt 1985, Bradley and Fagre 1988*b*, Windberg and Knowlton 1988) Home range size did not differ among seasons on the WWR (Andelt 1985). Minimum home ranges of adult male and female transients averaged 28 mi^2 and 21mi^2, respectively on the WWR. The home ranges of pups increased in size as the pups grew older.

Adult pairs and groups primarily occupied non-overlapping but contiguous home ranges (Andelt 1985, Knowlton et al. 1985, Windberg and Knowlton 1988) The home ranges of transients overlapped those of residents; transients were found more frequently on the perimeter than on the interior of resident adult coyote home ranges (Andelt 1985, Knowlton et al 1985, Windberg and Knowlton 1988). The minimal overlap among adjacent resident coyote home ranges, observations of resident coyotes chasing intruders, and the higher proportion of transient locations on the perimeter than interior of resident home ranges indicates resident home ranges were territories

Coyote and bobcat (*Felis rufus*) home ranges overlapped and there was no indication of avoidance among the 2 species in southern Texas (Bradley and Fagre 1988*a*, W. F. Andelt, unpublished data).

Some adult coyotes on the WWR were found within the same home range for at least 48 months and 1 pup was found within its natal range for at least 29 months (Andelt 1985). Coyotes also maintained stable home ranges in Jim Wells County for 153 to 499 days (Bradley and Fagre 1988*a*) Adult coyote home range size was not related to the number of adult coyotes living in groups on the WWR (Andelt 1985). Twelve to 29% of the adult males and 4-9% of the adult females on the WWR emigrated annually. The extended period that coyotes were found within home ranges and fairly low emigration rate suggests that coyotes within groups were related Coyotes in Jim Wells County, Texas appeared to have a high tolerance of human activity and did not shift home ranges in response to herbicide treatments of brush (Bradley and Fagre 1988*b*).

Territorial female coyotes were more likely to be captured (i e , trapped) on the edge or periphery of their home range than within their territories in southern Texas (Knowlton et al. 1985, Windberg and Knowlton 1990). However, the distribution of all coyote capture sites did not differ from that of trap locations (Windberg and Knowlton 1990), indicating non-resident coyotes were captured within resident home ranges.

Activity patterns

Coyotes were active during day and night but were most active at, and just after, sunset on the WWR (Andelt 1995) and during crepuscular periods in Jim Wells County, Texas (Bradley and Fagre 1988*b*). Timing of activity periods of adults and pups were similar. Coyotes were more active during the daytime on the WWR where they were not exploited than in Nebraska where they were exploited by humans (Andelt and Gipson 1979*b*).

Distances moved by adult male ($\bar{x}$= 5.0 mi) and female ($\bar{x}$= 5 2 mi) coyotes during 24-hour periods were similar, and were greatest during the breeding season. Movement distances were not related to the size of coyote groups nor to the size of prey in their diets

Reproduction

Pups were born in all 5 coyote groups studied during 1978 and 1979 on the WWR (Andelt 1985). Only 1 female was known to whelp pups in each of 2 groups containing multiple females. Knowlton et al (1985) reported that 12 of 14 territorial females ovulated and 6 whelped. Although 9 of 19 transient females ovulated, none whelped (Knowlton et al. 1985) Ovulation by non-territorial females and their establishment within some territories suggests transients range over large areas seeking breeding opportunities in resident groups as suggested by Messier and Barrette (1982).

The fairly large number of transients found in coyote populations suggests that an ample pool of reproductive coyotes are available to fill any vacancies created by animal damage control and reflects the resilience of coyote populations to exploitation (Knowlton et al. 1985).

Communication

Coyotes communicate through auditory (vocalizations), olfactory (scent marking), and visual (e.g. aggression, dominance, and greeting displays) means (Lehner 1978). Coyotes vocalized most frequently during the breeding season (16 Jan-15 Feb) on the WWR (W. F. Andelt, unpublished data) and in Jim Wells County (Walsh and Inglis 1989). They also vocalized more frequently during moderate than extreme temperatures, on clear nights, and during low wind speeds (Walsh and Inglis 1989). Walsh and Inglis (1989) cautioned that the increase in vocalizations heard during low wind possibly might have been related to a greater human ability to hear coyotes during low wind.

Coyote vocalizations were not related to the intensity of moonlight in Jim Wells County (Walsh and Inglis 1989), but coyotes vocalized more often during nights without moonlight than on nights with a full moon on the WWR (W. F. Andelt, unpublished data). The increased vocalizations on nights without a moon may have compensated for a presumed lower ability to see other coyotes during lower light.

Coyotes deposit urine scent marks more frequently on the edge than within the interior of their territories (Barrette and Messier 1980) Coyotes deposited numerous scats on roads of the WWR (Andelt and Andelt 1984); more scats were found on the edge than on the interior of their home ranges (W. F. Andelt, unpublished data). Scats likely function to mark territories.

Foraging behavior

Coyotes consumed a variety of prey items including mammals (primarily deer [*Odocoileus virginianus*]) and lagomorphs (primarily cottontails [*Sylvilagus* spp.]), fruits (primarily Texas persimmon [*Diospyros texana*]), and insects in southern Texas (Andelt et al. 1987, Windberg and Mitchell 1990) Coyote diets varied among years due to successional changes in vegetation and changes in prey abundance (Andelt et al. 1987, Windberg and Mitchell 1990). Coyote diets also varied seasonally, reflecting differences in abundance of a variety of food items, differential vulnerability of prey, effects of plant phenology and weather conditions (Andelt et al. 1987). Coyotes appear to feed selectively on cotton rats (*Sigmodon hispidus*) (Windberg and Mitchell 1990), fruits, and insects (Andelt et al. 1987) when they are available.

Learning

Coyotes are adaptable animals that are able to learn quickly how to avoid humans and their control techniques. Coyotes have maintained their numbers during considerable man-induced mortality by learning to detect and avoid strychnine drop baits, traps, lethal bait stations (Robinson 1948) and scent stations after being captured and released from traps (Andelt et al 1985). Coyotes apparently have learned to avoid humans in areas where they are exploited by becoming less active during the daytime (Gipson and Sealander 1972, Andelt and Gipson 1979*b*, Andelt 1985*a*) and by avoiding open areas near roads (Roy and Dorrance 1985). Coyotes also have adapted to exploitation by increased immigration into areas where they were removed (Knowlton 1972, Connolly and Longhurst 1975).

Coyote behavior: implications for management

Coyotes cause large economic losses for ranchers by killing significant numbers of livestock, especially sheep (National Agricultural Statistics Service 1991). We can apply our knowledge of coyote behavior to more effectively manage depredations with non-lethal and lethal control techniques. Because coyotes learn to avoid control techniques, nonlethal techniques (e.g., frightening devices) should not be used for extended periods. They should be employed shortly before predation begins (if it is predictable) to avoid the establishment of a problem or pattern that may be difficult to disrupt. Frightening devices should be removed as soon as they are no longer needed to minimize habituation by coyotes

Because most coyotes are territorial and have small home ranges, depredating coyotes can be selectivity removed by applying aerial and ground controls near sites of predation (Andelt and Gipson 1979*a*, Connolly and O'Gara 1987). If coyotes are not causing depredations, it seems unwise to attempt to kill these animals because they may learn to avoid the control technique, or they may be replaced by other coyotes that cause depredations or avoid control techniques.

Coyotes moved between ranches in southern Texas (Bradley and Fagre 1988*a*). Based upon simulation models, Windberg and Knowlton (1988) indicated that 35 coyotes would occasionally occupy an area of 1 mi2;, 97 an area of 10 mi^2; and 480 an area of 100 mi^2, although densities were only about 3.2 coyotes/mi^2 The large number of coyotes using an area and the presence of transients which readily occupy vacant territories indicates resolving coyote depredation problems through population reduction will be difficult, especially on small areas.

Lethal controls for removing specific offending animals should be employed as soon as predation begins to minimize livestock losses. If local populations of coyotes are removed before predation begins, control efforts should be implemented immediately before coyotes become a problem because other coyotes quickly move into vacated areas. Control applied long before damage starts likely will be relatively ineffective. Dorrance (1980) suggested that dispersal by coyotes, primarily from mid-February through April, probably negates the effect of preventive control on local coyote populations prior to mid-February in central Alberta.

Fruits and insects may buffer coyote predation on livestock and deer (Andelt et al. 1987) Thus, in some instances it may be possible to predict the intensity of coyote predation by monitoring fruit and insect abundance.

Literature Cited

Andelt, W F. 1979 Some observations on coyote home range and social organization on the Welder Wildlife Refuge Proc. Welder Wildl. Found Symp 1 249-251

_____ 1985 Behavioral ecology of coyotes in south Texas Wildl. Monogr 94 45pp.

_____. 1987. Coyote predation. Pages 128-140 *in* M. Novak, J A Baker, M. E. Obbard, and B. Malloch (Eds) Wild Furbearer Management and Conservation in North America. Ontario Ministry Nat. Resour and Ontario Trappers Assoc., Toronto, Ontario

_____. 1995 (In press). Carnivores. *In* P R. Krausman (Ed) Rangeland Wildlife Soc. Range Manage. Denver, Colo.

_____., and S. H Andelt. 1984. Diet bias in scat deposition- rate surveys of coyote density. Wildl. Soc. Bull 12:74-77.

_____., and P S. Gipson 1979*a*. Domestic turkey losses to radio-tagged coyotes. J. Wildl. Manage. 43:673-679.

_____., and _____. 1979*b*. Home range, activity, and daily movements of coyotes. J. Wildl. Manage. 43:944-951.

_____., C. E Harris, and F. F. Knowlton. 1985. Prior trap experience may bias coyote responses to scent stations. Southwest. Nat. 30:317-318

_____., J G Kie, F. F Knowlton, and K. Cardwell. 1987. Variation in coyote diets associated with season and successional changes in vegetation. J. Wildl. Manage. 51:273-277.

Barrette, C , and F. Messier. 1980. Scent-marking in free-ranging coyotes, Canis latrans. Anim. Behav. 28:814-819.

Bekoff, M., and M. C. Wells. 1980. Behavioral ecology of coyotes social organization, rearing patterns, space use, and resource defense. Z. Tierpsychol 60:281-305.

Bowen, W. D. 1981. Variation in coyote social organization: the influence of prey size Can. J. Zool. 59:639-652.

Bradley, L. C , and D B. Fagre 1988*a* Movements and habitat use by coyotes and bobcats on a ranch in southern Texas Proc. Annu Conf. Southeast Assoc. Fish Wildl Agencies 42:411-430.

_____ , and _____ . 1988*b*. Coyote and bobcat responses to integrated ranch management practices in south Texas J. Range Manage. 41:322-327

Camenzind, F J. 1978. Behavioral ecology of coyotes on the National Elk Refuge, Jackson Wyoming. Pages 267-294 *in* M. Bekoff (Ed.) Coyotes: biology, behavior and management. Academic Press, New York, N.Y.

Connolly, G. E., and W. M Longhurst. 1975. The effects of control on coyote populations. a simulation model Coop. Extension Serv. Bull. 1872. Univ. California, Berkeley. 37pp.

_____., and B. W O'Gara. 1987. Aerial hunting takes sheep-killing coyotes in western Montana Proc. Great Plains Wildl. Damage Control Workshop 8:184-188.

Dorrance, M. J. 1980. Use of toxicants for coyote control by livestock producers in Alberta. Proc. Vertebr. Pest Conf 9.209-214.

Gipson, P. S., and J. A. Sealander. 1972. Home range and activity of the coyote (*Canis latrans frustror*) in Arkansas. Proc. Annu. Conf. Southeast Assoc. Game and Fish Comm 26·82-95

Knowlton, F F. 1972. Preliminary interpretations of coyote population mechanics with some management implications. J. Wildl. Manage. 6:369-382.

_____., L A. Windberg, and C. E. Wahlgren. 1985. Coyote vulnerability to several management techniques. Proc Great Plains Wildl. Damage Control Workshop 7:165-176

Lehner, P N 1978. Coyote communication. Pages 127-162 *in* M. Bekoff (Ed.) Coyotes: biology, behavior, and management. Academic Press, New York, N.Y.

Messier, F., and C. Barrette. 1982. The social system of the coyote (*Canis latrans*) in a forested habitat. Can. J. Zool. 60:1743-1753.

National Agricultural Statistics Service. 1991. Sheep and goat predator loss. U.S. Dep. Agric., Agric. Stat. Board, Washington, D.C. 12pp.

Robinson, W. B. 1948. Thallium and compound 1080 impregnated stations in coyote control. J. Wildl. Manage. 12:279-295.

Roy, L. D., and M. J. Dorrance. 1985. Coyote movements, habitat use, and vulnerability in central Alberta. J. Wildl. Manage. 49:307-313.

Windberg, L. A. and F. F. Knowlton. 1988. Management implications of coyote spacing patterns in southern Texas. J. Wildl. Manage. 52.632-640

_____., and _____ 1990. Relative vulnerability of coyotes to some capture procedures Wildl. Soc Bull 18:282-290

_____, and C. D Mitchell. 1990. Winter diets of coyotes in relation to prey abundance in southern Texas. J. Mammal. 71:439-447.

Walsh, P. B., and J M Inglis. 1989 Seasonal and diel rate of spontaneous vocalization in coyotes in south Texas. J. Mammal. 70·169-171.

SELECTED PARAMETERS OF THE REPRODUCTIVE PHYSIOLOGY AND ENDOCRINOLOGY OF COYOTES

MAX S. AMOSS, JR., Department of Veterinary Physiology and Pharmacology, Texas A&M University, College Station, TX 77843-4466

CONNIE M. HODGES, Department of Veterinary Physiology and Pharmacology, Texas A&M University, College Station, TX 77843-4466

***Abstract*:** The development of the reproductive system and the dynamics of reproductive hormones were studied in captive male and female coyotes (*Canis latrans*). Captive male coyotes exhibited incomplete sexual maturation at the first reproductive season (< 12 months of age). Peak serum testosterone levels in 1-year old males were 50% (300±200 vs. 810±300 pg testosterone/ml) and total sperm production was only 10% (57.4±6.6 vs. 558.8±26 x 10^6 total sperm) of that observed in males older than 1 year. Yearling males were never observed copulating with a female. The sexual maturation of captive female coyotes was less equivocal than their male counterpart's. The pregnancy rate of yearling females was 40% compared to 63% in older females. Average peak serum LH values at the ovulatory surge were 33 ng/ml in yearling females compared to 60 ng/ml in older animals. Serum FSH, estradiol and progesterone levels were similar. There also appears to be an inhibition of fecundity in subordinate females, the mechanism for which is currently unknown. Our long range goal is to capitalize upon this information to develop methodologies for coyote population control

The coyote has been able to adapt and reproduce effectively in a variety of environments from wilderness areas to metropolitan communities. Such success is due in part to its highly flexible social system which is related to its reproductive patterns. In addition to the behavioral patterns necessary for survival, numerous researchers (Bekoff 1976, Bruss et al. 1983, Cary et al. 1982, Hodges 1990, Kennelly 1972, Kennelly 1978, Kennelly and Johns 1976, Stellflug et al. 1981) have described various aspects of coyote reproductive biology.

The coyote is a seasonal breeder, reproductively active between November and June dependent upon geographical location (Gier 1975, Kennelly 1978, Green et al 1984). The female is monestrus The estrous cycle is initiated in December; estrus occurs early in the spring and is distributed over 2 months. Parturition occurs in May or June after a gestation of 60 days (Kennelly and Johns 1976, Bekoff and Diamond 1976, Stellflug et al. 1981). Proestrus lasts 2-3 months and estrus lasts on average of 10.2 days, with ovulation occurring any time between the first and ninth day of estrus (Kennelly and Johns 1976, Cary et al. 1982) Serum estradiol at the pre-ovulation surge averaged 22 8 pg/ml and post-ovulation progesterone levels averaged 15 ng/ml (Stellflug et al 1981).

Electroejaculation of mature males during the height of the reproductive recrudescence yielded total sperm counts of 63 x 10^6 (Bruss, et al., 1983) and 193 x 10^6 (Green et al 1984) Kennelly (1972) reported that the duration of the seminiferous epithelial cycle averaged 13 6 days and epididymal sperm transport was approximately 14 days. The average spermatogenic cycle (the time it takes for a germ cell to develop to a spermatozoa and to be released from the testicle) averaged 54.4 days

The studies summarized here (see Hodges 1990) were undertaken to qualitatively and quantitatively describe the maturation and recrudescence of the reproductive system, and to establish some parameters of behaviorally-associated endocrine responses

Methods

These data were collected over 4 years from wild captive coyotes housed in family units of 1 male and 2 females The foundation animals were trapped, given complete health checks and prophylactic vaccinations, then housed outdoors in 10 X 30-ft enclosures at the Veterinary Medical Research Park at Texas A&M University. All procedures were performed following tranquilization with acepromazine maleate (1 1 mg/kg) or with a combination of xylazine (2.2 mg/kg) and ketamine hydrochloride (22 mg/kg); the latter was used at testicular biopsies and electroejaculations.

Blood samples were obtained weekly from the males from November-April and bimonthly thereafter. Testicular biopsies were obtained at monthly intervals. The estrous cycle was identified by vaginal bleeding, vulvar swelling, vaginal smear cytology, increased male interest, and retrospectively, by hormone analysis Blood samples and vaginal smears were collected at 3-day intervals from December-April and bimonthly thereafter. Serum levels of LH, FSH, estradiol, progesterone and testosterone were determined by validated radioimmunoassays (Hodges 1990). Histological sections of formalin-fixed wedge biopsies were evaluated for the presence of spermatogonia, primary and secondary spermatocytes, and spermatids (Clermont 1963).

Electroejaculations were performed at monthly intervals (Seager 1974). The ejaculate was analyzed for volume, concentration, motility and pH. Vaginal smears were obtained with a vaginal swab or the aspiration of vaginal fluid when present, dried, stained with Diff-Quick R, and evaluated according to Kennelly and Johns (1976) and Cary et al. (1982). Behavior was monitored for 1 hour at dawn each day during proestrus and estrus (December through March) and at biweekly intervals thereafter. Dominance, subordinance, affiliative behaviors and copulatory behaviors were recorded Ethograms of coyotes (Bekoff 1978, Gier 1975) and grey wolves (*C. lupus*) (Packard 1980) were used to categorize these behaviors (see Hodges 1990 for the complete ethograms)

Results

Males. Reproductive system recrudescence appears to be initiated in November as evidenced by the increase in serum levels of testosterone (Fig. 1). Recrudescence was preceded by a rise in LH and the appearance of spermatozoa in testicular biopsies. It was also apparent that full fertility, as predicted by adequate numbers of sperm in the ejaculate (i.e., $>100 \times 10^6$), occurred between January and March (Fig. 2)

Young coyote males entering their first reproductive season exhibited an elevation in serum testosterone and sperm in the ejaculate. However, the increases temporarily lagged behind those of mature males, and the levels were significantly reduced. From behavioral observations made throughout the year, no male coyote less than 1 year of age exhibited any copulatory activity.

Females. The estrous cycle endocrine profile of mature dominant coyotes was unremarkable (Fig. 3). Proestrus was observed as early as late December and estrus (as defined by vaginal cytology) occurred between late February and early March, and lasted 10 days. The ovulatory LH surge was preceded by a rapid rise in estradiol

Although several yearling coyotes exhibited estrus, the entire cycle temporally lagged behind that of mature females by 12-17 days, dependent upon the criterion used Of the 9 trials (defined as 2 females paired together with a male during 1 breeding season) in which behavioral parameters were monitored, only 4 subordinate females exhibited estrus and had an LH surge. Estrus in the subordinate female occurred 11.0±2.7 days after that of her dominant pen mate (Fig. 4). None of the subordinate females gave birth to live young during these trials.

Discussion and Management Implications

These studies substantiated and further delineated the coyote as a seasonal, monestrus canid. The serum endocrine profiles for the estrous cycles of individual animals were qualitatively similar to other mammals However, several issues were raised that may impact on the possibility of exogenously regulating the coyote population by manipulating reproduction.

The yearling male coyote does not enter into the reproductive equation. Neither does he produce enough sperm cells nor attains serum testosterone levels high enough to support copulatory behavior. It has been suggested by others (Bekoff and Wells 1982) that these animals can serve as helpers in obtaining food etc., with no repercussions from the alpha male. It would appear that physiological maturity (sperm in the ejaculate) requires less testosterone than copulation, a behavioral correlate of reproduction.

On a more practical note, it seems counterproductive to attempt to render male coyotes infertile between April and December. Application of this principle may have some ecological implications on non-coyote species. Agents that induce infertility (as opposed to sterility) in the male coyote should be available from January-March Some non-coyote species would not have access to the agent at critical times in their reproductive cycle.

Our studies (and those of others) on the female coyote indicate that estrus and ovulation occur during a very circumspect time frame, late-February to mid-March. Therefore, to be effective, anti-gametogenic agents should be applied between January and March; antiovulatory compounds in February and March; and abortifacient materials in March and April. Female fecundity appeared to be related to the social hierarchy; however, the effect was not precise nor was it complete. Until the actual mechanism is determined, it is highly unlikely that this characteristic can be exploited.

Summary

Much of this symposium is devoted to discussions on ways to control coyote populations. Previously-used methodologies have been only marginally successful, and a significant portion of those have the potential for producing negative effects on the surrounding ecological systems. We suggest that there may be vulnerable events in the reproductive biology of the coyote that may lend themselves to external manipulation with less damage to the environment, and more precise management of the coyote population. One of our goals should be to identify those vulnerable events in coyote reproduction, then exploit them to our advantage.

Literature Cited

Bekoff, M., and J Diamond 1976. Precopulatory and copulatory behavior in coyotes. J. Mamm. 57:372-375

_____. 1978 Behavioral development in coyotes and eastern coyotes. Pages 97-126 in M. Bekoff (Ed.), Coyotes: biology, behavior, and management. Academic Press, New York.

_____, and M C Wells. 1982. Behavioral ecology of coyotes. Social organization, rearing patterns, space use, and resource defense Z. Tierpsychol. 60 281-305.

_____ 1986 Social ecology and behavior of coyotes Adv. Study Behav. 16:251-338.

Bruss, M L , J.S. Green, and J. N Stellflug. 1983. Electroejaculation of the coyote. Theriogenology 20:53-59.

Cary, D.H., J.D Phoades, and D. Schmidt. 1982. Proestrus and estrus of Missouri coyotes. Trans. Missouri Acad. Sci. :107-110.

Clermont, Y. 1963. The cycle of the seminiferous epithelium in man. Am. J. Anat. 112:35-45.

Gier, H.T. 1975. Ecology and behavior of the coyote (*Canis latrans*). Pages 247-277 *in* M.W. Fox (Ed.), The Wild Canids. New York: Van Nostrand Reinhold Company.

Green, J.S., R A. Adair, R.A Woodruff, and J. N. Stellflug. 1984. Seasonal variation in semen production by captive coyotes. J Mamm. 65:506-509.

Hodges, C.M. 1990. The reproductive biology of the coyote (*Canis latrans*). Ph.D. Thesis, Texas A&M Univ. 150pp

Kennelly, J J 1972. Coyote reproduction J. Reprod. Fert. 31 163-170.

_____. 1978 Coyote Reproduction. Pages 73-93 *in* M. Bekoff (Ed.), Coyotes: biology, behavior, and management. Academic Press, New York.

Kennelly, J.J. and B.E. Johns. 1976. The estrous cycle of coyotes. J. Wildl. Manage. 40:272-277.

Packard, J.M 1980. Deferred reproduction in wolves (*Canis lupus*) Ph.D Thesis, Univ. Minnesota, Minneapolis

Seager, S W.J. 1974. Semen collection and artificial insemination in captive wild cats, wolves and bears. Ann Proc. Am. Ass. Zoo Vet. 75:29-35.

Stellflug, J.N , P.D. Muse, D.O. Everson, and T.M. Louis 1981. Changes in serum progesterone and estrogen of the nonpregnant coyote during the breeding season. Proc Soc. Exper Biol Med 167.220-223.

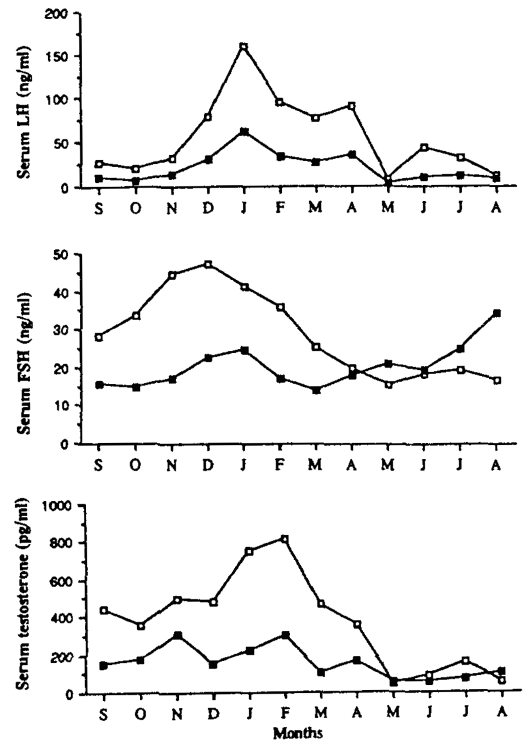


Figure 1. Average serum concentrations of LH, FSH and testosterone in immature (<1 year old) and mature (>1 year old) male coyotes Standard deviations are omitted to preserve clarity Open symbols depict immature coyotes(n=3); closed symbols depict mature coyotes (n=4)

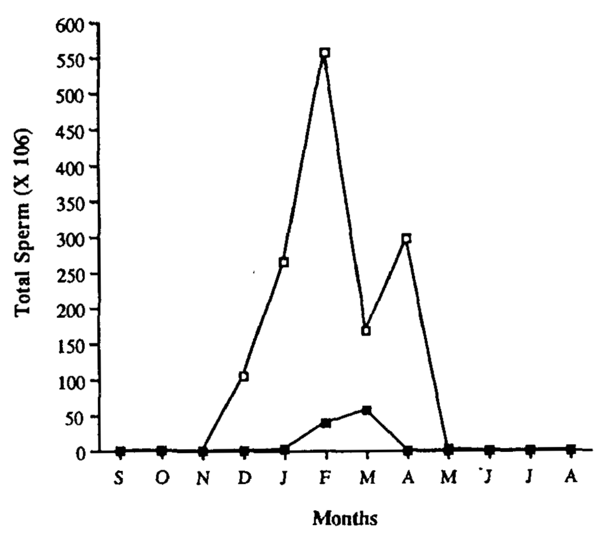


Figure 2. Total sperm in the ejaculate, following electroejaculation, of immature and mature male coyotes. Open circle depicts immature coyotes (n=3); closed diamonds depict mature coyotes (n=4).

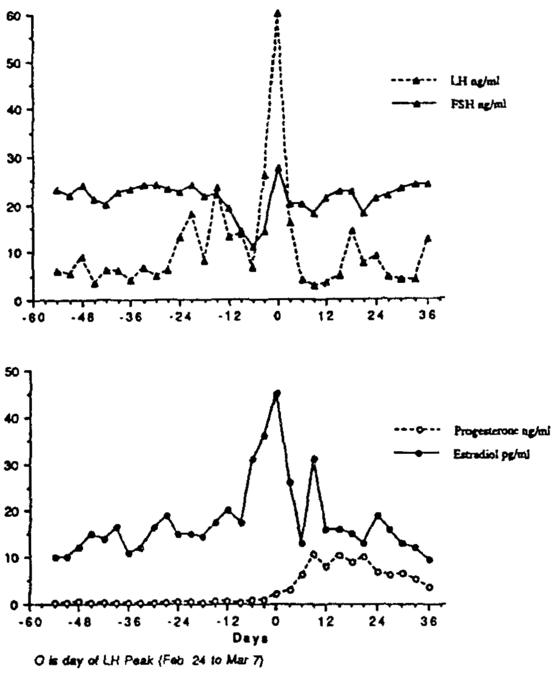


Figure 3 Endocrine profile of reproductive hormones in mature female coyotes (>1 year old) during the estrous cycle (n=8 cycles). Shaded area represents estrus as determined by vaginal cytology. Hormone concentrations of individual animals were initialized to the day of the LH peak. Open triangles depict LH; closed triangles FSH, open circles progesterone; closed circles estradiol.

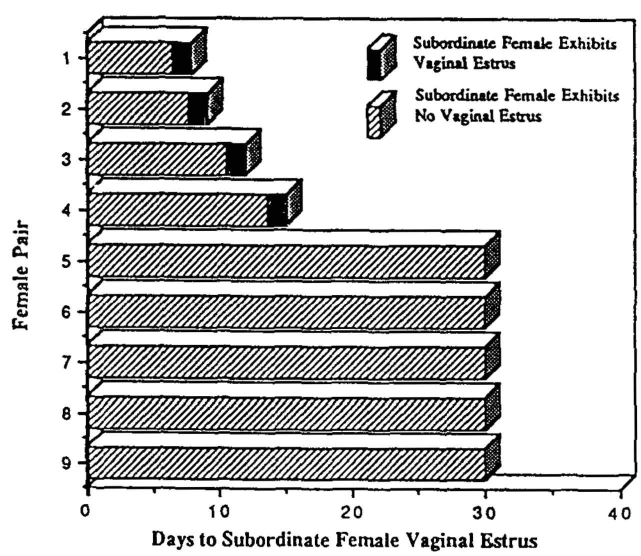


Figure 4. Time (days) to vaginal estrus of subordinate female coyotes Day 0 = first day of vaginal estrus of the dominant female of that pair. Each line represents the response of 1 family unit at 1 breeding season. Mean time to subordinate female estrus was 11.0±2.7 days (range = 8-15 days; n=4 pairs of females). Solid black bar represents estrus. NOTE: In 5 pairs the subordinate female had not exhibited vaginal estrus (or an LH surge) by 30 days following estrus of the dominant female of that pair, these females were not included in the calculation of the mean

DISEASE AND COYOTES IN TEXAS

DANNY B. PENCE, Department of Pathology, Texas Tech University Health Sciences Center, 3601 4th Street, Lubbock, TX 79413

Abstract: The coyote (*Canis latrans*) population in southern Texas has a recurring group of 3 common helminths and several peripheral species of lesser importance. Although recurrent group analyses have not been applied to other macro- or microparasite communities, there are certain infectious agents with high prevalences that could form recurrent groups, and that are potentially important in terms of impacting host population (i e , coyote) abundance While the current rabies epizootic involving coyotes in southern Texas is of public health concern, it probably will not have a major impact on the coyote population. Most likely, the net effect of canine rabies will be compensatory with other mortality factors as occurred in other introduced microparasitic (canine distemper virus, canine parvovirus) and periodically recurring macroparasitic (sarcoptic mange) infections that have caused recent epizootics in this coyote population. In contrast, neotatal mortality from hookworm is conjectured to have a possible regulatory effect on the coyote population in southern Texas, but this remains unproven The effects of disease on the host population should always be considered prior to initiating management or control strategies for any vertebrate species

With some notable exceptions, coyotes are infected with most of the diseases occurring in other wild and domestic canid species. The last comprehensive review of diseases of coyotes and other canids in North America was by Pence and Custer (1981). Herein, I have not elected to update that publication for Texas Rather, I will discuss the impact of several recently studied disease epizootics of a coyote population in southern Texas with particular reference to their effect on the host population.

Relative importance of infectious agents

Radomski and Pence (1993) using data on helminth species collected over 9 years from 329 coyotes in southern Texas found a temporally persistent recurrent group of 3 common helminth species. The importance of this study was that it not only determined which of the co-occurring helminth species were members of an interactive recurrent group, but it also provided insight on which of the many helminth species infecting coyotes could potentially affect the coyote population Because of problems with quantification (collection and culture procedures) and in determining present versus past experience with infection (serological data), there have been no recurrent group analyses on other macroparasites (arthropods) or microparasites (viruses, bacteria, protozoa), or on the collective community of infectious agents.

However, there are certain of these micro- and macroparasites with high prevalences that have caused recent epizootics in this coyote population. These include rabies, distemper, canine parvovirus, sarcoptic mange and hookworm Probably, they would be important members of a recurrent group of "all infectious agents", certain species of which could potentially impact the host population.

The actions of parasites as mortality factors on host populations are reviewed by Holmes and Price (1986) The net effect with any infectious agent may be either:

(1) compensatory with other mortality factors, with individual losses having no net effect on the overall population abundance and composition, or

(2) additive, where losses affect the abundance of the host population

The additive effects of parasite-induced mortality may be severe in some instances, causing host population levels to drop substantially below the threshold for maximum sustained density. However, such cases are not common and often involve introduced pathogens or invading host species. Additive micro- or macroparasite-induced mortality also may function to regulate the host population, with gains or losses in abundance adjusting the number of individuals in the population at a threshold near equilibrium with maximum sustainable density for the host species. Proven examples of the latter are rare.

It is emphasized that recurrent group members vary across geographic localities in helminth communities and probably also across other gradients that could be established for other macro- and microparasitic communities. Thus, the potential importance of a given parasite to its host population may vary dramatically across geographic localities (Pence 1990)

Rabies

Prior to 1988, rabies occurred only sporadically in coyotes, involving just a few individuals (usually fewer than 10) in the more than 10,000 laboratory confirmed cases per year reported in North America (Pence and Custer 1981). However, in the latter months of 1988, there was a mortality event involving coyotes and domestic dogs in the extreme southern counties of Texas and adjacent Republic of Mexico. Between 1988 and June 1995 there have been 2 human and 638 animal cases (laboratory-confirmed) of rabies with 244 and 322 of these in dogs and coyotes, respectively, across 20 counties of southern Texas (Anonymous 1995). The rabies virus involved is known as the "canine/coyote" or "Mexican dog" strain.

Current efforts are directed toward containment and control of the rabies epizootic in southern Texas through utilization of a vaccine/bait aerial delivery program (Anonymous 1995) The first vaccine/bait drop of the South Texas Oral Rabies Vaccination Project for coyotes was undertaken in February 1995, delivering 830,000 vaccine/bait units over much of southern Texas in the largest single oral vaccination deployment ever undertaken in the world (Anonymous 1995). The oral vaccination project was an attempt to stop the northward and eastward movement of rabies in southern Texas. If this project fails, the epizootic will undoubtedly continue to spread throughout Texas. Also, the epizootic will continue to spread if individuals fail to observe the statewide rabies quarantine on movement of unvaccinated wild canids The strain already has been identified in Alabama, Florida, Montana and The Netherlands (Anonymous 1995).

There are many unanswered questions concerning the current rabies epizootic in southern Texas. Despite the occurrence of very high densities of coyotes and the concurrent existance of rabies in dogs in southern Texas for many decades, why did it take so long for the virus to become enzootic in the coyote population? Also, regardless of the much publicized present "epizootic" in coyotes, the prevalence of rabies in this coyote population remains lower than that in similar fox, skunk or raccoon rabies epizootics in other geographic regions in North America. Finally, while there have been no definitive studies on abundance or composition, the coyote population in southern Texas does not appear to be declining due to the present rabies epizootic (S E. Henke, pers. commun.).

In the red fox (*Vulpes vulpes*) population of central Europe, enzootic rabies acts as a form of time-delayed density-dependent regulator of fox population growth The length of time lag is determined by how long the fox density is below a critical threshold density for transmission of the disease (about 1 fox 400 acres). As a result of this damped oscillatory cycle, epizootics recur every 3 to 5 years in many areas (Anderson 1981, May 1983). Because of its high pathogenicity, rabies persists within this fox population at very low prevalences between epizootic periods

Once established as an enzootic disease, will the coyote/dog strain of rabies function in a similar capacity as fox rabies in Europe, to regulate population abundance of coyotes from southern Texas? More likely, the rabies-induced mortality simply will be compensatory with other mortality factors in this population, as has occurred in other recently introduced viral pathogens. It should be noted that host population regulation has not been demonstrated for rabies in red fox or other carnivore populations in North America.

Canine distemper

Certainly distemper virus can be highly lethal to coyote pups in captivity (Gier and Ameel 1959). However, after finding 37% of a small sample of coyotes in southern Texas serologically positive for distemper, Trainer and Knowlton (1968) suggested that canine distemper was enzootic and perhaps not an important mortality factor in free-living coyote populations. This was confirmed by Guo et al. (1986) who examined 228 randomly selected coyote serum samples from a serum bank assembled from specimens collected in southern Texas. The proportion of seropositive coyotes increased from 30% to 86% in the period 1975 to 1984, respectively, reflecting the establishment of enzootic infection (over 60% seropositive rate) The seropositive rate of distemper virus was age-dependent in this coyote population. Antibodies against canine distemper virus were found in 25%, 67% and 91% of coyotes less than 1-year-old, those from 1 to 2 years old, and those over 2 years old, respectively. This increase in seroprevalence with age is not reflective of a disease with high pup mortality. Conversely, it indicates that coyotes may be a reservoir and source of the infection of canine distemper virus for domestic dogs. Thus, distemper-induced mortality losses in the coyote population of southern Texas are regarded as compensatory with other mortality factors.

Canine parvovirus

In 1978 a previously unknown parvovirus caused an extensive epizootic of hemorrhagic enteritis and myocarditis in domestic dogs in North America. Canine parvovirus infection was characterized by high morbidity and mortality (10% to 50%) in young domestic dogs. Thomas et al. (1984) examined the seroprevalence of canine parvovirus in serum samples collected from coyote populations in southern Texas, Utah and Idaho between 1972 and 1983.

The onset of canine parvovirus seroprevalence in coyotes began in 1979, coinciding with the domestic canine epizootic The seroprevalence rapidly increased to more than 70% by 1982 indicating enzootic establishment of the infection Prevalence ultimately reached 90% to 100% in all sites These high antibody prevalence rates are reflective of a highly contagious infection with low mortality rates. In 1980-81 just following introduction of canine parvovirus, the southern Texas coyote population experienced a decrease in population abundance. The decline resulted from increased pup mortality as reflected by lower juvenile adult ratios (Pence et al. 1983). However, in the following years, coyote population abundance and juvenile recruitment subsequently returned to previous levels once canine parvovirus became enzootic

Thus, in addition to distemper virus, the establishment of canine parvovirus as another new and highly contagious pathogen capable of causing high juvenile mortality in a naive population failed to ultimately affect the abundance or composition of this coyote population.

Sarcoptic mange

Pence et al. (1983) and Pence and Windberg (1994) documented the effects of an epizootic of sarcoptic mange caused by the mite *Sarcoptes scabiei* in the coyote population of southern Texas from 1971-91 Although sporadic cases were reported previously, during the initial phase of the epizootic (1975-1978) mange prevalence increased from 14 to 24% in this coyote population. From spring 1979 to spring 1982 the mange prevalence peaked at 69% during the stationary period of the epizootic. The fall of 1982 marked the beginning of the decline phase of the epizootic with prevalences slowly decreasing to 0% by spring 1991. Subsequently, only sporadic cases have been reported.

From its point of origin in Webb County in 1975, the mange epizootic expanded centrifugally to encompass most of southern Texas during 1982-89, plus an unmeasured area in the adjacent Republic of Mexico The high prevalences of mange, reaching nearly 70% at the peak of the epizootic with only about 1% of these animals recovering Coupled with the decreased reproductive rates in mature territorial females infected with mange, the epizootic increased disease-induced mortality and natality rates in this coyote population.

Despite such mortality, the abundance and juvenile adult ratios remained stable at levels consistent with a high-density population over the 21 year period of study (Pence and Windberg 1994) Thus, mange-induced mortality was regarded as compensatory with other mortality factors in this coyote population

Hookworm

Radomski and Pence (1993) found that of 8 common species, there was temporal persistence of a small recurrent group of 3 dominant, unrelated species. This group dominates the intestinal helminth community in the coyote population of southern Texas The dog hookworm (*Ancylostoma caninum*) was the most important pathogen of these 3 species. Further, it was the most abundant helminth, with prevalences always over 95% in all host subpopulations over the 9-year study period.

Of all the species of helminths in this coyote population, hookworm is the only macroparasite that has the long-standing host-parasite relationship with an aggregated distribution that could effect the degree of density-dependent pathogenesis in juveniles (Anderson 1978, May 1983) necessary to regulate the host population. This effect would manifest itself by decreasing the number of juveniles available for recruitment. Hookworm disease-induced mortality results from a complex interaction of parasite density-, host age-, and nutritional-dependent factors in coyote neonates and juveniles (Radomski 1989)

Pence et al (1988) demonstrated that coyote pups were infected naturally at a very young age by transmammary transmission. Radomski (1989) showed that a threshold dose of about 300 infective hookworm larvae were sufficient to account for over 50% mortality in coyote neonates experimentally infected with hookworm in the first few weeks of life Extrapolated to a free-ranging population, this indicates that juvenile mortality can be expected in populations with high hookworm abundances

In the coyote population of southern Texas, fall-collected juvenile (6 to 7 months old) coyotes still had very heavy infections (Pence and Windberg, 1984). There were 78%, 63%, 42%, and 24% of these juveniles with more than 150, 200, 250 and 300 hookworms, respectively (D. B. Pence and L. A. Windberg, unpublished data). These were juveniles which had survived the initial effects of hookworm disease due to heavy transcolostrally-acquired infections as neonates.

Because most hookworm infections of coyotes in southern Texas probably result from transmammary transmission (Pence and Windberg 1984, Pence et al 1988), and 78% of the 6 to 7 month old juveniles harbored over 150 hookworms, neonates which had slightly higher abundances of hookworms probably were lost from the population About 25% of the 6 to 7 month old coyote neonates had over 300 hookworms, the LD_{50} threshold of Radomski (1989) in experimentally-infected neonates

There was an associated hemorrhagic enteritis and ancylostomiasis in these juveniles which was complicated by high intensities of other intestinal helminths. Despite this, these animals appeared to be in reasonably good condition at the end of the warm season and prior to the fall dispersion from the family group.

Based on overwinter juvenile mortality from fall-to-spring (Windberg et al. 1985), it is estimated that perhaps one-third of the coyote pups whelped in southern Texas die between birth and 6 months of age, with another one-third of these survivors dying during the first overwinter period (L. A. Windberg, pers. commun.).

The following may occur in at least some of the juvenile coyotes that survived the initial consequences of prenatal-colostrum hookworm infections, but maintained moderate-to-heavy hookworm infections through the summer and into early fall.

Food supplies in southern Texas are most abundant following whelping (Brown 1977), and neonates should be able to maintain the highest level of nutrition when they are part of a family group living in a territorial range. Dispersal of juveniles from parental territories occurs during the fall and early winter (Andelt 1985). Although fall food supplies appear adequate in most years, this is a period of dietary transition when diets shift from fruits as a major component to greater use of rodents and lagomorphs (Brown 1977). Therefore, heavy hookworm infections may compound an already nutritionally-, behaviorally-, and socially-stressed juvenile coyote. Thus, ancylostomiasis could have an effect on the growth rate and survival of juvenile coyotes during the fall and the subsequent overwinter period

Knowlton and Stoddart (1978) concluded that explanations regarding regulation of coyote populations were speculative. However, evidence at that time suggested that social intolerance, as mediated by abundances and availability of food, were the primary determinants of coyote densities. Behavioral characteristics are linked with survivorship. Although available evidence indicates that hookworm-induced juvenile mortality may provide a mechanism for regulation of this coyote population, this remains to be verified through further field studies

Conclusions

Coyote populations, such as the 1 in southern Texas that have been studied extensively, can suffer what appear to be frequent and severe disease epizootics. The casual observer witnessing morbidity or episodes of mass mortality may interpret the effects of these epizootics as devastating to the population (Pence and Windberg 1994). However, the disease-induced mortality from distemper, canine parvovirus and mange that have recently caused epizootics in the coyote population of southern Texas was compensatory with other mortality factors Probably the same effect will be observed in the present rabies epizootic, once the virus becomes enzootic Though unproven, it is conjectured that the abundant and pathogenic dog hookworm represents the only macroparasitic infection that may effect regulation by reducing juvenile recruitment in this coyote population.

As emphasized by Pence and Windberg (1994) in their study of sarcoptic mange in the coyote population from southern Texas, more critical examination of host-disease ecological relationships may reveal an insignificant effect at the host population level. Alternatively, certain diseases could be very important to a host population if the effects of mortality were additive and contributed to the regulation of the population abundance at the threshold of its maximum sustainable density, as is suspected in hookworm infection. Thus, it is of importance to understand the actual effect of the common diseases on the specific host population in question prior to implementation of any intervention or control procedures for those diseases. Further diseases and parasites should be considered when developing an overall management or control strategy for any given host population

Literature Cited

Andelt, W F. 1974 Behavioral ecology of coyotes in south Texas Wildl. Monogr. 94. 45pp.

Anderson, R. M 1978 The regulation of host population growth by parasitic species. Parasitol 76· 119-157.

Anderson, R M. 1981 Fox rabies. Pages 242-261 *in* R. M Anderson (Ed.) Population dynamics of infectious diseases. Chapman and Hall, London

Anonymous. 1995. (Unpuplished) Monthly rabies reports. Tex. Dept Health, Publ. Health Region II, Harlingen.

Brown, K L 1977. Coyote food habits in relation to a fluctuating prey base in south Texas M.S. Thesis, Tex A&M Univ., College Station. 58pp.

Gier, H T., and D. J. Ameel 1959 Parasites and diseases of Kansas coyotes. Kansas St. Univ. Agric. Exp. Sta. Bull. 91. 34pp.

Guo, W., J F. Evermann, W. F. Foreyt, F F Knowlton, and L A Windberg. 1986. Canine distemper virus in coyotes· A serologic survey J. Am. Vet. Med. Assoc. 189. 1099-1100.

Holmes, J. C., and P. W. Price. 1986 Communities of parasites. Pages 187-213 *in* D J. Anderson and J. Kikpawa, (Eds.) Community ecology: Pattern and processes. Blackwell. Oxford.

Knowlton, F F., and L C. Stoddart. 1978. Coyote population mechanics. Another look. Pages 93-111 *in* F. L Bunnell, D. S. Eastman, and J. M Peak, (Eds.) Symp.on natural regulation of wildlife populations Forest, Wildl. Range Exper Stat , Univ Idaho. Moscow

May, R. M. 1983. Parasite infections as regulators of animal populations Amer Sci 71· 36-45

Pence, D B 1990. Helminth community of mammalian hosts: concepts at the infracommunity, component and compound community levels Pages 233-260 *in* G W. Esch, A O. Bush, and J. M Aho, (Eds.) Parasite communities. patterns and processes. Chapman and Hall N.Y

______., and J. W. Custer. 1981. Host-parasite relationships in the wild Canidae of North America. II. Pathology of infectious diseases in the genus *Canis*. Pages 760-845 *in* J. A. Chapman and D. Pursley, (Eds.) Proc. Worldwide Furbearer Conference R R. Donnelley and Sons, Falls Church

______., F F Knowlton, and L. A Windberg 1988 Transmission of *Ancylostoma caninum* and *Alaria marcianae* in coyotes (*Canis latrans*) J. Wildl. Dis 24 560-563

Pence, D. B.. and L. A. Windberg. Population dynamics across selected variables of the helminth community in coyotes, *Canis latrans*, from south Texas. J. Parasitol. 70: 735-746.

_____., and _____. 1994. Impact of a sarcoptic mange epizootic on a coyote population. J. Wildl. Manage. 58: 624-633

_____., _____., , and R Sprowls. 1983. The epizootology and pathology of sarcoptic mange in coyotes, *Canis latrans*, from south Texas. J. Parasitol. 69. 1100-1115.

Radomski, A A. 1989. Host-parasite relationships of helminths in a coyote population from southern Texas with particular reference to dog hookworm. M.S, Thesis Texas Tech Univ., Lubbock 132pp

_____., and D. B. Pence. 1993. Persistence of a recurrent group of intestinal helminth species in a coyote population from southern Texas. J Parasitol. 79 371-378.

Thomas, N. J., W. J. Foreyt, J. F. Evermann, L. A. Windberg, and F. F. Knowlton. 1984. Seroprevalence of canine parvovirus in wild coyotes from Texas, Utah, and Idaho (1972 to 1983). J. Am. Vet. Med. Assoc. 185: 1283-1287.

Trainer, D. O., and F. F. Knowlton. 1968. Serologic evidence of diseases in Texas coyotes. J. Wildl. Manage. 32: 981-983.

Windberg, L. A., H. L. Anderson, and R. M. Engeman. 1985. Survival of coyotes in southern Texas. J. Wildl. Manage. 49: 301-307.

THE EFFECTS OF CONTROL ON COYOTE POPULATIONS: ANOTHER LOOK

GUY E. CONNOLLY, USDA-APHIS Animal Damage Control, Denver Wildlife Research Center, P. O. Box 25266, Denver CO 80225

***Abstract*:** Population dynamics models are useful for estimating coyote (*Canis latrans*) population responses to exploitation as well as to hypothetical birth intervention techniques At least 6 coyote simulation models have been developed over the past 25 years. This paper reviews the model developed by Connolly and Longhurst (1975), and identifies some potential improvements based upon new biological information and modern computing technology The biological concepts embodied in the Connolly-Longhurst (C-L) model seem as valid in 1995 as they were in 1975. Newer studies have tended to reaffirm rather than revise earlier concepts of coyote population mechanics. One significant shortcoming of the C-L model, as acknowledged by the authors at the time, was its failure to include immigration as one of the mechanisms for replacement of coyotes removed in control Subsequent studies have reiterated the importance of immigration and emigration in the dynamics of exploited coyote populations, but researchers have not made corresponding progress toward the incorporation of these phenomena into simulation models. Updating the C-L model would consist largely of revamping it to run on modern computers and software. A new edition would make the model useful to wildlife managers interested in the effects of predator control on the dynamics of selected coyote populations. The updated model would calculate births and deaths monthly rather than annually, and minor changes could be made to the birth and natural mortality functions. However, the revised model probably would sustain most of the conclusions stated in 1975.

The coyote is much admired for its survival ability. As Gabrielson (1951) recognized many years ago, no other American mammal has shown greater adaptability and stamina in the face of ruthless oppression In spite of guns, dogs, poisons, and traps, pursued by hired hunters and carrying a price on his head, the coyote has managed not only to survive but to extend his range into new territory. Hundreds of thousands of coyotes are killed each year in the western United States, yet large and healthy populations remain.

How does the coyote do it? The biological answers to this question have been sought in many field studies of coyote populations (Connolly 1978). Additionally, several teams of biologists have analyzed the elements of coyote population dynamics and assembled them into mathematical simulation models of coyote populations.

The models that help us understand the coyote's legendary survival ability are those that provide numerical estimates of coyote population responses to management; i.e , exploitation (killing or harvest) and birth control At least 4 such models were developed in the 1970s (Connolly 1978). This paper reexamines one of these models (Connolly and Longhurst 1975; hereafter termed the C-L model) in light of more recent information Herein I identify some improvements that, if implemented, would update the model and make it more useful to wildlife managers.

The C-L model

The C-L model established an initial population 100 coyotes. Coyote numbers in this population changed over time due to births, "control kill" (defined later), and natural losses The model was developed for the purpose of estimating the probable effects of exploitation, birth suppression, or both on coyote populations.

Simulation experiments with the C-L model showed that the primary effect of killing coyotes was to reduce coyote population density, thereby stimulating density-dependent changes in natality and natural mortality rates. The simulated population survived indefinitely when 70% of its members were killed annually, but declined to zero in about 50 years when 75% were killed each year. Coyote populations reduced by intensive control returned to pre-control densities within 3-5 years after control was terminated

In the C-L model, birth suppression as the sole management tactic reduced the coyote population significantly only when most (80-95%) of the females were prevented from producing pups. Birth suppression combined with killing appeared to be more effective in reducing coyote numbers. The model and its use to determine population responses to various control strategies were described in detail by Connolly and Longhurst (1975)[1].

The C-L model revisited: assumptions, input parameters, and computations

Population stability. In the absence of control or exploitation, the C-L model's coyote population was stable, both in numbers and age structure The carrying capacity of the environment also was stable and did not change regardless of the level of exploitation These principles would be retained if I was updating the C-L model.

Area inhabited by the coyote population. The population inhabited an area of unspecified size, but with sufficient resources to sustain a breeding population of just 100 coyotes each year. The carrying capacity of this area was assumed to be constant year after year. In updating the C-L model, I would now make it functional with geographic areas of any desired size. The size of the area, together with an estimated coyote density, would be specified with other initial input parameters at the start of each run The initial coyote population would be the product of coyote density and geographic area. For example, an initial input of 1,000 mi^2 with a density of 1.5 coyotes/mi^2, would yield an initial population of 1,500 coyotes.

Number of age classes. All coyotes in the C-L model were either pups (0-12 months old) or adults (over 12 months old). Pups approaching their first birthday were termed yearlings for purposes of birth computations. Adults were not tracked as yearly age classes, so natural death rates were constant for adult coyotes of all ages. In the updated model it would be desirable to track individual cohorts up to 8 or 10 years of age.

Causes of death. In the C-L model, all coyote deaths resulted from either control (killing by humans) or natural causes (all non-human causes). This would not change in the updated model

Control kill specifications. A "control kill" rate was specified as one of the initial input parameters for each run of the C-L model. Control kill was specified as a percentage of the maximum (post-whelping) population, and the same percentage was applied to pups and adult coyotes. It was not possible to take different proportions of different age classes nor to distribute the control kill among different seasons of the year. An updated model could permit the control kill to be specified separately for each month, with zeros entered for those months when no kill would occur. Control specifications could be entered as either percentages or number of coyotes to be removed from each age class.

Birth control specifications. Birth control in the C-L model was simulated by preventing specified percentages of the normally-breeding females from having litters This procedure would be retained in the updated model, and I would add the ability to specify birth prevention as either percentages or numbers of females in each age class. The pragmatic reader may note that practical birth control methods for wild coyote populations are no nearer to realization now than they were 20 years ago. Therefore, the simulation of birth intervention impacts has little relevance to coyote management as practiced in 1995

Birth and death computations. Each annual cycle in the C-L model consisted of one computation of births, followed by a single computation of control removal (if any) from the maximum (post-whelping) population, followed by a single computation of natural mortality. Natural mortality rates were applied to those coyotes that survived control. At the end of each year, the closing population became the beginning (breeding) population for the next year Seasonal differences in control or natural mortality rates could not be simulated in the C-L model.

The updated C-L model would perform calculations monthly rather than annually. Births could all occur in 1 month, as in the C-L model, or could be distributed across 2-3 months as they actually occur in most wild coyote populations. The distribution of births would be specified in the initial

[1]*This publication can be obtained from the Denver Wildlife Research Center, P.O Box 25266, Denver CO 80255*

input. Control kills would be subtracted in the month(s) specified in the initial input.

Natural mortality in the updated model would be subtracted in each month, unless the model user specified no natural mortality for the month. Users would have the option of specifying the proportion of total annual natural mortality that would occur in each month separately for each age class. If no distribution was specified in the initial input, the model would automatically distribute the total annual natural mortality evenly over the 12 months of each year.

In the revised model, the computation sequence each month would proceed as follows:

OPENING INVENTORY
+ BIRTHS (if any)
- CONTROL KILL (if any)
- NATURAL MORTALITY (if any)
= CLOSING INVENTORY.

The closing inventory each month would become the opening inventory for the next month. Each set of 12 months in the model would comprise one annual cycle. Monthly statistics would be summed as necessary to produce annual statistics.

Sex ratios. Even (i e , 50 males:50 females) sex ratios were assumed in the C-L model for each age class, including pups at birth. All mortality, whether from control or natural causes, applied to males and females equally. Other coyote population models reviewed by Connolly (1978) also assumed a 50:50 sex ratio, as did more recent simulations (Sterling et al. 1983; Windberg and Knowlton 1988)

More recent field studies, however, have been inconsistent on this point. Some reported even sex ratios (Nellis and Keith 1976; Crabtree 1989), but others suggested that there was a preponderance of males among samples of adult coyotes from populations where exploitation was low (Gese et al. 1989) or a preponderance of females where exploitation was more intense (Knowlton 1972) Therefore, it is not clear to me whether an updated C-L model should or should not incorporate sex differential birth or death rates. It would be easy enough to incorporate sex-differential birth or mortality functions into the model, but difficult to develop valid sex-differential functions from information currently available. Considering all current information, I probably would retain even sex ratios as in the C-L model.

Compensatory natality and mortality. A key assumption in the C-L model, and in all other coyote population models known to me, is the principle of compensatory natality and mortality. That is, removal of coyotes enhances conditions for the animals that survive exploitation so that birth rates are higher and natural mortality lower than in the unexploited population These phenomena were simulated in the C-L model by density dependent functions, i.e , equations that caused average litter size, proportions of female coyotes producing young, and proportions of animals dying of natural causes to vary with relative coyote density (Figs. 2-4 in Connolly and Longhurst 1975).

A few reports published since 1975 have reiterated the existence and importance of compensatory or density dependent relationships in coyote population dynamics (Connolly 1978, Sterling et al 1983) Variations in emigration rates also may be density dependent (Knowlton and Stoddart 1983). Thus, the assumption of density dependent compensations in birth and death rates appears to be as valid in 1995 as it was in 1975.

Explicit quantification of the magnitude of these compensatory responses, however, was lacking in 1975 and remains equally lacking in 1995. Connolly and Longhurst (1975) presented birth and death rate functions as speculative and pointed out a need for additional research to refine them The C-L model was constructed so that improved functions could readily replace the initial ones. As of 1995, however, improved functions have not been forthcoming, and the specific forms of these functions remain a matter of speculation. If further work is done with the C-L model, sensitivity analyses would be desirable to determine how much the model output is affected by changes in the shapes and slopes of these functions

Birth rate functions. The C-L model contained 3 density-dependent birth rate functions (Connolly and Longhurst 1975.Figs. 2-3) Two of these expressed the relationship between relative population density and the proportion of adult females and yearling females, respectively, that would produce litters. The third function established mean litter sizes that varied with relative population density. In the C-L model, mean litter size for yearling females was the same as that for adult females. The shapes of these functions were highly speculative, but there is little new research that would help refine them.

The C-L functions for yearling and adult pregnancy rates were concocted from published estimates of the ranges of variation in pregnancy rates, i.e., 0-70% for yearlings and 60-90% for adult females Subsequent studies have tended to yield pregnancy rates that fall in or near these ranges. Nellis and Keith (1976), for example, found pregnancy rates of 94% for adults and 14% for yearlings in central Alberta Examinations of female coyotes from a lightly exploited population in southeastern Colorado showed that all 10 adults contained placental scars, but none of 11 yearlings showed evidence of whelping (Gese et al. 1989). Crabtree (1989), in contrast, found that alpha females aged 2-6 years were the most successful breeders in an unexploited coyote population in eastern Washington, overall, 40% of his females were productive and the age at first breeding was 2-3 years

These studies do not indicate a need to revise the yearling or adult pregnancy rate functions in the C-L Consequently, I would not change them in an updated model

Mean litter sizes also have been estimated in several studies published since 1975. Nellis and Keith (1976) reported an average of 5.3 pups/litter for 26 litters examined at dens in Alberta. In northern Utah, mean litter sizes were estimated to vary in different years from less than 5 to more than 8 pups per litter based on placental scar counts; mean litter size was correlated with jackrabbit (*Lepus californicus*) abundance (Knowlton 1989). The model of Sterling et al. (1983) assumed mean litter sizes to range from 4 3-7.6 pups/litter. The lightly exploited Colorado population of Gese et al. (1989) had an average of 3.2 pups/litter (n = 16), whereas an average of 5.6 pups/litter was reported from an almost unexploited Washington population (Crabtree 1989) Crabtree suggested that litter size is relatively insensitive to the level of exploitation

Considering all of these findings, I would be inclined to reduce mean litter sizes slightly from the range of 4.5-9 pups/litter used in the C-L model to about 4-8 pups/litter in the revised model.

Natural mortality functions. The C-L model had 2 density-dependent natural mortality functions (Connolly and Longhurst 1975 Fig 4). They assumed annual natural mortality of 40% for adults and approximately 61% for pups in an unexploited population. These rates declined to 10% as the coyote density was reduced to 0 by control kills. As with the birth functions, these mortality functions were conjectural, and there is little basis in new research to help refine them.

A review by Knowlton and Stoddart (1983) showed that annual adult mortality rates of 25-45% are common with 65-75% mortality indicated in a few studies. This report also drew attention to apparent high rates of post-natal losses of pups, perhaps as high as 30 to 60% during the first 6 months of life. Nellis and Keith (1976) estimated mortality rates (all causes) of 71% for pups and 36-42% for coyotes over 1 year old. Gese et al. (1989) found annual mortality rates for adults, yearlings, and pups of 13, 48, and 49%, respectively. These workers also reported that resident coyotes, transients, and dispersers had annual mortality rates of 13, 39, and 61%, respectively. The Gese et al. study took place on a 400-mi^2 area where coyotes were not exploited, however, coyotes were exploited on surrounding areas The relatively unexploited population[2] studied by Crabtree (1989) was found to have annual adult mortality of only 10%, but 58% of pups died during their first 14 weeks of life Crabtree suggested that early pup survival is the major reproductive response to exploitation.

Considering all these sources of information, I would be inclined to retain the C-L model's current natural mortality function for pups, where much of the annual mortality occurs in the first month or two after birth I would replace the single adult mortality function in the C-L model with 3 functions--one for yearlings, another for 2-6 year adults, and another for older animals Prime-age adults (i.e., 2-6 years old) would have lower mortality rates than yearlings or coyotes older than 6 years.

Immigration and emigration. The C-L model assumed that immigration and emigration either did not occur or occurred at equivalent rates. Connolly

[2] *Crabtree's study area in eastern Washington certainly supports 1 of the least exploited coyote populations in the lower 48 states, but all the adult coyote mortality he recorded was associated with human causes and there was a net loss of animals through egress. Thus this population should be regarded as lightly exploited, not unexploited.*

and Longhurst (1975) agreed with Knowlton's (1972) contention that immigration (dispersal or infiltration) of coyotes from lightly hunted areas provides the mainspring for restocking areas under high rates of exploitation, but they left this aspect of coyote biology out of the C-L model because they couldn't devise a workable rationale to simulate it. Other coyote models reviewed by Connolly (1978) also omitted ingress and egress, perhaps for the same reason.

Biologists have made few advances on this topic over the past 20 years. Immigration has continued to be identified as a major element of coyote population dynamics (Connolly 1978; Knowlton and Stoddart 1983; Gese et al. 1989; Crabtree 1989). However, information on rates of ingress and egress and the explanations for these movements remain scanty (Knowlton and Stoddart 1983). More recently published coyote population simulations (Sterling et al. 1983; Windberg and Knowlton 1988) also failed to account for ingress and egress.

Perhaps one reason why modelers haven't made more effort to simulate the dynamics of unbounded coyote populations is the attractive simplicity of models involving closed populations. In real populations, coyote numbers change over time as the aggregate product of births, deaths, ingress and egress. But in a closed population, coyote numbers can change only through births and deaths, and recruitment to any age class consists of the survivors from a younger age class.

Given the relative simplicity of computing the dynamics of closed populations, some modelers could find it convenient to ignore immigration and emigration, even if workable techniques were available to simulate these processes.

It seems likely that someone eventually will devise a practical way to integrate ingress and egress in coyote simulation models. Pending such developments, the best way to minimize the adverse effects of ignoring ingress and egress may be to limit the application of coyote population models to large geographic areas, the larger the better. On small areas, I speculate that the erroneous assumption of a closed population, if substantial ingress actually occurs at high rates of exploitation, would yield model output that understates a coyote population's resilience to control.

Also, it seems that any errors introduced by assuming populations to be closed decrease in proportion to the size of the area occupied by the simulated population. That is, it may be invalid to assume that the population on a small geographic area is closed but more valid to make such an assumption for a large area. Of course, a population could in fact be closed if it inhabits an island or is bounded by large water bodies, coyote-proof fences, or other genuine barriers to coyote movements. Truly closed coyote populations, however, are extremely rare if they exist at all.

Computing hardware. The C-L model ran on a Wang Model 360 electronic calculator with a CP-1 card programming attachment. This calculator displayed results visually; there was no printed output. The program was designed with stop commands at each critical point so that, as computations proceeded, each desired result could be copied manually from the display.

As crude as this may seem by 1995 standards, it worked quite well in 1974. The slow computation speed was not a problem, but the Wang unit did not have enough memory to allow separate computations for animals by year classes. Also, it would have been desirable to compute births and deaths on monthly rather than annual cycles, but this would have been nearly impossible with the Wang system.

In 1995, of course, one would not run a simulation model on a programmable calculator but on a desktop computer using statistical software. Output would be printed and could include both tabular and graphical summaries. In my conception, the revised C-L model would run on a variety of computer models and be transportable on floppy discs or by electronic transfer

One feature of the C-L model that could and should be retained in any update is its mathematical simplicity. The C-L model involved no computations other than simple addition and multiplication, and I know of no reason why an updated model should be more complicated.

Discussion

It appears to me that wildlife biologists' understanding of coyote population responses to exploitation have not changed appreciably over the past 20 years. Additional studies have refined the numerical ranges of some parameters, but the new information confirms rather than revises the concepts set forth in Knowlton's (1972) landmark p-aper Most coyote population simulations (including the C-L model) add little more than descriptive arithmetic to Knowlton's model, which elucidated the basics of coyote population mechanics in a form that has seen little improvement since 1972.

The C-L model was based largely on Knowlton's (1972) concepts and information. Except for revisions to incorporate the mechanisms of ingress and egress, which eluded Connolly and Longhurst (1975) as well as other coyote simulation models to date, I see no need for major revisions in the C-L model

This is not to say that there have been no advances in our understanding of coyote population biology. Since 1972, Knowlton and others have identified social intolerances as an important factor in, if not the basis for, natural regulation of coyote population density (Knowlton and Stoddart 1983, Gese et al. 1989). The territorial pair is now recognized as the basic unit of coyote populations, and disruption of social patterns may be an important, undesirable result of exploitation (Knowlton 1989, Crabtree 1989). To date, however, these principles have not been applied to coyote simulation models.

Simulation efforts since 1975 have tended to confirm the C-L model in showing that coyote populations can support high rates of exploitation. Sterling et al. (1983) found in their simulations that control programs inflicting less than 50% annual mortality could not be expected to produce declining populations using any combination of litter size and percent breeding. Windberg and Knowlton (1988) showed that the number of coyotes actually using small geographic areas, and therefore the number that would have to be removed to gain population control, is much greater than one might infer from density estimates. Therefore, it appears that the main conclusions stated by Connolly and Longhurst (1975) remain valid today.

There have been major changes on the computing front, however. The programmable calculator used for the C-L model was scrapped long ago, and the utility of this model would be very much enhanced by revamping it to run on modern computers. Improved realism would result from incorporating the changes detailed earlier in this paper, but I expect that the updated model would generate results similar to those produced by the C-L model.

The updated model would be particularly useful to biologists who need a way to evaluate ADC programs or other human impacts on coyote populations in specific geographical areas, e.g. states, ecological regions, national forests, or BLM resource areas in connection with the preparation of environmental analyses under the National Environmental Policy Act.

Literature Cited

Connolly, G E 1978. Predator control and coyote populations: a review of simulation models. Pages 327-345 *in* M Bekoff (ed.) Coyotes: Biology, Behavior and Management. Academic Press, N.Y. 384pp.

_____., and W. M. Longhurst. 1975. The effects of control on coyote populations. Univ. Calif., Div. Agric. Sci. Bull. 1872. 37pp.

Crabtree, R. L. 1989. Sociodemography of an unexploited coyote population. Ph.D. Thesis, Univ. Idaho, Moscow. 79pp.

Gabrielson, I. R. 1951. Foreword *in* S. P. Young and H.T. Jackson, The Clever Coyote Wildl. Manage Inst., Washington, D.C.

Gese, E. M., O. J. Rongstad, and W R. Mytton. 1989. Population dynamics of coyotes in southeastern Colorado. J. Wildl. Manage. 53:174-181.

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

_____ 1989 Predator biology and livestock depredation management Proc. Western Section, Am. Soc. Animal Sci 40:504-509.

_____., and L. C. Stoddart 1983. Coyote population mechanics: another look. Pages 93-111 *in* F. L. Bunnell, D. S. Eastman, and J. M. Peek (Eds.), Proc. Natural Regulation of Wildl.Pop.. Forest, Wildlife, and Range Expt. Sta., Univ. of Idaho, Moscow, ID. Proc. No. 14, Sept. 1983.

Nellis, C. H., and L. B. Keith. 1976. Population dynamics of coyotes in central Alberta, 1964-68. J. Wildl. Manage. 40:389-399.

Sterling, B., W. Conley, and M. R. Conley. 1983. Simulations of demographic compensation in coyote populations. J. Wildl. Manage. 47:1177-1181.

Windberg, L. A., and F. F. Knowlton. 1988. Management implications of coyote spacing patterns in south Texas. J. Wildl. Manage. 52:632-640.

COYOTE INTERACTIONS WITH OTHER CARNIVORES

TERRY L. BLANKENSHIP, Biologist, Welder Wildlife Foundation, P.O. Box 1400, Sinton, TX 78387

Abstract: Coyotes (*Canis latrans*) occur sympatrically with several predators throughout their range. Habitat and food resources are similar, although the coyote typically utilizes a wider range of food items. Larger predators generally select larger prey, allowing predators of different sizes to coexist. Coyotes exhibit aggressive actions towards smaller predators, but in most cases they avoid contact with other predator species. Studies indicate that coyotes can exclude or displace foxes (*Vulpes vulpes*, *Urocyon* spp.), and an inverse relationship exists between abundance of coyotes and foxes. There is evidence suggesting that extensive reduction of coyote populations allows other predator populations to increase.

The coyote competes or coexists with several predators throughout its range. In Texas, the mountain lion (*Felis concolor*), bobcat (*Felis rufus*) and both red and grey foxes (*U. cinereoargenteus*) are predators that share resources with the coyote. Raccoons (*Procyon lotor*) and striped skunk (*Mephitis mephitis*) are 2 other small carnivores that are found in similar habitats and utilize the same foods Research has identified the resources utilized by each of these species. However, dietary overlap alone does not imply competition is occurring. Studies of competition for resources, and the effects of such competition, are fewer and inherently more difficult to determine.

Food resources or prey availability is a major factor in determining an animal's use of an area or habitat. Numbers of predators and use of the same habitat and prey items can result in competition for resources. The purpose of this paper is to review current knowledge on (1) resource use by, (2) interspecific relations between/among, and (3) population response to coyote control, in order to determine the impacts of coyotes on the carnivores listed above. Data included here illustrates how little has been done on interspecific relationships of predators in Texas or the Southwest.

Resource use

The coyote, mountain lion, bobcat, gray fox, raccoon, and striped skunk are found throughout the state. The red fox now ranges from the eastern part of the state to central Trans-Pecos region excluding south Texas (Davis and Schmidly 1994). These carnivores use similar habitats and can be found in close proximity to each other. However, each may prefer specific habitat characteristics. Densities of each predator vary depending on area. Mountain lions prefer the dense cover found in the thick brush habitats of South Texas or the broken rough country characterized by rimrocks, boulder piles, cliffs and canyons of the Trans Pecos (McBride 1977). Foxes seem to prefer edges along brush and woodland areas where clearings have been created for pasture or cropland. They also do well around human habitations (Samuel and Nelson 1982) The raccoon prefers habitats with larger trees and are usually found close to water However, they are a common predator in the brush habitats of South Texas and the semi-desert areas of West Texas (Davis and Schmidly 1994).

The prey items utilized by each carnivore are also similar, but the proportions are not similar. Prey items taken are related to size of the predator, habitat type, time of year, and abundance of prey. McBride (1977) analyzed mountain lion stomach contents and scats from the Trans Pecos and reported the major foods were deer (*Odocoileus* spp.), javelina (*Tayassu tajacu*), and porcupine (*Erethizon dorsatum*).

Leopold and Krausman (1986) documented the diets of mountain lions, bobcats, and coyotes in Big Bend National Park during 2 time periods. Their data indicate how 3 predators in the same area prefer certain prey items and how this can change when prey abundance changes (Table 1). A significant decline in the desert mule deer (*Odocoileus hemionus crooki*) population occurred during the second time period Mountain lions increased the use of javelina when the deer population decreased.

Coyote and bobcat diets showed greater

Table 1. Average relative frequency of prey species in mountain lion, bobcat, and coyote scats for 2 time periods (1972-74 and 1980-81) in Big Bend National Park, Texas (after Leopold and Krausman 1986).

	Mt. lion		Bobcat		Coyote	
Prey	72-74	80-81	72-74	80-81	72-74	80-81
Deer	0.75	0.39	0.24	0.03	0.22	0.05
Javelina	0.15	0.38	0.06	0.02	0.10	0.02
Rodents	0.10	0.05	0.31	0.28	0.24	0.26
Rabbits	0.03	0.14	0.51	0 78	0.38	0.56
Birds, reptiles	0.04	0.03	0.14	0.18	0.17	0.22
Porcupine	0 07	0 01	-	-	-	-
Seeds, fruits	0.44	0 49	-	-	-	-

overlap. Rabbits and rodents were the primary items in bobcat diets Deer were of secondary importance for both bobcats and coyotes, however when deer populations declined, bobcats and coyotes increased their use of rabbits. Coyote diets were most diverse and included seeds and fruits during the year. Leopold and Krausman (1986) suggested deer use decreased in the lion's diet because the deer population had declined. They speculated that because mountain lions were not preying as much on deer, less deer carrion was available for coyotes or bobcats.

Beasom and Moore (1977) studied the effects of a change in prey abundance on bobcat prey selection in South Texas. During one year 80% of the diet consisted of cotton rats (*Sigmodon hispidus*), cottontails (*Sylvilagus floridanus*), and white-tailed deer (*O. virginianus*). A total of 21 prey species was found in the diet. The following year there was an increase in cotton rat and cottontail populations. The diet changed to 96% cottonrats and cottontails, and only 6 different species of prey were recorded.

The diet of the fox changes during the year. During winter, foods included 56% small mammals (cottontails, cotton rats, pocket gophers (*Geomys* spp.), pocket mice (*Perognathus* spp.), 23% insects (mostly grasshoppers [Acrididae]), and 21% birds. The late summer and fall diets included 30% persimmons and acorns, 26% insects, 16% small mammals, 14% birds, and 14% crayfish (Davis and Schmidly 1994).

Raccoons are considered to be 1 of the most omnivorous animals; their diet can include fruits, small mammals, birds, insects, carrion, garbage, grains, plant material, and most human foods (Sanderson 1987) Similar to raccoons, 78% of the striped skunk's diet consist of insects during different seasons of the year The remainder of their diet may include small rodents, birds, reptiles, and vegetation (Davis and Schmidly 1994).

Interspecific interactions

Interspecific interactions can result in the death of a competing predator, or merely the exclusion of the subordinate species. Although aggressive interactions occur, most predators avoid contact. To determine if a predator is being excluded by another, studies are conducted on the dietary overlap and habitat use during different weather conditions, seasons, or years.

Mountain lions, bobcats, and coyotes in central Idaho utilized different habitat and topographic characteristics during summer. Mountain lions and bobcats were associated with habitats providing stalking cover, whereas coyotes used open areas more frequently. The bobcat's inability to move through deep snow influenced use of areas in the winter. A greater degree of overlap of habitat and prey occurred during the winter as predators and prey moved to lower elevations

Dietary overlap in winter resulted in mountain lions killing 4 bobcats and 2 coyotes near feeding sites. These attacks involved mountain lions defending or usurping food caches (Koehler and Hornocker 1991) Boyd and O'Gara (1985) reported that mountain lions were a major cause of mortality for bobcats and coyotes. Five of 8 bobcats and 3 of 7 coyote deaths were attributed to mountain lions apparently protecting food caches. Analysis of mountain lion food habits have found trace amounts of coyote, bobcat, and fox present in stomach contents (Robinette et al. 1959, Krausman and Ables 1981).

It has long been believed that coyotes out-compete bobcats, resulting in reduced populations of bobcats. Major and Sherburne (1987), conducting research in Maine, indicated that coyotes and bobcats shared home ranges, habitat use, and diets, but there was no data to support interference competition. Coyote and bobcat diets and habitat use overlapped in Oregon, however there was little competition between the two because prey populations were high (Witmer and deCalesta 1986).

Litvaitis and Harrison (1989) studied bobcat-coyote relationships during a period of coyote expansion in Maine. Seasonal habitat use by coyotes varied more than bobcats, perhaps because of the greater variety of food items in coyote diets. They also indicate that bobcat food habits have changed since the arrival of coyotes to Maine.

Litvaitis and Harrison (1989) found that coyotes did not displace or exclude bobcats. They speculated that coyotes have reduced the carrying capacity of bobcats by reducing prey availability and suggested that bobcat numbers will decline and stabilize at lower densities as a result of increasing coyote densities. They also report one incident of coyotes preying on a bobcat. Under the right circumstances it is not impossible for a coyote or group of coyotes to kill a bobcat.

Coyotes are believed to influence the distribution and abundance of red foxes (Sargeant 1982). Sargeant et. al (1993) reported study areas that had increased coyote track counts had a corresponding decrease in fox track counts. Major and Sherbure (1987) reported simultaneous locations of coyotes, bobcats, and foxes that shared ranges maintained distances between individuals. Avoidance is believed to be the principal motive for this spatial segregation.

In areas where coyotes and red fox occur sympatrically, fox territories are located on the edges or outside of coyote territories. These data supported the conclusion of interference competition between foxes and coyotes (Major and Sherburne 1987). Schmidt (1986) suggested that red foxes are excluded or displaced from areas inhabited by coyotes. The fox seems to do well around human habitations because of the lower number of coyotes (Samuel and Nelson 1982)

Schmidt (1986) cited references indicating that coyotes kill red foxes, although he indicated that coyotes are an insignificant source of mortality. Sargeant and Allen (1989) reported on coyotes' antagonistic behavior towards foxes and identified instances of coyotes killing foxes. However, they also cited radio-telemetry studies that found no mortality of foxes in areas inhabited by coyotes

Population responses from coyote control

Although there have been studies conducted on the overlap of diets and habitat use between/among predators, there have been few studies designed to study the response of predators to removal of coyotes. If competition exists between coyotes and other predators, the reduction of coyotes should reduce competition and allow other predator populations to increase.

Toxicants, such as strychnine and compound 1080, were used in coyote control programs until their uses were banned in 1972. Compound 1080 was used extensively in western states (including Texas) as an effective and selective predacide for coyote management (Nunley 1977). Nunley (1977) and Schmidt (1986) indicated that coyote population trends decreased in western states with the initial use of compound 1080. Nunley (1977, 1978) reviewed United States Fish & Wildlife Service catch records from New Mexico to look at coyote control efforts on non-target species. He indicated that the use of Compound 1080, which increased substantially in 1950, resulted in a decrease in coyote numbers and a subsequent increase in bobcat, badger (*Taxidea taxus*), skunk, and fox numbers. This response was believed to be a result of reduced competition for food and not a reduction in predation by coyotes. Similar trends occurred in other western states, therefore Nunley (1978) deemed it unlikely that the population responses among other predators was caused by natural cycles in prey abundance.

Robinson (1961) and Linhart and Robinson (1972) reported on the densities of bobcat, skunk, badger, raccoon, and fox in areas under sustained coyote control Trapper catch records in New Mexico, Colorado and Wyoming were used as an index to determine fluctuations in densities. Thus high densities of various carnivore species would be reflected by high catch records. They concluded that coyote control was having little effect on carnivore populations. Data from Wyoming showed that fewer coyotes were caught, but an increase in captures of bobcats, badges, raccoons, and red fox were noted.

A year-round intensive coyote control program was conducted in Andrews County, Texas to study the population response of selected mammalian predators (Henke 1992). The relative abundance of bobcats, badgers, and gray fox increased on controlled areas after initiation of coyote removal. No change was detected in skunk populations

Conclusions

Sympatric predators often share habitats and utilize similar foods depending on location, season, and prey availability Decreases in prey abundance can result in increased competition and increase interspecific interactions. Differences in size allow similar predator species to coexist in the same area (Rosenzweig 1966). No studies have identified coyote predation as a cause for limiting or decreasing other predator populations. Studies do indicate that coyotes can and do exclude or displace foxes, and there is an inverse relationship between abundance of coyotes and foxes. No studies show that coyotes exclude bobcats, raccoons, or skunks. There is evidence to indicate that extensive reduction of coyote populations allows other predators to increase. This response is probably related to the increase in food availability.

Literature Cited

Beasom, S.L. and R A. Moore. 1977. Bobcat food habit response to a change in prey abundance Southwest. Nat. 21:451-457.

Boyd, D and B. O'Gara. 1985. Cougar predation on coyotes. The Murrelet 66.17.

Davis, W.B. and D.J. Schmidly. 1994. The mammals of Texas. Texas Parks & Wildlife Dept., Austin. 338pp

Henke, S.E. 1992. Effect of coyote removal on the faunal community ecology of a short-grass prairie Ph D. Thesis, Texas Tech Univ., Lubbock.

Koehler, G.M. and M G. Hornocker. 1991 Seasonal resource use among mountain lions, bobcats, and coyotes. J. Mamm. 72:391-396.

Krausman, P.R and E.D. Ables 1981. Ecology of the Carmen Mountains white-tailed deer. U.S Natl. Park Serv. Sci. Monogr. Ser. 15. 114pp.

Leopold, B D and P R. Krausman. 1986. Diets of 3 predators in Big Bend National Park, Texas. J. Wildl. Manage. 50:290-295

Linhart, S.B and W.B. Robinson. 1972. Some relative carnivore densities in areas under sustained coyote control. J. Mamm. 53:880-883.

Litvaitis, J.A. and D.J. Harrison 1989. Bobcat-coyote niche relationships during a period of coyote population increase. Can. J. Zool. 67.1180-1188.

Major, J.T. and J.A. Sherburne. 1987. Interspecific relationships of coyotes, bobcats, and red foxes in western Maine. J. Wildl. Manage. 51:606-616.

McBride, R.T. 1977. The status of the mountain lion (*Felis concolor stanleyana*) of the Texas-Mexico border. M S Thesis, Sul Ross State Univ., Alpine, TX. 160pp.

Nunley, G.L. 1977. The effects of coyote control operations on non-target species in New Mexico. Great Plains Wildl. Damage Workshop 3:88-110

______. 1978. Present and historical bobcat population trends in New Mexico and the west. Proc. Vertebr Pest Conf. 8: 177-184.

Robinette, W.L., J.S. Gashwiler, and O.W. Morris. 1959. Food habits of the cougar in Utah and Nevada J Wildl. Manage. 23:253-273.

Robinson, W.B 1961. Population changes of carnivores in some coyote-controlled areas J. Mamm. 42 510-515

Rosenzweig, M L. 1966 Community structure in sympatric carnivora J Mamm 47:602-612.

Sanderson, G.C 1987. Raccoon. Pages 487 - 499 *in* M Novak, J.A. Baker, M.E. Obbard, and B Malloch (Eds.) Wild furbearer management and conservation in North America Ontario Trappers Assoc., Toronto 1150pp..

Samuel, D.E. and B. B. Nelson. 1982. Foxes. Pages 475-490 *in* J.A Chapman and G.A. Feldhamer, (Eds.) Wild Mammals of North America. Johns Hopkins Univ. Press, Baltimore, MD 1147pp.

Sargeant, A. B. 1982. A case history of a dynamic resource-the red fox. Pages 121-137 *in* G.C. Sanderson, (Ed.) Midwest furbearer management. Midwest Fish and Wildl. Conf., Wichita, Kans

_____, and S. H Allen. 1989 Observed interactions between coyotes and red foxes. J. Mamm. 70:631-633.

_____, R.J. Greenwood, M.A. Sovada, and T.L. Shaffer. 1993. Distribution and abundance of predators that affect duck production-prairie pothole region. U.S Fish and Wildl. Serv. Resour. Pub. 194. 96pp.

Schmidt, R.H. 1986. Community-level effects of coyote population reduction. Pages 49-65 *in* J. Cains, Jr. (Ed.) Community toxicity testing. Amer Soc. for Testing and Mat. STP 920.1

Witmer, G.W. and D.S deCalesta. 1986. Resource use by unexploited sympatric bobcats and coyotes in Oregon Can J. Zool. 64:2333-2338.

EFFECTS OF COYOTE CONTROL ON THEIR PREY: A REVIEW

SCOTT E. HENKE, Campus Box 218, Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX 78363.

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 overgrazing 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 ($\leq$ 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.

Literature Cited

Andelt, W.F. 1985 Behavioral ecology of coyotes in south Texas Wildl Monogr 94:1-45.

Arthur, L.M. 1981. Coyote control: the public response. J Range Manage. 34:14-15

Baker, R 1985 The American hunting myth. 1st Ed , Vantage Press, New York, 287pp.

Beasom, S.L 1974. Intensive short-term predator removal as a game management tool. Trans. N. Am Wildl. Nat. Resourc. Conf 39:230-240.

_____, J. Heffelfinger, S. Coughlin, and C.A. DeYoung. White-tailed deer response to harvest and coyote reduction in South Texas. Unpubl. Rep., 79pp

Clark, F.K. 1972. Influence of jackrabbit density on coyote population change. J. Wildl Manage. 36:343-356.

Connolly, G E. 1978. Predator control and coyote populations: a review of simulation models. Pages 327-345 *in* M. Bekoff, (ed.), Coyote biology, behavior, and management. Academic Press, New York.

_____, and M W. Longhurst. 1975. The effects of control on coyote populations: a simulation model. Univ. Calif. Div. Agric Sci Bull 1872 1-37

Cook, R.S., M. White, D O. Trainer, and W.C. Glazener 1971. Mortality of young white-tailed deer fawns in South Texas J Wildl Manage. 35:47-56

Davison, R.P. 1980. The effect of exploitation on some parameters of coyote populations. Ph D. Thesis, Utah State Univ., Logan. 139pp.

Defenders of Wildlife. 1978. Public comment on U.S. Fish and Wildlife Service's mammalian predator damage management for livestock protection in the western United States. Final EIS:443-465.

Garner, G.W., J.A Morrison, and J.C. Lewis. 1978. Mortality of white-tailed deer fawns in the Wichita Mountains, Oklahoma. Proc. Southeast. Assoc. Game and Fish Comm. 30:493-506.

Guthery, F.S. 1977. Efficacy and ecological effects of predator control in South Texas. Ph.D. Thesis, Texas A&M University, College Station. 50pp.

_____, and S.L. Beasom 1977. Responses of game and nongame wildlife to predator control in South Texas J. Range Manage. 30:404-409.

Hamlin, K.L., and LL Schweitzer. 1979. Cooperation by coyote pairs attacking mule deer fawns. J. Mammal. 60.849-850.

_____, S.J. Riley, D. Pyrah, A.R. Dodd, and R.J. Mackie. 1984. Relationships among mule deer fawn mortality, coyotes, and alternate prey species during summer. J. Wildl. Manage. 48:489-499

Henke, S.E. 1992 Effect of coyote removal on the faunal community ecology of a short-grass prairie. Ph.D. Thesis., Texas Tech Univ., Lubbock 229pp

Humane Society of America. 1978 Public comment on U.S. Fish and Wildlife Service's mammalian predator damage management for livestock protection in western United States. Final EIS:404-407.

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

_____, and L.C. Stoddart. 1992. Some observations from two coyote-prey studies. Pages 101-121 *in* Ecology and management of the eastern coyote, A.H. Boer, ed., Wildl. Res. Unit, New Brunswick

Knudson, J.J. 1976. Demographic analysis of a Utah-Idaho coyote population. M.S. Thesis, Utah State Univ , Logan, UT. 210pp.

Neff, D.J., R.H Smith, and N.G. Woolsey. 1985. Pronghorn antelope mortality study. Arizona Game and Fish Dept. Proj. No. W-78-R. 22pp.

O'Gara, B.W. 1982. Let's tell the truth about predation. Trans. N. Am. Wildl. and Nat. Res. Conf. 47:476-484.

Scrivner, J.H., D.A. Wade, G.E. Connolly, and L.C. Howard. 1985. Cost and other effects of predation on an angora goat ranch. Rangelands 7:54-57.

Sierra Club. 1978 Public comment on U.S. Fish and Wildlife Service's mammalian predator damage management for livestock protection in the western United States. Final EIS.408-411.

Stoddart, L.C. 1987. Relative abundance of coyotes, jackrabbits and rodents in Curlew Valley, Utah. Final Report, Proj. DF-931.07, Denver Wildl Res. Center, Denver, CO. 14pp.

Teer, J.G., D.L. Drawe, T L. Blankenship, W.F. Andelt, R.S. Cook, J.G. Kie, F.F. Knowlton, and M. White 1991 Deer and coyotes: the Welder experiments. Trans. N. Am. Wildl. Nat. Res. Conf. 56:550-560.

Truett, J.C. 1979. Observations of coyote predation on mule deer fawns in Arizona. J. Wildl. Manage. 43.956-958.

United States Fish and Wildlife Service. 1978. Predator damage in the west: a study of coyote management alternatives. U.S.D.I., Washington, DC 168pp.

Wagner, F.H., and L.C. Stoddart. 1972. Influence of coyote predation on black-tailed jackrabbit populations in Utah. J. Wildl Manage. 36:329-342.

THE COYOTE'S ROLE IN A RABIES EPIZOOTIC

KEITH A. CLARK, Texas Department of Health, Zoonosis Control Division, 1100 W. 49th Street, Austin, TX 78756

PAMELA J. WILSON, Texas Department of Health, Zoonosis Control Division, 1100 W. 49th Street, Austin, TX 78756

Abstract: In 1994, the canine rabies epizootic in South Texas was declared a state health emergency; a statewide rabies quarantine was enacted in 1995. Prior to 1988, rabid coyotes (*Canis latrans*) were reported only infrequently in Texas. In 1988, Starr and Hidalgo Counties, located in extreme South Texas, experienced an epizootic of canine rabies resulting in 11 laboratory-confirmed cases of canine rabies in domestic dogs and 6 cases in coyotes. By 1991, the epizootic had expanded approximately 100 miles north of the US-Mexico border and included 10 counties. During the next 3 ½ years, 10 additional counties became involved in the epizootic as it continued to move northward. There have been 644 cases of canine rabies documented in this 20-county area from 1988-95. Antigenic and genetic analysis revealed the ecotype primarily affecting domestic dogs and coyotes in South Texas to be urban Mexican dog (UMD). The epizootic is approaching large metropolitan areas. An increase in vaccination levels of domestic animals would help provide a barrier between rabid wild animals and humans.

Rabies, a fatal viral disease that is transmitted from animals to humans, has become a serious problem in Texas. A canine rabies epizootic (i.e., an epidemic in animals) began in 1988 in South Texas and has continued through June 1995. In July 1994, the ongoing rabies epizootic was declared a state health emergency Subsequently, in January 1995, a statewide rabies quarantine was enacted

Between 1961 and 1988, only 25 rabid coyotes (*Canis latrans*) were reported in Texas. In 1988, however, a viral ecotype that had been confined to urban dogs became established in the coyote population along the US-Mexico border. This canine strain of rabies is readily transmitted from coyotes to domestic dogs and, subsequently, between domestic dogs (Clark et al. 1994). The transmission capability of the virus is pertinent from a public health standpoint because a rabies outbreak involving domestic animals greatly increases the chances for human exposure, as opposed to an outbreak that is maintained strictly in a wild animal population.

The first case was recorded in Starr County, located in extreme South Texas. Adjacent Hidalgo County became involved by the end of 1988, and these were the only 2 active counties through 1990. In 1991, the epizootic expanded to include 8 additional counties, followed by 4 more counties between 1992 and 1993 and an increase of 4 new counties in 1994. The northward advance of the epizootic was now approximately 160 miles north of the US-Mexico border. During the first 6 months of 1995, 2 other counties were included in the epizootic. By mid-1995, the northeasterly movement of the epizootic had expanded to include 644 laboratory-confirmed cases of canine rabies in 20 contiguous counties

Methods

Case report form Each case of animal rabies was investigated by Texas Department of Health (TDH) Zoonosis Control Division (ZCD) personnel. A standardized form, the Zoonotic Incident Case Report (ZIR), was used statewide The form included date, location and description of the incident that caused rabies to be suspected and the animal's medical history (if known), vaccination status, and any human or domestic animal contacts. The policy of the TDH is to test only animals that have potentially exposed a human or a domestic animal. Active surveillance is not conducted routinely because an adequate sampling is provided under this policy.

Laboratory procedures. Brain tissue specimens were tested for rabies antigen by immunofluorescence microscopy at the TDH Laboratory in Austin. Positive specimens were further tested with a panel of monoclonal antibody (MAB), each directed against a specific antigenic site on the rabies virus nucleocapsid and were evaluated by immunofluorescence microscopy (Smith et al. 1986) Differences in nucleotide sequences were examined by polymerase chain reaction (PCR) techniques (Smith et al. 1984, Smith et al. 1991).

Monoclonal antibody and PCR procedures identified 3 ecotypes common in terrestrial animals in Texas, which were designated as Texas skunk, Texas fox (TF), and urban Mexican dog (UMD). Although the Texas skunk ecotype was distinguished using only MAB techniques, the TF and UMD ecotypes could not be differentiated by MAB. Polymerase chain reaction techniques were required on specimens that were classified, according to MAB results, as Texas fox/Mexican dog (TFMD) to determine if they were the TF or UMD ecotype. The TF ecotype was found in southwest Texas in gray foxes (*Urocyon cinereoargentus*) and animals infected by contact with gray foxes, and the UMD ecotype was found along the US-Mexico border in dogs, coyotes, and animals infected by dogs and coyotes (Clark et al. 1994).

Results and Discussion

The index case for the canine rabies epizootic in South Texas occurred on 3 September 1988 in Starr County, which is located on the US-Mexico border A coyote that had fought with 2 vaccinated dogs was submitted for rabies testing and determined rabid by immunofluorescence microscopy. This was the first rabid terrestrial animal reported in the area in 18 years. Four weeks later, another rabid coyote was detected approximately 10 miles north of the index case. It was tested after it attacked 3 unvaccinated dogs.

Two months after the index case, a rabid coyote was reported near Rio Grande City, which is located on the US-Mexico border in south-central Starr County. This coyote also fought with 3 unvaccinated dogs prior to being tested. Three weeks later, the first rabid dogs in Starr County were recorded, both from the Rio Grande City area. By the end of 1988, there were 6 rabid coyotes and 2 rabid dogs reported from Starr County. Hidalgo County, adjacent to Starr County, became involved in the epizootic on 15 November 1988 when a 9-week-old dog was confirmed positive for rabies. This incident occurred 35 miles southeast of the index case and involved a dog that had been mauled 12 days earlier by a wild animal that was suspected to be a coyote. From mid-November through December 1988, there were 9 rabid dogs recorded in Hidalgo County.

During the first 6 months of 1989, only 1 rabid coyote was reported from Starr County. However, from July through December, 15 rabid dogs (all from the Rio Grande City area), 4 rabid coyotes, and 1 rabid raccoon (*Procyon lotor*) were detected in this county. Hidalgo County continued to have recorded cases of rabid dogs; 19 dogs, 1 coyote, 1 domestic cat, and 1 raccoon were confirmed rabid during 1989 In 1990, the localized Rio Grande City epizootic continued and involved 15 dogs, 3 cats, and 3 coyotes. Two of the dogs had a known attack by a coyote within a month prior to developing clinical signs. In Roma, 15 miles upriver from Rio Grande City, 16 rabid dogs were reported. After state health department officials and local health professionals initiated aggressive rabies control measures, Hidalgo County had no reported rabies cases during 1990.

In 1991, the canine rabies epizootic expanded approximately 100 miles north of the US-Mexico border to include the following 10 counties: Brooks, Duval, Hidalgo, Jim Hogg, Jim Wells, Kenedy, Kleberg, Nueces, Starr, and Zapata. By the end of 1991, there were 25 dogs, 42 coyotes, and a raccoon, cat, skunk (*Mephitis mephitis*), and cow confirmed rabid A human death attributable to canine rabies also occurred in 1991. The patient, a 55-year-old Starr County woman, had no history of exposure, but laboratory tests determined that she was infected with the canine strain of rabies virus.

Webb and Willacy counties became active in 1992, there were 41 rabid dogs, 70 rabid coyotes, and a rabid bobcat (*Felis rufus*), cat, cow, goat, horse, and raccoon reported from the 12-county area. Cameron County, located in the southernmost tip of Texas, was included in the epizootic in May 1993 when a raccoon with the canine strain of rabies was reported. La Salle County became the northernmost extension of the epizootic in November 1993. During 1993, positive rabies cases in the 14 South Texas counties included 42 dogs, 69 coyotes, 7 cats, 4 raccoons, 1 cow and 1 bobcat.

The northward movement continued in 1994 with the addition of Live Oak and McMullen counties in March and Frio and Dimmit Counties in September, extending the epizootic approximately 170 miles north of the US-Mexico border. Confirmed rabies cases for 1994 included 32 dogs, 74 coyotes, 7 raccoons, 4 cows, 2 horses, 2 cats, and 1 bobcat. Another human death attributable to canine rabies occurred in South Texas in 1994. The 14-year-old Hidalgo County boy had no history of exposure, but the rabies virus was confirmed to be the UMD strain (Kelley et al.1995). This second case of human rabies with the Texas canine strain of rabies virus emphasizes the fact that, because it involves the domestic dog population, the canine rabies epizootic is particularly dangerous to humans due to increased exposure rates.

During the first 6 months of 1995, Zavala and Atascosa Counties were included in the leading northern front of the epizootic. Canine rabies cases from January through June 1995 included 29 dogs, 57 coyotes, 10 raccoons, 8 cows, 6 cats, 2 bobcats, and 1 horse From 1988 through June 1995, the epizootic encompassed 20 South Texas counties and 644 laboratory-confirmed cases of canine rabies consisting of 245 dogs, 327 coyotes, 25 raccoons, 21 cats, 15 cows, 5 bobcats, 4 horses, 1 goat, and 1 skunk (Fig. 1)

From 1989 through 1990, the number of rabid dogs reported in South Texas was greater than the number of rabid coyotes. In 1991, more rabid coyotes than rabid dogs were recorded per year; this trend has remained consistent through mid-1995. The shift in predominant rabid species may be attributed to increased vaccination levels in dogs initiated by increased public awareness and low-cost vaccination clinics In Starr County, clinics have been sponsored by the Texas Department of Health, the U.S. Army, Rhone Merieux, Inc., the Texas National Guard, and a local veterinary practitioner. Consequently, vaccination levels in Starr County dogs that were exposed to a known rabid animal increased from 18% in 1988 to 50% in 1994.

Management Implications

The northernmost identified case of canine rabies was within 25 miles south of San Antonio. Based on the average spread rate of the epizootic since 1988, it will reach this large metropolitan area by the end of 1995 if it is not controlled As in many major cities in the United States, San Antonio has an urban coyote population, which combined with an estimated 75% unvaccinated dog population in the area, forms an explosive combination for the canine rabies epizootic.

To prevent the translocation of animals that play a critical role in the epidemiology of the canine rabies epizootic (and the gray fox rabies epizootic in west-central Texas) to unaffected portions of Texas or to other states/countries, a statewide rabies quarantine was enacted in January 1995 (Rules of the Board of Health, Rabies Control Act). The quarantine prevents movement within or out of Texas of any dogs, cats, or wolf-dog hybrids 3 months of age or older for which a current, official rabies vaccination certificate cannot be produced, plus any coyotes, indigenous foxes, or raccoons.

In addition, the Rabies Control Act was amended in May 1995 to prohibit the transportation or sale (or possession for purposes of transportation or sale) of any dogs or cats 3 months of age or older for which a current, official rabies vaccination certificate or tag cannot be produced, plus any animals that are defined in the Rules of the Board of Health as high risk for transmitting rabies (coyotes, foxes, raccoons, skunks, and bats).

An increased vaccination level in pets and livestock is very important for rabies prevention. Historically, human rabies cases declined when canine rabies cases decreased because of increased vaccination rates, even though rabies cases in wild animals were elevated during the same time period. In the early 1950s, the number of U.S rabies cases in dogs and humans peaked. In the mid-1950s, dog and human rabies cases declined with the advent of highly effective rabies vaccine for dogs and maintained this lower level through the early 1990s However, U S. rabies cases in wild animals peaked in the early 1960s, the late 1970s and early 1980s, and again in the early 1990s.

People do not commonly encounter rabid wild animals; but rabid pets and livestock can bring the disease into the home or ranch area. Rabid domestic animals are 5 (Clark 1988) to 10 (J.C. Mahlow, TDH, pers commun.) times more likely to come into contact with a human than are rabid wildlife. Vaccinated domestic animals can break the rabies transmission cycle by creating a buffer zone between rabid wild animals and humans. It is also beneficial to decrease the number of stray animals and increase knowledge of bite avoidance techniques. To ensure these actions, rabies education for government employees, animal control officers, and the general public is essential.

Acknowledgment: We thank S.U. Neill of the Texas Department of Health and J.S. Smith of the Centers for Disease Control and Prevention for laboratory assistance. Our thanks also go to G.M Moore, G.E. Pye, V.M. Kamble, B.N. Hicks, V W Whadford, K.M. Woods, E.C. Newman, C. Tull, M.G. Fearneyhough, and R.E Rohde of the Texas Department of Health for technical assistance.

Literature Cited

Clark, K. A. 1988. Rabies. J. Am. Vet. Med. Assn. 192:1404-1406.

_____, S U. Neill, J. S Smith, P. J. Wilson, V. W. Whadford, and G W McKirahan 1994. Epizootic canine rabies transmitted by coyotes in south Texas J Am Vet. Med. Assn.. 204:536-540.

Kelley, M., L Robinson, R. Chapman, D. Simpson. 1995. Human rabies - Texas Morbidity Mortality Weekly Rept. 44:269-272.

Smith, J. S., J W. Sumner, L. F. Roumillat, G. M. Baer, and W. G. Winkler 1984. Antigenic characteristics of isolates associated with a new epizootic of raccoon rabies in the United States. J Infect Dis. 149:769-774.

_____, F. L Reid-Sanden, L. F. Roumillat, C. Trimarchi, K. A. Clark, G. M. Baer, and W. G. Winkler. 1986. Demonstration of antigenic variation among rabies virus isolates by using monoclonal antibodies to nucleocapsid proteins. J. Clin. Microbiol. 24:573-580.

_____, D. B. Fishbein, C. E Rupprecht, and K. A. Clark. 1991. Unexpected rabies in three immigrants in the United States. N. Engl. J. Med. 324 205-211.

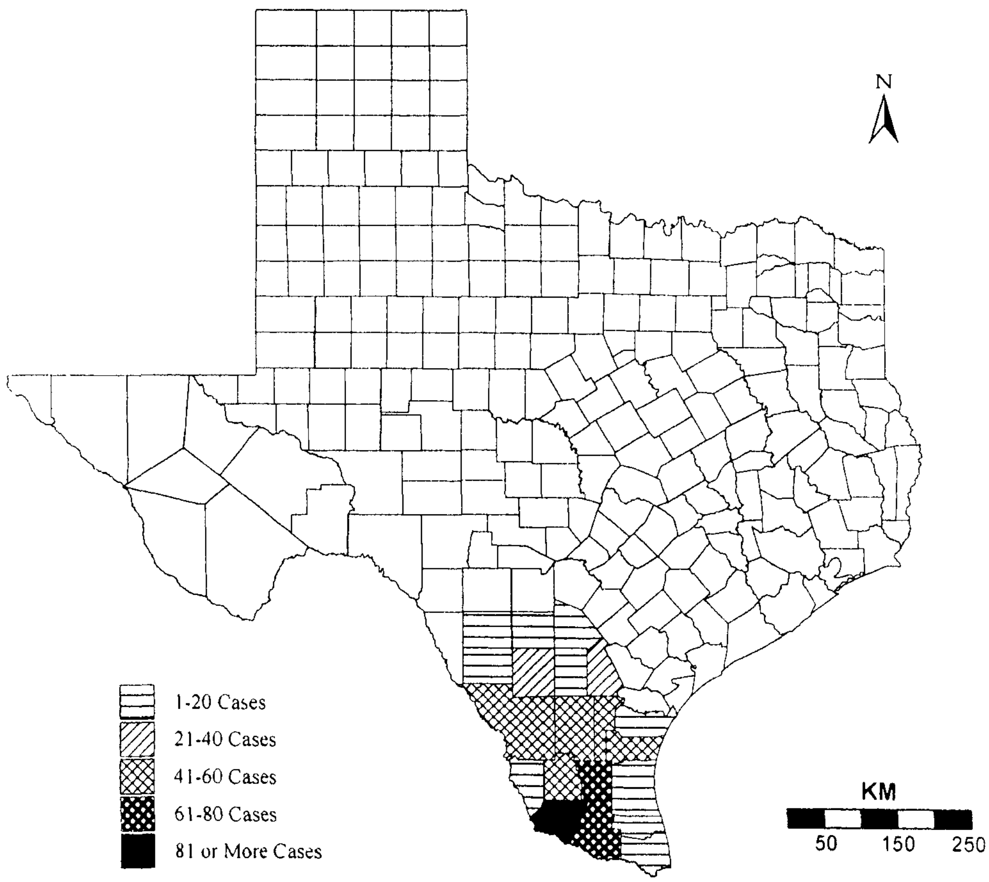


Figure 1. Rabies cases in south Texas during a rabies epizootic, 1988-95.

COYOTES: A MATTER OF PERSPECTIVE

DALE ROLLINS, Associate Professor and Extension Wildlife Specialist, Texas Agricultural Extension Service, 7887 N. Hwy. 87, San Angelo, TX 76901

Abstract: Predators and predator management in general are always controversial topics. As with most controversies, both ends of an emotional continuum vy for the attention of the nonvocal, uncomitted majority. To provide unbiased information on the controversy surrounding coyotes (*Canis latrans*) in Texas, the Texas Agricultural Extension Service produced a 23-minute video in 1991. The video addresses both "sides" of the coyote "coin" while providing factual biological information on the topic. The video has been quite popular, and has received both state and national awards.

The relative and absolute merits of coyotes and coyote management will be cussed and discussed during this conference. As with most emotional debates, neither end of the emotional continuum is likely to change its position(s) significantly. However, both sides plead their case to the 80 percent of so of Americans who comprise the non-aligned, nonvocal majority. Their voting power will ultimately decide the direction of coyote (i.e., predator) management.

Educating this segment of society (i.e., largely urban, middle-aged and youth audiences) requires more innovation than the traditional Extension "factsheet." In 1991, the Texas Agricultural Extension Service (TAEX) produced the video "*A Matter of Perspective*" as an attempt to educate both urban and rural audiences on the issues surrounding coyotes and their management in Texas.

Video production

From the outset, I decided that the message of the video should be unbiased and be based on biological information, not simply rhetoric. However, when addressing such emotional topics, one cannot, and probably should not, divorce emotion from the message entirely. Thus, my goal was for the completed video to have a foundation of science, but adequately embrace the emotion of both "ends" of the argument.

Scripting for this video was a difficult task. I had my own personal biases to put aside Further, being stationed in San Angelo, the "sheep and goat capital" of Texas, and working with a predominantly agricultural clientele (i.e., sheep and goat ranchers), my writing position was tenuous at times. I hoped to incorporate not only the statistics of each argument (e.g., financial losses to coyotes), but to also provide the non-aligned viewer with the perspectives involved at each end of the continuum.

"*Where you stand on an issue usually depends upon where you sit.*" -- *Anonymous*

I knew that one side (the ranchers) would insist that I show video of a coyote attacking a lamb and similar greusome scenes to drive home their premise that coyotes are bloodthirsty, insatiable killers. Similarly, I knew the other side ("environmentalists") would argue that a coyote in a steel leghold trap should be seen, jerking violently while chewing at its restrained paw to demonstrate the perceived inhumaneness of some control practices. However, I chose to exclude such inflammatory scenes that would do more to incite than educate the viewing audience If I could keep both "sides" equally upset, I figured that I was in just about the right position!

Taping and production

Once the script had been written and reviewed by at least five technical reviewers, it was time to bid the project out for production. Bids for the project ranged from \$9,000 to \$27,500. The successful bid was from Texas Farm Bureau, so I arranged a planning meeting with their video producer Mr. Gary Joiner Initially, I was concerned that the bid from Texas Farm Bureau was too low, and that the production would wind up as a "stuffy" corporate-type production that lacked the emotion that I wanted. However, after meeting with Mr Gary

Joiner, TFB's video specialist, I was convinced that he had the talent and where-with-all to make the video what I had pictured in my mind

We began the project only a limited amount of stock video of coyotes Therefore, we (Joiner, his cameraman Tab Patterson, and me) spent three days in Kent, Dickens, and Shackelford counties calling and videotaping coyotes in August 1991. Despite the hot weather, we were able to get sufficient coyote footage, including some outstanding scenes of a coyote "challenging" me (the caller) at a distance of about 50 feet from the camera. This scene is used at the opening sequence of the video.

Once the field taping was completed, Joiner and Patterson began editing and producing the video. Now it was time to secure the narrator. From the outset, I had Mr. Rex Allen in mind for the narrator. My reasoning was that Rex Allen's voice offered instant recognition and credibility (per his experiences with Walt Disney nature films) to both rurarl and urban audiences. I was able to secure his telephone number and contacted him directly, telling him what the project entailed and its purpose After some negotiations, he agreed to narrate the film, much to my elation

Once completed, the total running time of the video was 23 minutes, about six minutes longer than what we had planned initially. However, Joiner and I agreed that the story didn't really drag anywhere, so we decided to stay with the 23-minute length.

Audience response

Since 1991, the video has been shown to an estimated 40,000 Texans. Additionally, it has been broadcast on at least one national and one state cable TV program with potential audiences of over 400,000 viewers. Response to the video has been exceptionally positive, even from those viewers at the far right and left of the coyote controversy. The video was awarded the "Outstanding Marketing Video" from the National Agricultural Marketing Association in 1992, Outstanding Video Feature by the Texas Chapter, The Wildlife Society in 1992, and the Outstanding Communication in Wildlife Damage Management by the Berryman Institute (Utah State University) in 1994.

I have personally shown the video to some 3,000 viewers since 1992, ranging from civic groups to sheep and goat ranchers. It has been especially interesting to gauge the responses from urban viewers, who were the intended target of the video.

Indeed, several analogies were used in the script itself to give an urban perspective on a very rural situatioin (i.e., predation). For example, in one instance a rancher describes his stock losses to coyotes as that of a burglar's victim. While urbanites are insulated from losses to predators, they can relate well to burglary and theft. Similarly, another scene relates the nuisance aspect of coyotes (a rural problem) to urban dwellers by showing dogs digging in garbage cans (an urban problem)

Video as an educational format does pose one problem relative to more traditional "slide talks" in that video projectors are uncommon, sometimes unwieldy, and expensive. A traditional TV (eg , 21 inch screen) and VCR can be used for small audiences (e.g., < 40 people), but a projector is needed for audiences > 100 viewers Likewise, a good audio system is necessary to adequately address larger groups. However, given these caveats, a well thought out and visually appealing video can serve as a very effective instructional tool.

Conclusion

I believe that "*A Matter of Perspective*" has achieved its objective of providing unbiased information on an emotional, controversial topic of which there seems to be no shortage in the wildlife management world. Other species/topics that I've considered doing a sequel on include mountain lions, endangered species, and hunting in general Copies of the video are available for $20 per copy from TAEX, 7887 N. Hwy. 87, San Angelo, TX 76901. I welcome any comments or criticisms from those viewing the video.

Acknowledgements. I would like to thank Gary Joiner and Tab Patterson, Texas Farm Bureau, for their intrepid spirit and creativity during the field taping Thanks also to Karen Spoo, Angel Fattorini, Johnny Hudman, Bo Whittaker, Robert Kensing, Jeff and Debbie Giles, Steve Byrns, and Bennie Kothmann. Don Steinbach and Jack Payne provided moral support during scripting Funding for the video was provided by Texas A&M University, U.S. Fish and Wildlife Service, Renewable Resource Extension Act, and Texas Farm Bureau.

COYOTES IN THE ROLLING PLAINS OF TEXAS

WYMAN P. MEINZER, JR., P O. Box 195, Benjamin, TX 79505

Abstract: Coyotes (*Canis latrans*) in the Rolling Plains region of Texas have experienced several factors in the last 40 years that may have possibly influenced population dynamics and feeding niche. The 3 most important changes were (a) the demand for coyote pelts during the 1970s, (b) a region-wide growth of the stocker cattle industry and (c) the increasing incidence of sarcoptic mange. The availability of stocker cattle carcasses may be providing a source of dependable food during a previously stessful period, thus inflating coyote survival and abundance superficially relative to traditional cow/calf ranching areas Sarcoptic mange has been present in Rolling Plains coyotes for about 10 years and appears to be depressing the abundance of coyotes in this region.

Over the last 40 years, the Rolling Plains coyote has experienced perhaps some of the most dramatic changes within its environment since the turn of the 20th century. Since the inception of government-funded predator control shortly after the turn of the century until 1965, coyote populations within most counties in the Rolling Plains were harvested heavily by state- and county-funded animal damage control agents. Since 1965, many counties have discontinued concentrated control efforts, specifically the ranches around and in Knox county of which I am most familiar. With the exception of private hunting efforts, and sport shooting from private aircraft, some areas of the Rolling Plains experienced little to no control efforts for the next 10 years

For the first 4 or 5 years after 1965, Knox County experienced a progressive increase in coyote abundance on a 500,000-acre area of rangeland under my observation. In about 1970, the population seemed to level off, with a large percentage of coyotes harvested for study showing an average age of about 4 years.

According to interviews with old timers in the region, during this 5 or so year period, coyote habitat and food sources were consistent with those dating back about the last 40 years.

Increased pelt demand

In 1974 a dramatic change occurred which, for the remainder of the decade, would affect the Rolling Plains coyotes' population dynamics significantly With the value of fur prices escalating throughout the entire state, for the first time in about a decade, the Plains coyote again faced heavy harvest pressure in almost every area in the region.

Age-class data collected from about 1,000 coyotes over a 5-year period suggested a significant drop in the Rolling Plains population density from 1974.

Stocker cattle industry

Also in the mid 1970s, ranching practices in the Rolling Plains began a slow transition away from the historical cow/calf operations. Winter grazing of stocker cattle on wheat pasture became popular and cost effective, thus significantly reducing a ranching practice (i.e , cow/calf enterprises) which had been this region's norm since the late-1800s.

The historical cow/calf operations had effectively offered the coyote a consistent environment for many decades throughout the Plains. Although the coyote was rarely a serious threat to livestock on the ranches subject to my observations, it is common knowledge to most students of coyote behavior that coyotes gravitate to cattle herds throughout the year. With many operations reducing their mother cow herds, and resting pastures until the fall stocking period, coyotes seemed to emigrate away from those ranches maintaining the old cow/calf operations and onto the areas developing the new stocker operations.

With the decline of hunting pressure from private fur hunters in about 1980, population levels soon peaked, confirming this possible new trend in coyote dispersal. Although coyotes continued to maintain a visible presence around calving grounds, by late- fall and early-winter, coyote abundance appeared to have increased dramatically on the ranches with stocker cattle. This phenomenon appears to parallel the activity of wolves in the last days of the buffalo slaughters in the late-19th century. With carcasses available at every turn, a superficially high population of wolves would congregate around the main killing grounds.

On stocker cattle ranges, as many as 10,000 head of cattle are placed on relatively small acreages of land. This stock density, coulped with an average death rate of about 2%, yields many tons of beef for coyotes during the inclement winter months. This appears to result in a superficially high concentration of coyotes throughout the winter season on rangeland which would previously have harbored a fraction of the number With almost all ranchers and farmers in the Plains region now involved, to some degree, in the stocker program, it is plausible that the population dynamics of the Plains coyote has been affected greatly during the last 20 years.

This change in the overall environment for the Plains coyote could be responsible for some unexplained phenomena which seem to be occurring presently. During the past decade, a significant increase in white-tailed deer (*Odocoileus virginianus*) numbers has been observed in the Knox County region. My own personal observations seem to verify this as have interviews with game wardens and ranchers from throughout the region. It is conceivable that, with an almost inexhaustible meat supply (steer carcasses) available throughout a stressful time of the season, coyotes in this region may may be altering natural prey selection, e.g., white-tailed deer.

Sarcoptic mange

On the flip side, this "draw station" effect could be one reason why the Plains coyote has suffered so greatly during the past 9 years since the appearance of sarcoptic mange in north Texas. Dr. Dan Pence, Texas Tech University, informed me in the late-1970s that sarcoptic mange was spreading northward out of Mexico. He predicted its appearance in the Plains within a few years. I first observed mange in the Rolling Plains in 1986.

From harvested animals and observing incidental cases, I estimated the mange incidence in 1986 at 25% for coyotes in Knox county. It has increased steadily each year, and as of 1994, my estimate of incidence rate stands at about 80% With very little hunting pressure in the areas of my observations and fewer coyote sightings evident, mange seems to have reduced the overall coyote population in the Rolling Plains by as much as 50%. Congregating coyotes around cattle carcasses on ranches with stocker cattle could be of importance when considering the rapid spread of mange in north Texas.

COYOTES: A SOUTH TEXAS PERSPECTIVE

RICK L. SRAMEK, District Supervisor, USDA-APHIS-ADC, Campus Box 218, Kingsville, TX 78363

Abstract: Coyotes (Canis latrans) are abundant throughout North America, some of the highest densities occur in south Texas Most studies indicate abundance of food as a contributing factor of coyote density. High coyote populations can lead to localized depredation problems and the current canine rabies epizootic is of concern to residents of south Texas

The coyote was 1 of the native inhabitants of Texas when it was first settled by European settlers. It has survived and expanded its range despite control attempts that have surpassed those for any species in North America. For decades, coyotes have been killed by stockmen and ranchers because of their depredation on domestic livestock. Their adaptability is the main reason they flourished. Coyotes are now found in all of the continental United States

Coyote densities

The coyote is probably the most extensively studied carnivor, and considerable research has been conducted on the species' population dynamics. Since estimates were begun in 1965 (Knowlton 1972, Bean 1981), the greatest abundance of coyotes in North America consistently occurs in the southern region of Texas. Most studies of the factors limiting coyote populations have identified food as the predominant constraint (McLean, 1934; Murie, 1940; Robinson, 1956; Gier, 1968; Clark, 1972). Since the abundance of coyotes is related to abundance of winter foods, one would expect coyote densities to increase from north to south as food supplies become more available.

Limited studies of absolute densities for coyotes are available A breeding population of 2 0 coyotes/mi^2 in a 6-county area of Kansas was estimated by Gier (1968). Clark (1972) estimated post-whelping season densities in Curley Valley, Utah, at 1 coyote per 2-4 mi^2 Andelt (1985) estimated that pre-whelping coyote densities on the Welder Wildlife Refuge in southern Texas were 2.1-2.3/mi^2.

Studies conducted by Knowlton (1972) suggest coyote densities in certain areas of south Texas may average 4-6/mi^2, with 0.5-1 0/mi^2 seemingly realistic over a large portion of their range. High coyote densities in the region are associated with a broad food base as evidenced by dietary studies. Coyotes in south Texas feed on a variety of native fruit and insects during the lengthy warm season, then shift their diets to mammalian prey during the winter months.

Coyotes are most vulnerable to natural and human-caused mortality during their first year. Most studies show a correlation between coyote mortality and human exploitation. In south Texas, human exploitation of coyotes has been light because control efforts for livestock protection are limited, with no significant sport hunting or trapping Human activity still accounted for 57% of all coyote mortality (Windberg et al. 1985) Shooting, trapping, and road fatalities were the most common cause of mortality A much smaller percentage apparently succumb to other causes such as disease and malnutrition

Coyote diets

Diet-wise, the coyote is an extremely versatile scavenger and predator (Murie 1939, Sperry 1941, Gier 1975). Unlike the wolf, which is a predator almost exclusively of ungulates (Mech, 1970; Pimlott, 1975), the opportunistic character of coyote feeding is likely most responsible for its great success in the face of habitat manipulation and destruction by man (Hilton 1978).

The abundance and availability of food affect both coyote density and reproduction. Fluctuations in coyote abundance have been related to abundance of rodents (Knowlton 1972), carrion (Todd and Keith 1983, Todd 1985), and black-tailed jack-rabbits (*Lepus californicus*) (Clark 1972, Gross et al 1974, Knudsen 1976, Stoddart 1977) and to social intolerance mediated by food supplies (Knowlton 1983).

In southern Texas, the coyote food base is broad and abundant, and coyotes attain high densities (Andelt 1985, Bean 1981, Knowlton 1972, Knowlton et al. 1986). Based on dietary studies in the region, coyotes ate primarily mammalian prey in winter, and fed mainly on a variety of fruit, insects, and white-tailed deer (*Odocoileus virginianus*) fawns as available during the warm season (Andelt 1985, Andelt et al. 1987, Brown 1977, Knowlton 1964). Coyotes are known for their particular fondness of watermelons and cantaloupes and will readily seek them as a food source.

Andelt (1985) found that mammals composed 87% of the winter and 28% of the summer diet on the Welder Wildlife Refuge in south Texas. Fruits, including persimmon (*Diospyros texana*), agarito (*Mahonia trifoliata*), dewberry (*Rubus trivialis*) and pricklypear cactus (*Opuntia lindheimeri*) composed 65% of the summer diet, but only 1% of the winter diet. White-tailed deer composed a large percentage of the diet in June, coinciding with births of fawns. Lagomorphs, rodents (cotton rats, pocket gophers, harvest mice, and woodrats), and cattle appeared in coyote diets primarily during the winter. Insects, mostly grasshoppers, occurred in the diet primarily in late summer.

In summary, coyotes consume a variety of foods year-round but emphasize small mammals, fawns, plants and assorted birds and invertebrates during summer. Winter diet emphasizes larger items such as deer (either prey or carrion), livestock carrion, or locally abundant lagomorph species (Voigt 1987, Berg, 1987)

Damage caused by coyotes

Coyote depredation to livestock and poultry has been reported from all counties of south Texas. Numerous exotic game ranches have requested assistance from the Texas Animal Damage Control Service after axis deer (*Axis axis*) , blackbuck antelope (*Antelopa cervicapra*) and other exotic animals were reportedly killed by coyotes. Severity of individual losses range from light to extremely high levels. Sheep and goat ranches located in Jim Wells, Live Oak, and Bee counties have also experienced losses contributed to coyotes.

Studies reveal that fawns compose a large percentage of the coyote's summer diet. South Texas is known for its substantial trophy white-tailed deer population and subsequently, the high dollar figure demanded for prime deer hunting leases. One component of the ADC program is the protection of this species. The overall impact of coyotes on deer populations is unknown; however, fawn survival increased after coyote control programs were implemented in south Texas (Beasom 1974).

A common concern to individual producers in Jim Wells, Duval, Brooks, Starr, Hidalgo, and Cameron counties is coyote damage to watermelon and cantaloupe crops. During early-spring and fall plantings, coyotes and other carnivores are attracted to ripe watermelons as a food source and can cause considerable damage. In some areas, coyotes and other species disrupt irrigation by chewing holes in plastic pipe

A unique project to south Texas is the removal of coyotes and other predators from the spoil islands of the Padre Island National Seashore where colonial water birds traditionally nest At the request of the Texas Parks and Wildlife Department, this project is carried out to improve survival rates of ground nesting birds and their young. In the past, TADCS personnel have initiated control efforts on 10 separate islands where coyote sign had been found A spokesman for the Padre Island National Seashore states that as a result of these control efforts, 1993 was the first time in the last several years that birds had nested on 2 particular islands which in the past were scarce of birds.

Rabies in South Texas

It would be difficult to mention coyotes without discussing the current rabies outbreak in south Texas involving the canine strain of rabies virus Canine rabies is a strain of rabies virus that has become established in coyotes and is readily transmitted from coyotes to domestic dogs and, subsequently, between domestic dogs Because it often infects domestic dogs, this rabies strain poses a greater risk for human exposure.

Since September 1988, 20 counties in South Texas have become involved in the canine rabies epizootic: Atascosa, Brooks, Cameron, Dimmit, Duval, Frio, Hidalgo, Jim Hogg, Jim Wells, Kenedy, Kleberg, La Salle, Live Oak, McMullen, Nueces, Starr, Webb, Willacy, Zapata, and Zavala A total of 638 animal rabies cases and 2 human rabies cases associated with the canine strain of rabies occurred during that time period. The animal rabies cases included: 322 coyotes, 244 dogs, 25 raccoons (*Procyon lotor*), 21 cats, 15 cattle, 5 bobcats (*Lynx rufus*), 4 horses, 1 skunk (*Mephitis mephitis*), and 1 goat (Table 1). The outbreak has reached epidemic proportions, prompting Governor Ann Richards to declare the rabies outbreak in South Texas a State Health Emergency in July 1994.

In an effort to contain the rabies epidemic, the Texas Department of Health has declared an Area Rabies Quarantine for all of Texas effective January 13, 1995. Under this quarantine no person shall remove from or transport within the quarantine area any dog or cat over the age of 3 months without a current rabies vaccination certificate for the duration of the quarantine. Also included in this list are hybrids (any offspring of 2 animals of different species), skunks, bats (Chiroptera), foxes (*Urocyon* spp., *Vulpes vulpes*), coyotes, or raccoons.

In February 1995, 850,000 dog-food-based baits filled with an oral rabies vaccine were air-dropped over a 15,000 mi^2 area of south Texas in an effort to stop the northern spread of the epizootic. This project was made possible by a cooperative agreement between USDA-APHIS-ADC and the Texas Department of Health. Additional drops are planned for January 1996. The canine rabies virus remains a public health threat.

Literature Cited

Andelt, W.F. 1985. Behavioral ecology of coyotes in South Texas. Wildl. Monogr. 94. 45pp.

_____, W.F., J.G. Kie, F.F. Knowlton, and K. Cardwell. 1987. Variation in coyote diets associated with season and successional changes in vegetation. J. Wildl. Manage. 51:273-277.

Bean, J.R. 1981. Indices of predator abundance in the western United States, 1981. U. S. Fish and Wildl. Serv., Denver Wildl. Res. Center, Denver, Colo. 103pp.

Beasom, S.L. 1974. Relationships between predator removal and white-tailed deer net productivity. J. Wildl. Manage. 38:854-859.

Brown, K.L. 1977. Coyote food habits in relation to a fluctuating prey base in South Texas. M.S. Thesis, Texas A&M Univ., College Station, 58pp.

Clark, F.W. 1972. Influence of jackrabbit density on coyote population change. J. Wildl. Manage. 36:343-356.

Gier, H.T. 1975. Coyote. Pages 247-262 *in* M. W. Fox (Ed.) The wild canids: their systematics, behavioral ecology and evolution. Van Nostrand-Reinhold, New York.

_____. 1968. The coyote in Kansas. Kans. Agric. Exp. Stn. Bull. No.393. (Rev)

Gross, J.E., L.C. Stoddart, and F.H. Wagner. 1974. Demographic analysis of a northern Utah jackrabbit population. Wildl.Monogr. 40. 68pp.

Hilton, H. 1978. Systematics and ecology of the eastern coyote. Pages 209-228 *in* M. Bekoff (Ed.), Coyotes: biology, behavior, and management. Academic Press, New York, N.Y.

Knowlton, F.F. 1964. Aspects of coyote predation in South Texas with special reference to white-tailed deer. Ph.D. Thesis, Purdue Univ., Lafayette, Indiana. 189pp.

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

_____. 1983. Coyote population dynamics: another look. Pages 93-111 *in* F.L. Bunnell, D.S. Eastman, and J.M. Peek (Eds.), Proc. Symp. Natural Regulation of Wildlife Populations. Univ. Idaho For., Wildl., and Range Exp. Stn., Moscow.

_____, L.A. Windberg, and C.E. Wahlgren. 1986. Coyote vulnerability to several management techniques. Proc.Great Plains Wildl. Damage Control Workshop 7:165-176.

Knudsen, J.J. 1976. Demographic analysis of a Utah-Idaho coyote population. M.S. Thesis, Utah State Univ., Logan. 195pp.

McLean, D.D. 1934. Calif. Fish Game 20:30-36.

Mech, L.D. 1970 The wolf: the ecology and behavior of an endangered species. Nat. Hist. Press, Garden City, New York. 384pp.

Murie, A. 1939. Ecology of coyotes in the Yellowstone. Fauna Ser No. 4, U.S. Dep. Agric., Washington, DC. 206pp

_____. 1940. U.S. Natl. Park Serv. Fauna Natl. Parks U.S. Fauna Ser. Bull. No. 4.

Pimlott, D.H. 1975. Pages 280-285 *in* M. W. Fox (Ed.), The wild canids: their systematics, behavioral ecology and evolution. Von Nostrand-Reinhold, New York.

Robinson, W.B. 1956 Am. Cattle Producer 38(4), 8-12.

Sperry, C C. 1941. U S Fish Wildl Serv., Wildl. Res Bull 4, 70pp.

Stoddart, L.C. 1977. Population dynamics, movements and home range of black-tailed jack rabbits (*Lepus californicus*) in Curlew Valley, northern Utah. U.S. Energy Res. Dev Adm., Contract No. E(11-1)-1329, Annu. Prog. Rep. 42pp.

Todd, A.W. 1985 Demographic and dietary comparisons of forest and farmland coyotes, *Canis latrans*, populations in Alberta. Can. Field-Nat. 99:163-171.

_____., and Keith, L.B. 1983. Coyote demography during a snowshoe hare decline in Alberta. J. Wildl. Manage. 47:394-404.

Voight,D R. and Berg, W.E. 1987. Coyote. Pages 345-357 *in* Wild Furbearer Management and Conservation in North America.

Windberg, L.A., H L. Anderson, and R M Engeman 1985 Survival of coyotes in southern Texas. J. Wildl. Manage 49:301-307

Table 1. Species involved in a canine rabies epizootic in south Texas, 1988-1995.

COUNTY	COYOTES	DOGS	OTHER*	TOTAL
Atascosa	4	2	1	7
Brooks	47	14	4	65
Cameron			3	3
Dimmit	2	1		3
Duval	18	21	8	47
Frio	7	3	2	12
Hidalgo	5	60	8	73
Jim Hogg	26	12	5	43
Jim Wells	31	15	11	57
Kenedy	12	1	2	15
Kleberg	24	20	6	50
La Salle	16	5	2	23
Live Oak	22	2	6	30
McMullen	1		2	3
Nueces		7	1	8
Starr	42	68	7	117
Webb	45	5	3	53
Willacy	5	2		7
Zapata	7	12	1	20
Zavala	1	1		2
TOTALS	322	244	72	638

**Others - raccoon, cat, cattle, bobcat, horse, skunk, and goat.*

THE RE-ESTABLISHMENT OF THE COYOTE IN THE EDWARDS PLATEAU OF TEXAS

GARY LEE NUNLEY, U. S. Department of Agriculture, Animal and Plant Health Inspection Service, Texas Animal Damage Control Program, P.O. Box 100410, San Antonio, TX 78201-1710

***Abstract*:** In the early 1900s organized predator control was initiated to remove coyotes (*Canis latrans*) and wolves (*C. lupus* and *C. rufus*) from the sheep and goat producing areas of Texas. Operations were begun in the Edwards Plateau, the largest area of sheep concentration. By the 1920s, many of the inner Edwards Plateau counties were considered to be almost free of coyotes and wolves In the 1950s coyotes and wolves were extirpated from most of the Edwards Plateau After a coyote population irruption in the early 1960s, coyotes began to re-establish themselves on the periphery of the Plateau. This encroachment process has accelerated in the 1990s and thus continues to expose more sheep and goats to predation by coyotes.

In the early 1900s, organized predator control was initiated to remove coyotes and wolves from the sheep and goat producing areas of Texas Operations were begun in the Edwards Plateau, the largest area of sheep concentration. The Edwards Plateau and, to a lesser extent, portions of other adjoining ecological areas presently (1995) account for 19% (1.7 million head) of the sheep and 90% (1.95 million head) of the goats in the United States (USDA 1995) (Fig. 1). The Edwards Plateau itself encompasses about 24 million acres of "Hill Country" in west-central Texas, comprising all or portions of 37 counties (Fig. 2). By the 1920s, many of the interior Edwards Plateau counties were considered to be practically free of coyotes and wolves.

In 1950, there were 33 counties covering nearly 24 million acres which were considered to be coyote free (Fig. 3) This area remained virtually void of coyotes for several decades until their encroachment began in the 1960s. This process has been described by several authors (Caroline 1973, Shelton and Klindt 1974, Hawthorne 1980, Nunley 1985). The purpose of this paper is to review and update the progress of the re-establishment of coyotes into the Edwards Plateau of Texas. This area is historically and currently unique because of its unsurpassed intensive level of coyote control over such an extensive area

Organized predator control

The predecessors of what is now known as the cooperative Texas Animal Damage Control Program have been involved in providing predatory animal control services for the last 80 years. This cooperative wildlife damage management agency is comprised of the Animal Damage Control Program of USDA's Animal and Plant Health Inspection Service, the Texas Animal Damage Control Service of the Texas A&M University System, and the Texas Animal Damage Control Association.

One of the functions of the cooperative program is to conduct direct control operations for the protection of sheep and goats from depredation by coyotes and other predators Historically, the program's primary control strategy has been to attempt to prevent the infiltration of coyotes into the major sheep and goat production areas

Extirpation of coyotes

The coyote and wolf take by county of the organized control program during fiscal year 1950 is reflected in Fig. 4 (Landon 1950) This categorized illustration of the number of animals taken per county provides a relatively representative picture of the re-establishment of coyotes into the Edwards Plateau when examined every tenth year. Those counties within the sheep and goat production areas which indicate no "take", either had no program or had a program and did not take any coyotes. In either case, this usually indicated that few coyotes, if any, were present in those counties at that time.

In the predatory animal control agency's 1958 annual report, the status of coyotes and wolves in the Edwards Plateau in the 1950s was reported as

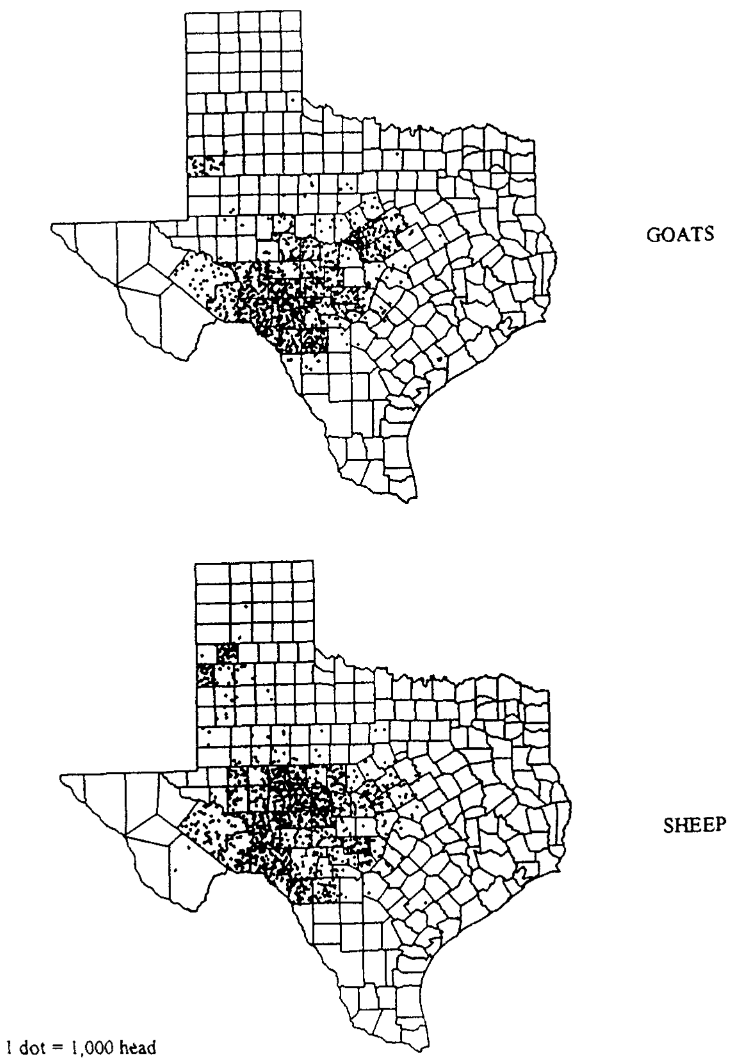


Figure 1. Distribution of sheep and goat numbers in Texas (Texas Crop and Livestock Reporting Service 1994).

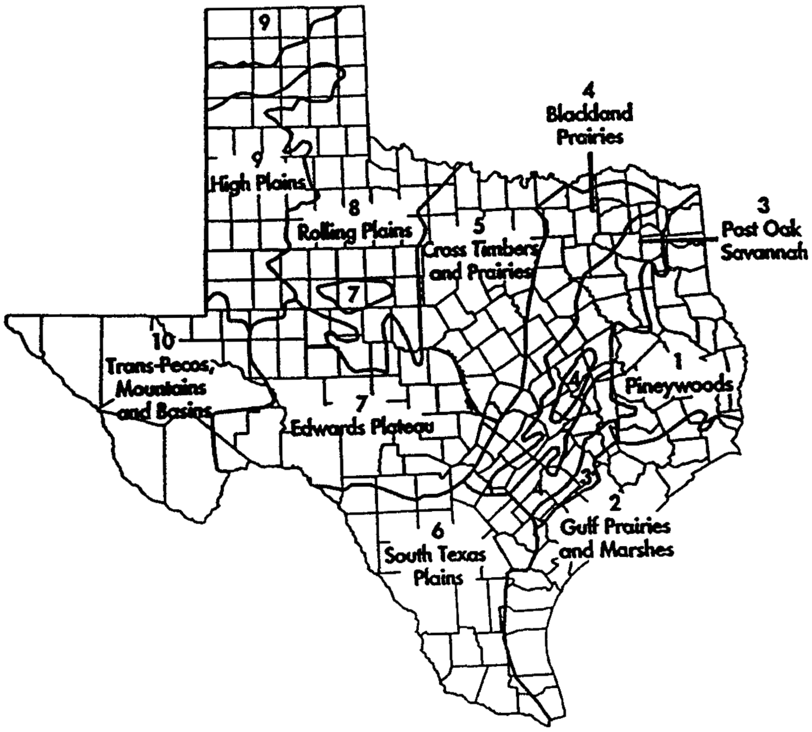


Figure 2 Texas ecological regions (F W. Gould, Texas Plants, 1969 revised).

follows (Landon 1958):

In those counties where the sheep and goat industry is a major importance the coyotes have been practically eradicated, and they were well under control even in the border counties. The gray or lobo wolf is no longer found in Texas. The Texas red wolf of central and east Texas is no longer numerous where the hog, turkey and cattle raisers show much more interest in control than formerly.

Caroline (1973) cited several reasons why this early control work in the Edwards Plateau was successful:

(1) the wild canid population contained a large proportion of red wolves or hybrids which were relatively easy to capture;

(2) many ranchers participated with professional ADC staff;

(3) the increased use of net wire fencing;

(4) many ranchers kept hounds to remove coyotes;

(5) economic incentives to ranchers; and

(6) extensive use of traps

Shelton and Klindt (1974) suggested that the success of early control work resulted from a "massive human effort using all of the tools and techniques which could be brought to bear."

Re-establishment of coyotes

In 1960, 118 coyotes were taken from within the former coyote-free area. Nearly 31,000 coyotes were taken from throughout the coyote's range in Texas during that same year, double the amount taken in 1958. This very conspicuous upswing in coyote take was in response to the drought-breaking rains of the late 1950s. This increase was even more evident when an unprecedented 34,754 coyotes were taken in 1962. The relative intensity and distribution of the coyote and wolf take by the organized control program during FY1960 is reflected in Figure 5 (Caroline 1960). Thus, with the breaking of what was commonly called the "7 year drought" , the re-establishment of the coyote in the Edwards Plateau was underway in the early 1960s

In 1970, 420 coyotes were taken from within the formerly coyote-free area, and the distribution of coyotes within the Edwards Plateau continued to expand (Caroline 1970) (Fig. 6). In 1972, the use of chemical toxicants for predator control such as strychnine and Compound 1080 (sodium mono-fluroacetate) were canceled by EPA. The use of Compound 1080 on the periphery of the major sheep and goat production areas was employed successfully to prevent the infiltration of coyotes into these regions The protection of sheep and goats from predators has since been limited to more labor-intensive control tools, including traps, snares, shooting, calling, aerial hunting and M-44 devices utilizing sodium cyanide.

Caroline (1973) described the status of the coyote within the Edwards Plateau in 1973 as follows.

In 1950, coyotes were a rarity in the heart of the Hill Country. On occasion, a single animal would appear in the western part of the area but it was soon removed. Along the South Pacific tracks west of San Antonio ranchers to the north were interested in control south of the tracks, and for many years this was sufficient. However, when the severe drought of the 1950s came to an end, and after many ranchers cleared off their cedars and established more waterings, coyotes began to move in. Although much land improvement took place, "wolf-proof" fences were allowed to deteriorate. Coyotes could enter any pasture. (This is an important part because removal of the wolves was half due to fencing and half to organized control). For some time there was no one who recognized this fact. Losses were light and what were found were usually attributed to bobcats, foxes, and raccoons By the time it was known that coyotes were present, there were far more of them than anyone expected. Consequently, today and in some cases as late as this year, there are coyotes in every formerly coyote-free county in the heart of sheep and goat country.

The re-establishment of coyotes within the Edwards Plateau had further progressed by 1980 (Fig. 7) (Hawthorne 1980) A total of 637 coyotes was taken from within the former coyote-free area. This continued encroachment of coyotes into the sheep and goat production areas had become a serious concern. In 1981, a request for the emergency use of Compound 1080 bait stations as per Section 18 of FIFRA was prepared and submitted to EPA for consideration (Nunley 1981). The request was eventually denied by EPA after a lengthy administrative hearings process.

Present status of coyotes

In 1990, 2,168 coyotes were taken from within the former coyote-free area and the predators further ingressed into the Edwards Plateau (Nunley 1990) (Fig. 8). In 1994, coyote activity within this area continued to increase as reflected by the take of 2,594 coyotes (Fig. 9). Also, in 1994 the cooperative program worked on 7,552,000 acres from within the former coyote-free area. This was a 64% increase over the acreage worked in 1984. There was a corresponding increase from 1.5 million to 2.2 million sheep and goats protected in 1984 versus 1993.

The primary reason behind this surge in control effort is related to the increasing exposure of additional livestock to coyote predation. This exposure is directly related to the relative degree and geographical distribution of the coyote's movement into the Edwards Plateau. This can be further illustrated by the graduated average coyote take for every 10 square miles worked within each county (Fig. 10).

Factors responsible for coyote re-establishment

The range expansion of coyotes within the Edwards Plateau is directly related to the presence, viability, and geographical distribution of the sheep and goat industry. Gee et al. (1977) surveyed former sheep producers in Colorado, Texas, Utah, and Wyoming who had terminated sheep production. Factors which they rated of greatest importance in their decisions to discontinue sheep production were high predation losses, low lamb and wool prices, shortage of good hired labor, the sale of their land, and their own age. The sheep and goat industry is also now faced with the loss of the wool and mohair incentive program which will eliminate some additional producers.

A major factor for declining sheep and goat production on the eastern periphery of the Edwards Plateau has been the changing land use away from sheep and goat production. This occurs through the sale of properties due to economic pressures, especially near urban centers and recreational areas. It often follows that the new land managers or absentee landowners do not pasture sheep or goats. Further, they often do not engage in, or in many cases even allow, coyote control activities on their properties. Consequently, sheep and goat producers who border, or are surrounded by properties where coyote control is not conducted, bear the brunt of the coyote's tendency to depredate sheep and goats. These producers on the fringe of the sheep and goat production area find that it especially difficult to control losses to predators on their ranges (Nunley 1995).

Predation losses due to the limitations and cost of the application of current predator control techniques have also contributed to the decline in the number of sheep and goats in Texas. The loss of toxicants in 1972 greatly reduced the efficiency and effectiveness of coyote control over large areas.

Prognosis

In their discussion of eradication or control for vertebrate pests, Bomford and O'Brien (1995) provided 6 criteria to determine whether eradication is preferred over continuing control. Since there was no end point to control, the historical events in the Edward Plateau do not meet their specific definition of eradication. However, the criteria are still important when attempting to extirpate coyotes from a given area, thus allowing control efforts to concentrate on the area's periphery to prevent infiltration.

These essential criteria include (1) rate of removal exceeds rate of increase at all population densities, (2) immigration is prevented, (3) all reproductive animals must be at risk, (4) animals must be detected at low densities, (5) discounted benefit-cost analysis favors eradication over control and (6) suitable socio-political environment including access to private property. Bomford and O'Brien (1995) indicate that a negative in any 1 of the first 3 criteria will doom an eradication attempt; a negative in criteria 4-6 will greatly reduce the feasibility and desirability of eradication Considering the difficulties in achieving all of these criteria, it is likely that the re-establishment of coyotes within the Edwards Plateau will continue.

Literature Cited

Bomford M. and P. O'Brien 1995 Eradication or control for vertebrate pests? Wildl Soc. Bull. 23:249-255.

Caroline, M. 1960. Branch of Predator and Rodent Control. Texas District Fiscal Year 1960 Ann. Rept. U.S. Fish Wildl. Serv.50pp. + Appendices.

_____. 1970 Div. of Wildl. Serv. Texas. Fiscal Year 1970 Ann. Rept. U.S. Fish and Wildl. Serv Bur Sport Fisheries and Wildl. 28pp. + Appendices.

_____. 1973 A brief account of wild animal depredation problems in Texas. in Proc. Manage. Practices to Evade Predatory Losses Texas A&M Univ. Res and Ext. Center, San Angelo, Texas, Dec 11,1973. 3 pp.

Gee, K C., R. S. Magleby, D. B Nielsen, and D. M Stevens. 1977. Factors in the decline of the western sheep industry. Nat Res. Econ Div., Econ. Res. Serv., USDA. Agri. Econ. Rept. No 377. 31pp.

Hawthorne, D. W 1980 Annual Report, FY 1980. U.S. Fish and Wildl. Serv., San Antonio, Texas. 42pp. + Appendices

Landon, C. R 1950. Predatory Animal Control Operations Fiscal Year 1950 Ann. Rept. U.S.D.I. Bur. Biol. Surv. 8pp. + Appendices.

_____. Branch of Predator and Rodent Control. Texas District Fiscal Year 1958 Ann Rept. U.S. Fish Wildl. Serv. 28 pp. + Appendices.

Nunley, G L 1981. Memorandum of transmittal and emergency use request for 1080 bait station in Texas. Submitted to the U. S. Fish & Wildl. Serv. Area Mgr., Austin, Texas, June 19, 1981.

_____. 1985. The extirpation and re-establishment of coyotes in the Edwards Plateau of Texas Proc. Great Plains Wildl. Damage Control Workshop 7·9-27.

_____. 1990. Annual Report, FY 1990. Texas Animal Damage Control Program, USDA-APHIS-ADC, San Antonio, TX. 69 pp.

_____. 1995. Sheep and goat losses in relation to coyote damage management in Texas. Pages 114-123 in D. Rollins et al (Eds) Proc. Coyotes in the southwest. a compendium of our knowledge. San Angelo, TX. 180pp

Shelton, M., and J Klindt 1974. Interrelationship of coyote density and certain livestock and game species in Texas. Texas Agric. Expt. Stn. Bull. MP-1148. 12pp.

Texas Crop and Livestock Reporting Service. 1994. 1993 Livestock statistics. 52pp.

U.S. Dept. of Agric. 1995. Sheep and goats Natl. Agric Stat. Serv. 14pp

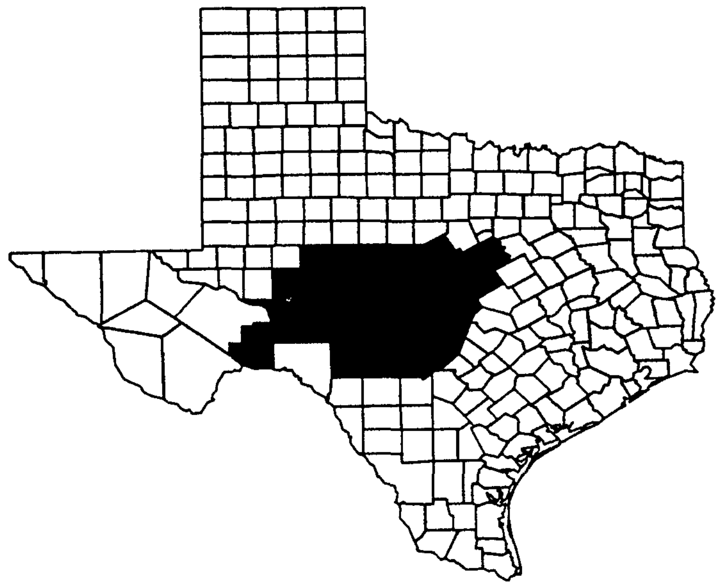


Figure 3. Coyote-free counties in 1950 (about 24 million acres).

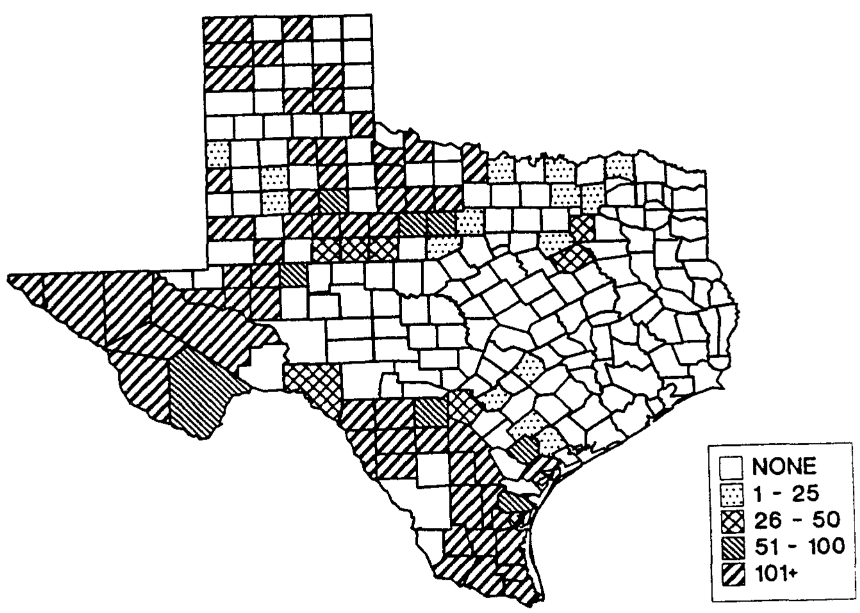


Figure 4 Coyote and wolf take of the cooperative animal damage control program in 1950.

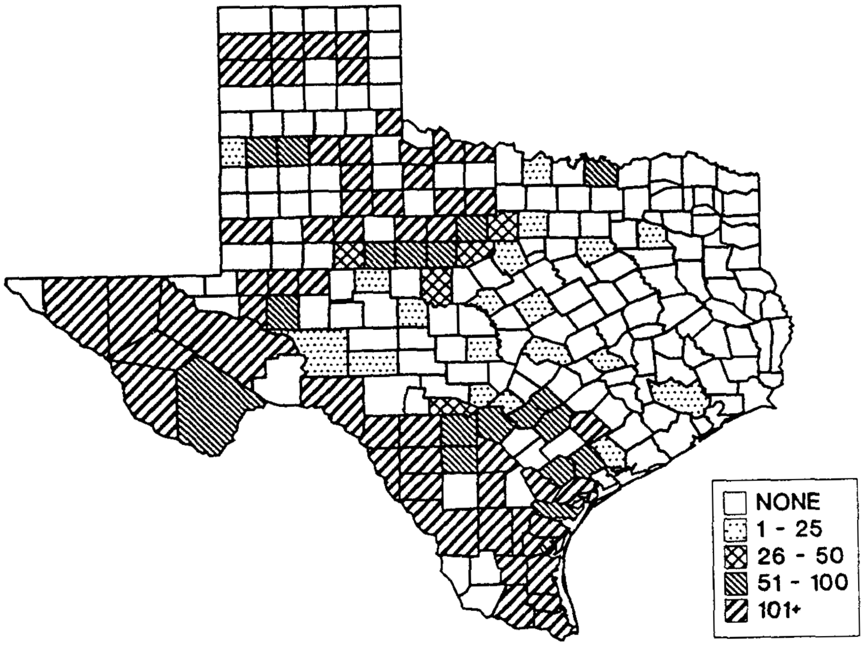


Figure 5 Coyote and wolf take of the cooperative animal damage control program in 1960

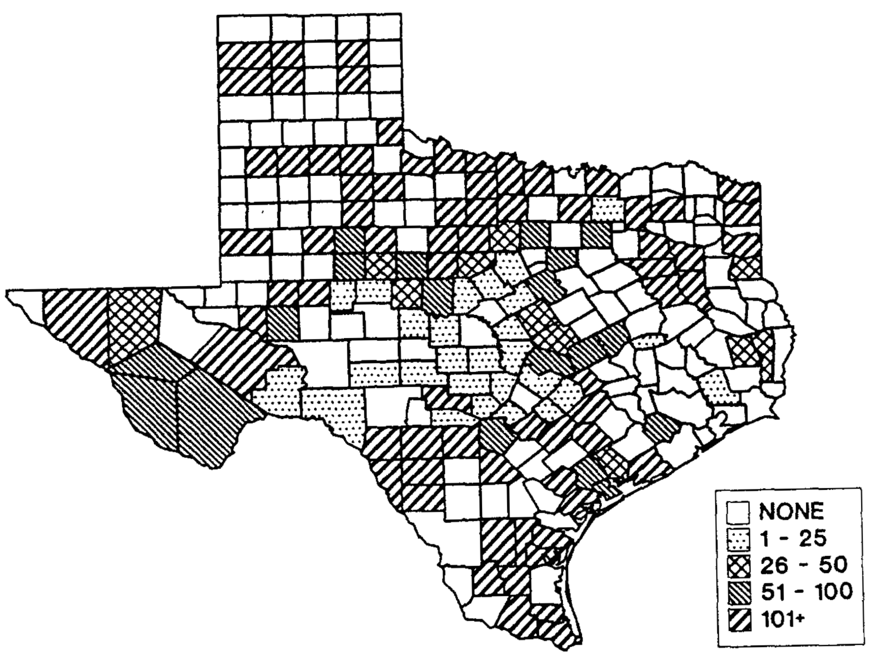


Figure 6. Coyote and wolf take of the cooperative animal damage control program in 1970.

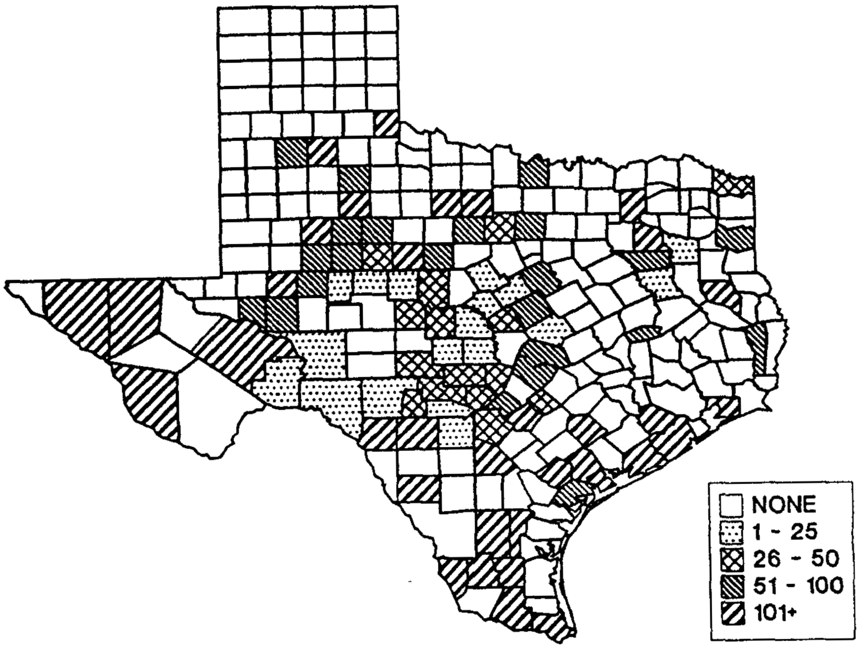


Figure 7. Coyote take of the cooperative animal damage control program in 1980.

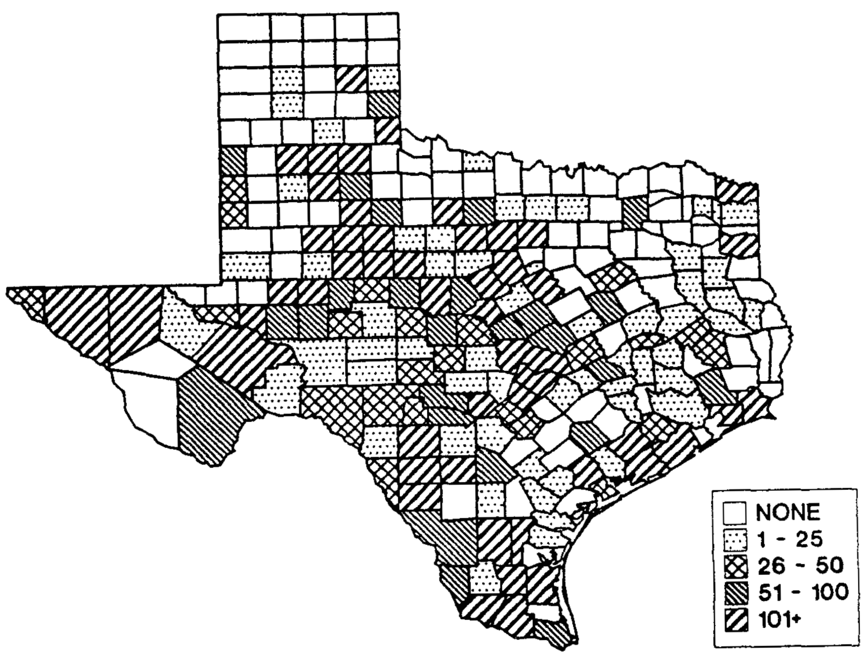


Figure 8. Coyote take of the cooperative animal damage control program in 1990

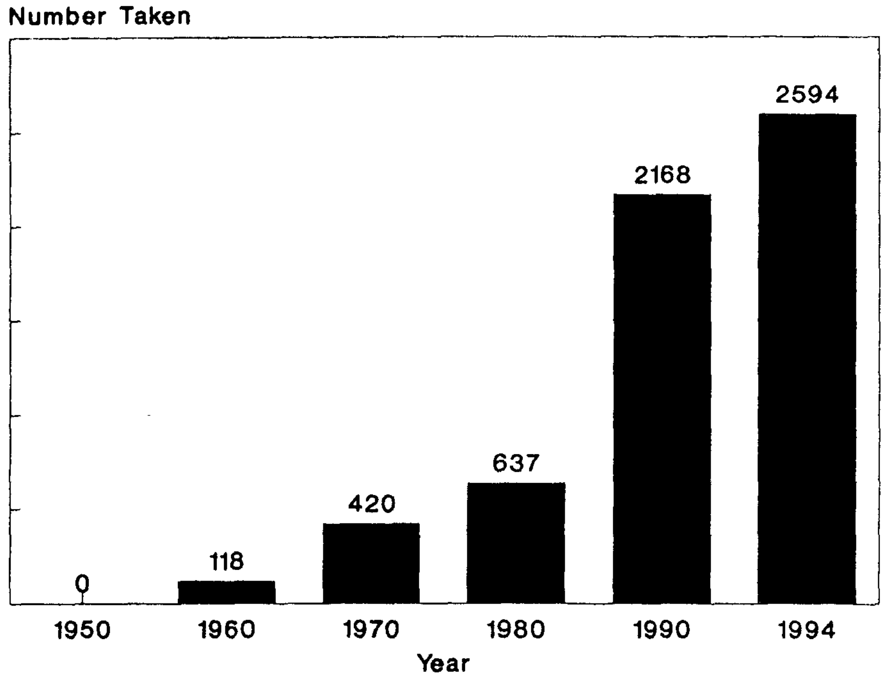


Figure 9. Trend in number of coyotes taken within the former coyote-free area shown in Fig. 3

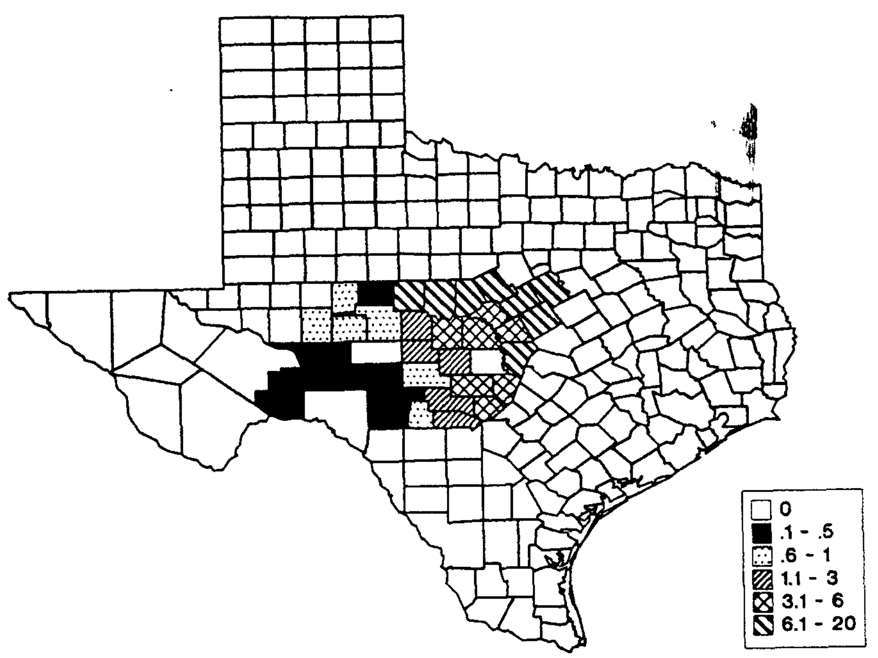


Figure 10. Coyotes taken per 10 square miles worked by cooperative animal damage control program, 1994.

COYOTES IN URBAN AREAS: A STATUS REPORT

JAN E. LOVEN, District Supervisor, Texas Animal Damage Control Service, Ft. Worth, TX

Abstract: Coyotes (*Canis latrans*) occur within the city limits of most urban areas in Texas, and the incidence of human X coyote interactions appears to be increasing in recent years. The major damage caused by coyotes in urban areas has been depredation on pets (primarily) and to other animals (e.g., ducks). Direct control of such problem coyotes is often hampered by city/state regulations and/or concern from local officials about negative publicity.

Coyotes are well known for their adaptability and probably have been in urban areas of Texas since settlement of the state began. An increase in the number of complaints received by offices of the Texas Animal Damage Control Service (TADCS) has occurred during the last 5 years. This increase has been especially noteworthy within the last 3 years. Coyotes, like many species, not only adapt, but thrive in the presence of man. Unlimited amounts of food, water, and shelter, accompany most urban areas, making them excellent habitat.

Coyote habitats and urbanization

One cause of coyote confrontations with people may be attributed to the rapid expansion and development of suburban areas which encroach on more traditional coyote habitat. In many cases, this is probably true However, many sightings and reports are up to several miles inside the city limits of older, established neighborhoods. An example would be the reported activities in the city of Westover Hills, an affluent community surrounded by the city of Fort Worth. There is no recent tract or property development, but coyotes have existed for several years in the area.

On June 13, 1994, an inspection was made on a public golf course in Arlington due to the complaints of coyotes attacking and eating pets adjacent to the course. The coyotes were raising young on the golf course and this property was not near undeveloped land. Coyotes were observed on another golf course in North Central Fort Worth on the fairways by the course manager. These animals were reportedly reluctant to give golfers the right-of-way. Immediately adjacent to the golf course is an undeveloped pasture area of several thousand acres. In years past, the owner of this adjacent property claimed to have lost several calves per year to coyotes.

During July 1994, a female coyote and two pups were trapped inside a department store warehouse 1 mile east of the intersection of Interstate 35 North and Loop 820 in Fort Worth. The coyotes came into the warehouse to feed upon scraps left over from employees' lunches and were trapped when an electrical storm caused the loading dock doors to close. An undeveloped area of approximately 1,000 acres is immediately adjacent to the industrial park in which the warehouse is found. Employees regularly fed coyotes at a plastics plant east of Meacham Field in Fort Worth, about three miles from the county courthouse.

Sporadic coyote nuisance complaints are received from DFW Airport regarding coyotes on runways. In this case, a large acreage around the runway areas is available for raising young and concealment. Complaints have also been received from Carswell AFB and Sheppard AFB

It is obvious that coyotes can be found anywhere there is suitable habitat Similarly, conditions for survival can vary greatly. In the Dallas-Fort Worth area, complaints and reports of coyotes have been received from the following municipalities: Tarrant County: Azle, Benbrook, Saginaw, Alliance Airport, DFW Airport, Grapevine, Southlake, Keller, North Richland Hills, Colleyville, Arlington, Mansfield, Rendon, Crowley, Fort Worth and Haslet. In Dallas County: Dallas, De Soto, Garland, Duncanville, Mesquite, Farmers Branch, Irving, Las Colinas, Carrollton, Wylie, Lancaster, and Sunnyvale. In Denton County: Denton, Flower Mound, and Lake Lewisville. In Johnson County: Burleson, Joshua, Cleburne, Godley, and Keene In Parker County: Weatherford, and Aledo. These were received within the last 2 years and multiple complaints are often received from a city. The complaints may concern 1 or several individuals, or groups of coyotes.

Scope of urban coyote damage

Damages from coyotes range from fear of rabies, to fear of being in close proximity to carnivores, to property, pet, and livestock damage. Several complaints have been received from joggers who are amazed at the boldness of these animals and are fearful of attack. After killing 11cats and 1 small dog, coyotes caused an elderly woman in extreme south Fort Worth to be afraid of leaving her house. While coyote attacks on humans have been documented in California, no incidents are known to occur in Texas. But with increasing coyote-human interaction in urban areas, an attack would not be surprising, especially on children.

Property damages generally are due to chewing or gnawing activities. During the 1970s coyotes gnawed on runway light wiring at DFW Airport and within the last 5 years this activity occurred at the Temple-Bell County Airport and at the Longview Airport.

The majority of complaints received by TADCS in the metroplex area concern depredation on livestock and pets. A complaint was received in June 1995, regarding 6 dairy calves being killed by coyotes at Crowley, a suburb south of Fort Worth approximately 1/2 mile west of I-35. It is believed that this is the same group of coyotes that terrified the above-mentioned elderly woman that lives nearby

Calf losses are reported all around the metroplex and are a common occurrence. Depredation on ratites, has been reported in 2 locations. Sheep depredations in North Richland Hills have occurred sporadically for 15 years. In July 1995, a fourth complaint was received from the Lakeside area of northwestern Tarrant County regarding coyote dep-redations on livestock. In this case, miniature goats were being killed inside a 15-acre enclosure. The use of llamas and guard dogs to protect the goats proved futile. Sheep, goats, and calves have been killed in this area of 5-20 acre properties. Adjacent, is a ranch of several thousand acres. Several complaints have been received concerning the loss of ducks and geese around ornamental ponds.

The largest portion of these depredation complaints pertain to pet losses. On June 4, 1995, an inspection was made of a coyote depredation site in De Soto, Dallas County. Small dogs and cats had been taken from an affluent neighborhood by a group of coyotes believed to be living in a nearby brushy creek area. A coyote was seen by the pet owner with his small white poodle in its mouth jumping the cyclone fence, where it disappeared into the darkness in Arlington. A group of coyotes regularly raid neighborhood areas in South West Fort Worth and Benbrook for pets.

Another group of coyotes in the northern section of Benbrook killed 18 of 20 mouflon sheep in a small enclosure along with all the ducks in the pond. The most publicized and blatant depredations occurred around the Eagle Mountain Lake area in developed lakeside residential areas. This Tarrant county residential area had several well witnessed incidents of broad daylight as well as nocturnal attacks on pets. One schnauzer was actually jerked from the leash and carried off before the owner's disbelieving eyes. Larger dogs were attacked by the group of coyotes when wandering through the neighborhood at night. This caused most pet owners to keep their animals confined. One woman witnessed a large male coyote killing and eating her 11-year old cat on her front porch. the owner's screams were of no avail to the hapless cat.

Damage control

These attacks in the lake area became so numerous, TADCS was contacted and a meeting was held January 25, 1993, in the local county commissioners' office. In attendance were 5 Texas Parks and Wildlife Department (TPWD) representatives, a U.S. Congressman's aide, Tarrant County Sheriff, media representatives, residents, and ranchers in the vicinity.

As the properties were not within the city limits, direct operational control was implemented on the adjacent ranches were the coyotes were living. An assignment of 1 month duration was implemented. It was so successful that 3 subsequent 1-month assignments have occurred since the initial effort, netting 469 coyotes. No more pet or livestock depredations have occurred.

Unfortunately, this incident was an exceptional circumstance. Most complaints cannot be responded to with direct methods. No direct control activities occurred at De Soto, after meetings with city personnel, for fear of adverse media coverage. No municipality has given consent or variance in local ordinances making operational control possible. Various local animal control officers have had no success with live traps of any type. One particular employee smeared the live trap with dog food and became a very successful opossum trapper.

In many cases, state law prevents the use of the M-44 device, but in any case, the tools needed to stop some of these problems have not been allowed. Other TADCS personnel around the state experience similar circumstances Technical assistance consultations are standard methods used to inform residents of their best possible courses of action under the circumstances. No change in status is anticipated at this time.

References

Meek, Steven, Wildlife Damage Control Specialist, Dallas County, pers. commun. 1995

Romines, Janean, Wildlife Damage Control Specialist, Travis County, pers. commun. 1995.

Ruffino, Denise, Wildlife Damage Control Specialist, Harris County, Pers. commun. 1995

Sandoval, Jude, Wildlife Damage Control Specialist, Bexar County, Pers commun. 1995.

Sramek, Rick, District Supervisor, Kingsville, Pers commun 1995.

Stean, Theresa, Wildlife Damage Control Specialist, Tarrant County, Pers. commun. 1994.

COYOTES: A HUNTER'S PERSPECTIVE

GERALD STEWART, Johnny Stewart Game Calls, Inc., P.O. Box 7594, Waco, TX 76714

Abstract: The challenge and thrill of recreational hunting for coyotes (*Canis latrans*) has increased greatly over the last 20 years. The popularity of calling coyotes especially is increasing east of the Mississippi River as coyote populations continue to increase their range and abundance in that area.

David had his Goliath, Don Quixote had his windmills and Willy Loman had his dreams. Each had an adversary that represented a challenge to overcome or conquer. I'm not sure what the connection is to coyotes, but it seemed like a good way to start I hope that I can weave these thoughts together as we go along, so you won't think I'm a total idiot

Increasingly over the last 8-10 years, the coyote has become that adversary or challenge to many of today's hunters To get a good perspective on today's hunter, let's look for a moment at yesterday's opportunities to hunt the cunning canine.

Range expansion of coyotes

The coyote, having started his trek a few hundred years ago into what we know as North America, has not occupied his present range for very long. Natural barriers forced the coyote's migration up and over the large rivers that ultimately form the Mississippi

Archeology has shown us that coyotes roamed the far eastern edge of the Canadian Provinces over 400 years ago For some unexplained reason, their range retracted to a more western domain Small numbers of them filtered down the northeastern edge of the continental U S. But it wasn't until we abandoned the river crossing ferry method for bridges that the eastern states were opened up to the coyote's migration eastward. Helped along by the transplantation of small numbers of coyotes by houndsmen who wanted sport for their dogs, coyote numbers started to grow east of the Mississippi River.

Not being considered a game animal, the coyote was not managed like deer or turkey The tremendous benefit of hunting as a management tool in the conservation effort was not applied to the coyote. They managed to do quite well on their own. They certainly were not in any trouble heading towards endangerment.

Coyote populations increase

The only factor in this area to regulate coyote numbers was basically the recreational fur trapper. Coyote fur was in high demand during the late 1970s and early 1980s, and the trapper was the vehicle that supplied it Then came the reduced demand for fur in 1988-89, and subsequently the collapse of the fur trapping industry. The fur market still hasn't recovered, thus fur demand may never again cause it to be a viable management tool for controlling coyote populations.

Coyote populations left unchecked grew rapidly. Their numbers have now grown to the point where disease and starvation will put the clamps on their advance in some areas. Left unchecked, coyotes continued to become more abundant in states where before they were known to occur, but were only rarely seen Today they are being seen with regularity.

What initially was a neat thrill for some hunters, i.e., to see a coyote passing by the deer stand became a concern for the coyote's effect on small game Even worse was the fear that fawns and turkey poults would also be affected.

It is at this point that the challenge to call in a coyote and shoot him started its meteoric rise. Paralleling this interest on the part of deer and turkey hunters was the effort of State Game Departments to encourage the sport hunting of coyotes. The effective tool of trapping was gone so now the states need help from hunters

The state of South Dakota developed a program of tagging and releasing coyotes with bounty tags of up to $500 to be redeemed by the lucky hunter that was able to get him. Restrictions on hunting coyotes in several eastern states started dropping like flies.

Hunter interest rising

What once was the coveted enjoyment of hearing the serenading harmony of the "song dog" has now become the call to battle. I think of the villagers with their torches storming Dr. Frankenstein's castle when I hear some hunters talk about coyotes. I've done seminars in the east where some in the audience sat fixed on my Wyman Meinzer coyote photographs with a lusting stare mumbling "gotta get one ... gotta get one".

You're probably wondering why I keep referring to "eastern this and eastern that." It's because I believe there is demand and a desire that is as yet untapped. There may be an opportunity that has not been seized upon Please understand that the opportunity to hunt coyotes may not be a big deal to many long time hunters in Texas; but it is to others.

Hunters from the East who have moved into our state are one segment, along with other Texans who have concentrated on deer, turkey, quail or doves all their life. They are just now discovering the thrill of coyote hunting. Combine them with nonresident coyote hunters and it's probably a sizeable group of hunters. Maybe the coyote can be managed as a cash crop just as the deer and the turkey have been. It's happening with feral hogs. Maybe it can with coyotes also.

I believe it was outdoor writer Larry Weishuhn who coined the phrase "Poor Man's Grizzly" when referring to a feral hog boar I assume using the word "grizzly" alludes to the element of danger and adventure involved while at a minimal investment of dollars.

Considering the coyote's sharp instincts and intelligence, the lure to hunt them is the bragging rights to say you were able to win or overcome the challenge. I talk to hunters all over the country that salivate at the thought of hunting our abundance of coyotes. They have had their appetite whetted by calling in their own states, but they dream of hunting on a Texas ranch with lots of coyotes. The coyote is to the northern and eastern hunter what the feral hog is to the southern and western hunter. There just aren't the numbers there to satisfy all of the desire. I've talked to many hunters who have traveled west for an opportunity to hunt coyotes. They are freely spending their hard-earned vacation money doing it.

During a seminar at a "Bowhunters University" weekend retreat, I asked how many, out of the 25 hunter present, had harvested deer with their bows. Eighteen or so raised their hand. I then asked how many had seen a coyote while bowhunting; 6-8 hands shot up. When asked how many had been able to shoot the coyote, only 2 hunters raised their hands. When I asked if the coyote had been called up only 1 responded. I then asked how many would like to call 1 up and take him, and virtually every hand shot back up.

Appeal of hunting coyotes

Occasionally I agree to spend a day or 2 with an out of state hunter who takes vacation time to come hunt for coyotes. Poor Mama and kids sit in the motel while Daddy gets his thrill in the woods hunting coyotes. Even if we strike out, he goes away giddy at the opportunity to hunt Texas coyotes.

One of the appeals of coyote hunting is the wide diversity of calling and hunting techniques. Day or night, almost any type of terrain and smart ones vs. dumb ones are all elements that come into play For those in Texas who have called a great deal, they might shrug their shoulders and say "what challenge"? But to someone who hasn't had the opportunities we have, they feel they may have conquered the world.

One hunter from the east coast who has called them successfully at home experienced his first ever night-calling on one of my trips He was almost wetting his pants at the sight of those eyes popping out of the darkness.

I've had several hunting guides relate to me that some of their clients would almost rather hunt coyotes than deer. More than one hunter who has hunted big game all over the world has stated emphatically "that [calling coyotes] was the most fun I've ever had hunting" after a successful day in the Texas brush

What creates this excitement? I believe it is the intensity of the anticipation that builds as the hunter waits impatiently. Understanding the coyote's extremely keen senses and ability to survive, the challenge to outwit the worthy adversary presses firmly on the hunter's consciousness. The coyote can burst onto the scene in a dead run, or it can sneak in silently only to appear out of nowhere. If you are skilled (or maybe just lucky!) enough to get one into rifle, handgun or bow range, then the real challenge begins. To get him in your sights without him detecting your movement, scent or sound will set apart the men from the boys so to speak.

Coyote calling can be a type of hunting that provides an incredible diversity in action, reaction and results. Styles and beliefs can vary widely among experienced hunters but I think they all will agree that coyote hunting can be a tremendously fun challenge for anyone

The coyote to some has taken on a mystical proportion like David's Goliath When they are able to place that perfect shot they have slain the obstacle to them winning the challenge. Some will pursue the coyote because he is perceived as the evil dragon, when in reality he is just another part of the landscape

Well, I haven't figured out how to work Don Quixote and Willy Loman into this yet, but there's a connection there somewhere But that will have to wait until another day.

TECHNIQUES FOR ESTIMATING COYOTE ABUNDANCE

SCOTT E. HENKE, Caesar Kleberg Wildlife Research Institute, Campus Box 218, Texas A&M University-Kingsville, Kingsville, TX 78363

FRED F. KNOWLTON, USDA-APHIS Denver Wildlife Research Center, Utah State University, Logan, Utah 84322-5295

Abstract: Knowledge of coyote abundance is needed to make intelligent management decisions Several methods have been devised to ennumerate coyote (*Canis latrans*) population size. We review several techniques and attempt to identify biases associated with each method. Once biases are understood, recommendations can be made to minimize their impact on data collection processes and yield better estimates of coyote population trends.

Enumeration of population status (i e , density, trends) is important in research and management of wildlife. Management of coyote populations has typically involved population control (Beasom 1974). Ranchers may be interested in the number of coyotes in an area to assess the potential severity of livestock losses (Scrivner et al. 1985). Wildlife managers sometimes attempt to reduce the density of coyotes to aid recruitment of game species (Beasom 1974, Garner et al. 1978, Hamlin et al. 1984) Assessing population size has been 1 method to judge the success of such management programs. Unfortunately, estimation of coyote population size is difficult because of species' secretive behavior and low densities.

Coyote population size can be expressed as density or relative abundance. However, these terms are sometimes confused and used erroneously. Population density is the number of individual animals per unit area, for example, the number of coyotes per square mile Relative abundance refers to the ranking of populations according to their population size. For example, Ranch A has more coyotes than Ranch B. Often, relative abundance is derived from an index or an indicator of population size.

Researchers of coyotes often rely on population indices because of the difficulty in obtaining adequate data to estimate population size. However, because the relationship between the index and the true population size is often unknown, the use of indices should be restricted to measures of relative abundance between populations of different areas during the same time period, or between populations on the same area over time.

Methods used to estimate coyote population size, density, and relative abundance have included scent stations (Linhart and Knowlton 1975, Roughton and Sweeney 1982), vocalization responses (Okoniewski and Chambers 1984), scat counts (Andelt and Andelt 1984), mark-recapture (Clark 1972), removal (Zippin 1958), radioisotope markers (Crabtree et al 1989), aerial surveys (Nellis and Keith 1976), and radiotelemetry (Andelt 1985) However, all methods provide variable results and none give a complete census of coyote populations (Spowart and Samson 1986). A census is a complete count of every animal within the population Obviously, because of the behavior of coyotes, a census is not practical

Our purpose here is to identify methods which can be used to assess coyote abundance and to identify some merits and problems of each. While not an exhaustive treatment of the subject, this report provides a general assessment of our current understandings

Density estimates

Aerial Counts: Aerial surveys are commonly used to sample animals or animal signs (e.g., nest colonies) visible from the air. Aerial counts can be conducted from either a fixed-wing plane or helicopter. Normally, a pilot and 1 or 2 observers are required to conduct aerial surveys. A Global Positioning System (GPS) is useful in maintaining flight patterns (R. Curnow, Denver Wildl. Res Center, pers. commun.) Surveys should be conducted when there is adequate visibility during the early morning or late afternoon hours (Beasom et al. 1981).

However, there have been few serious attempts to use aerial counts, either from planes or helicopters, to assess coyote abundance. Equipment costs may make the technique prohibitive for many situations, and biases associated with aircraft speed and height above ground, transect width, differing ground cover and terrain, differing vegetation conditions, time of day, and visual acuity of observers probably precludes this technique as a reliable procedure except under very specialized circumstances (e.g., snow cover). Use during the winter after deciduous foliage has fallen and where there is complete snow cover on the ground may improve the performance of this technique (Nellis and Keith 1976); however, little or no evaluation of the estimates obtained have been made.

Forward-Looking Infrared (FLIR) sensing shows promise as a new technique to count predators A plane equipped with a FLIR device would fly transects as outlined above, except the infrared image of the animal would be videorecorded for later analysis. Best results from this technique are obtained from transects flown during the early morning hours (within 2 hours of sunrise) over flat, open areas. Resolution of infrared images has improved significantly in recent years and now observers can differentiate among some species (S Beasom, Caesar Kleberg Wildl Res. Inst., unpubl data).

However, the FLIR technique is not without its problems Terrain, radiated heat from the ground or other environmental heat sources, and canopy cover can obscure images (G. Henicke, Caesar Kleberg Wildl Res. Inst., pers comm). At the present time, FLIR technology has not progressed to a point where it appears practical to use to assess coyote abundance.

Catch-mark-release: This technique typically involves multiple captures of individual coyotes. During the initial capture the coyote must be maintained alive, after which, subsequent collections can be by lethal means. Coyotes have been live-caught by foot-hold traps, snares, boxtraps, and tranquilizer darts

Turkowski et al. (1984) described improved foot-hold traps which resulted in coyote capture rates of over 84% and excluded smaller, non-target predators. Skinner and Todd (1990) reported that foot-hold traps resulted in a 3-fold greater coyote capture rate than foot snares Public opposition to the use of traps exists over concern that substantial injury to the trapped animals occurs (Jotham and Phillips 1994). Linhart et al. (1981) and Zemlicka and Bruce (1991) suggested that affixing tranquilizer tabs containing propiopromazine HCl can significantly decrease foot injury to coyotes. The drug diazepam also has been used to reduce injury to coyotes caught in steel foot-hold traps (Balser 1965).

Neck snares equipped with safety stops to prevent choking have been used to reduce injury to individual animals, and capture rates are typically greater than those of foot-hold traps (Guthery and Beasom 1978), at least in areas where net-wire fences are common. Also, experience in the placement of the safety stops is required; too tight or too loose will result in killing the coyote or escape by the coyote, respectively. Coyote pups have been caught at dens in live traps (Foreyt and Rubenser 1980); however, adult coyotes seldom enter boxtraps (R Sramek, Texas Animal Damage Control Serv., pers commun.).

Coyotes have been darted by use of a Cap-Chur gun from the ground (Ramsden et al. 1976) and from the air (Baer et al 1978). Dosages ranged from 8 - 21 mg/kg body weight for ketamine hydrochloride (Ramsden et al 1976, Cornely 1979) and 2 mg/kg body weight for phencyclidine hydrochloride (Bailey 1971). Both drugs have a wide margin of safety, were easily administered by syringe, and took effect typically within 5 minutes Recovery time for drugged coyotes can take up to 30 minutes (Pond and O'Gara 1994).

Nellis (1968) described a technique of chasing coyotes with motorized toboggans until they tired. At this point the coyote could be easily overpowered, however, he still advised using caution to avoid injury to all parties concerned. The use of ATVs could replace motorized toboggans in areas that lack sufficient snowfall. However, this technique appears to be limited to areas of open terrain which offer greater maneuverability to motorized vehicles. Death or disability can result from capture myopathy associated with over-exertion by the coyotes, especially in warm and hot conditions.

Clark (1972) estimated coyote density using a modification of the Petersen estimate (Bailey 1951) He located active coyote dens, eartagged the pups, and then trapped coyotes in the same area several months later The proportion of eartagged coyotes among the total number of pups captured was used to estimate the density of coyote pups. This procedure appeared to yield a reliable density estimate, but it was very labor intensive.

The major problem with catch-mark-release estimators is that recovery rates of tagged coyotes is typically low (Andelt et al. 1985, Windberg and Knowlton 1990). Gionfriddo and Stoddart (1988) reported that coyotes marked with ear tags and vinyl collars were recovered at rates of 21% and 25%, respectively Recovery rates increased to 50% if coyotes also were equipped with radio collars; however, telemetry equipment often can be cost prohibitive. Windberg and Knowlton (1990) demonstrated that coyotes are seldom captured in the areas they frequent most and are usually captured on the edges, or well outside their usual haunts.

Radioisotope markers have been used as a means to circumvent low recovery rates. Individual coyotes are intramuscularly injected with gamma-emitting radioactive isotopes, which eventually gets excreted (Pelton and Marcum 1975, Knowlton et al. 1989) The proportion of marked to unmarked feces can be used to construct a population estimate. Estimates derived from these procedures appear to be quite reliable, especially if the marked animals are equipped with radio transmitters to assess the degree to which the animals remain on the survey area, but this technique is labor intensive

Spotlight counts Spotlight counts have been used to estimate white-tailed deer (Harwell et al 1979) and lagomorphs (Kline 1965, Fafarman and Whyte 1979). Few attempts have been conducted to ennumerate coyote populations by this method (Henke 1992). Spotlight surveys should begin 1 hour after sunset and should be conducted several times during the same moon phase and under similar weather conditions The number of replicates depends upon the variability among counts as well as the precision desired. Two observers with 300,000-candlepower spotlights and a driver are required to count coyotes along each roadside. The vehicle should maintain a speed of approximately 10 mph during the survey

Coyote densities are obtained by dividing the number of coyotes observed by the visible acreage. Henke (1992) believed that this method overestimated the coyote population in West Texas, but stated that coyote populations could be positively or negatively biased by their use of secondary roads. Coyotes preferentially use secondary roads as travel lanes (Andrews and Bogess 1978), thus causing an upward bias in density estimates. However, if coyotes were routinely hunted from vehicles at night, a learned aversion to vehicles and roads could result, resulting in underestimation of coyote density. Factors which influence animal activity might also influence counts, including time of day, season, weather conditions, and condition of roadside cover. Therefore spotlight surveys as an enumeration technique for coyotes should be viewed with skepticism until the behavioral biases are assessed.

Relative abundance indices

Catch-per-unit effort: A variety of catch-per-unit effort indices have been used with carnivores in general and coyotes in particular. Many of the trapping techniques described above also could be used as long as capture effort is recorded. Despite whether effort is measured in man-years (Cain et al. 1972, Wagner 1972) or individual "unit-nights" (e.g., trap nights) (Clark 1972, Knowlton 1972), standardization of procedures remains a major problem, particularly with regard to the manner in which different individuals use or set equipment. Biases resulting from the use of various types of equipment as well as unequal capture vulnerability of animals within various population segments need to be addressed (Windberg and Knowlton 1990).

Most catch-per-unit-effort techniques are labor intensive and many have the added disadvantage of modifying the population by removing individuals Removal methods have been employed to estimate relative coyote population size (Henke 1992). This estimator is based on the assumption that more animals are caught during the initial effort and that the number of captures declines with subsequent efforts (Zippin 1958). However, the more intensive the capture effort in relation to the size of the area, the greater the potential impact upon the population being enumerated Also, coyotes quickly immigrate to areas where territorial vacancies occur. Henke (1992) noted that coyote density returned to pre-removal levels in less than 3 months after the removal effort Rapid recolonization rates can confound removal estimators

Scent station visitation rates: Coyote visitation rates to artificial scent stations probably have been the most widely used, standardized method for indexing coyote abundance. Scent station indices also have been evaluated more critically than any other technique for indexing coyote abundance (Linhart and Knowlton 1975, Roughton and Bowden 1979, Roughton and Sweeney 1982). This technique employs a series of transects, each composed of a set of regularly-spaced stations 39 inches (1 m) in diameter The ground surface is scarified and smoothed so that animal tracks can be recognized. Powdered clay soils are preferred for building stations.

Typically, stations are spaced at 550 yard intervals with consecutive stations located on alternate sides of a road The basic sampling unit is a 3 mile line containing 10 stations. A standard artificial olfactory attractant is placed in the center of each station. Attractants have included plaster-of-paris disks impregnated with a scent (Roughton and Sweeney 1982) or histology tissue capsules containing scented-cotton (Henke 1992) Stations are typically set out 1 day and examined the next to determine the number of stations that have been visited by coyotes. The index of abundance normally is expressed as

$$\frac{\textit{(No. stations with coyote visits)}}{\textit{(No. operable stations)}} \quad X \quad 1000.$$

Coyote behavior can affect the number of "visits". Harris (1983) found that coyotes are more likely to visit scent-stations when they were away from areas with which they were familiar than when they were within familiar areas. Andelt et al. (1985) suggested that previous adverse experiences, such as having been trapped, reduced scent-station visitations by coyotes. Fagre et al (1983) suggested that coyotes may become habituated to specific lures if they are repeatedly exposed to it; however, changing lures could elicit a different response.

Environmental factors such as strong winds, precipitation, and frozen ground, and biotic factors such as grazing livestock and vehicular traffic can render scent-stations unusable. Fagre et al. (1981) noted that young coyotes were more attracted to odors than adults; therefore, unequal vulnerability could result in bias.

Elicited howling responses: Sirens, bugles, broadcasting recorded coyote howls, human imitations of coyote howls, and a variety of other sound stimuli have been used to elicit responses from wild coyotes (Alcorn 1946, Wenger and Cringan 1978, Okoniewski and Chambers 1984). Locations for attempting to elicit coyote responses are identified along predetermined routes at spacings generally greater than 2 5 miles. The routes are usually driven between dusk and dawn and the number of stations with responses, or the number of responding groups per station, is used as the measure of relative coyote abundance.

Several factors have been identified which may influence the rate at which coyotes respond, irrespective of coyote abundance. Carley (1973) obtained a 4-fold difference in response rates to 3 types of sirens used to elicit the response. He also noted a bimodal response pattern during nocturnal sampling, with an absence of response in the middle of the night when animals were not active. Okoniewski and Chambers (1984) did not detect any appreciable difference between response rates elicited by siren and human voice but they did note, as did Quinton (1976) and Laundre (1981), a seasonal pattern in coyote responsiveness.

Among penned coyotes, it seems that animals not associated with "territorial groups" do not respond to other coyotes and likely would not respond to other sounds that normally elicit vocalizations. Camenzind (1978) and Bowen (1981) suggest similar behavioral differences among wild coyotes. This suggests that transients within a coyote population might be excluded from the enumeration process.

In addition to variable responsiveness on the part of coyotes, a variety of environmental factors including topography, vegetation height and density, relative humidity, wind velocity, air temperature, and presence or absence of temperature inversions can influence the range over which coyote responses can be detected (Wolfe 1974) Potentially differential auditory acuity among observers could also pose significant biases

Scat deposition rates This technique appears to be one of the more practical because it (a) requires only one observer with minimal training, (b) can accumulate information over a period of time without an observer in attendance (Clark 1972), and (c) does not require an artificial behavioral response on the part of the coyote. Davison (1980) and Stoddart (1984) have used the number of coyote scats deposited along 1.0 mile segments of unimproved road in a specified period of time to depict trends in coyote abundance. Each transect is walked at the beginning of the sample period and all scats detected are removed. Subsequently the transects are walked again at a later date and the number of scats recovered per mile per day is used as an index to coyote abundance.

Balcomb (unpubl. data) indicates biases associated with this technique include: (1) removal of scats may slightly reduce the number of scats deposited in subsequent days; (2) scat persistence is inversely related to the amount of vehicular traffic; and (3) failure to detect scats while walking the transects. About 30% of the scats were missed, independent of observer, each time a transect was walked, with some indication the problem was greater on transects with fewer scats. This bias can be reduced by walking transects twice, once in each direction. Also, seasonal changes in scat abundance may result from differential scat production associated with dietary changes (Andelt and Andelt 1984), suggesting comparison of scat deposition rates should not be made across seasons.

Standardized track counts. Establishing standard track counting areas may have the potential for being the most reliable technique for determining relative coyote abundance. In most situations it probably also entails the most work. This method consists of counting the number of fresh coyote tracks detected within set distances of road. In snow, sand, or soft earth it may be relatively easy, but on rocky or hard substrates it may be nearly impossible. Todd and Keith (1976) used fresh snowfall and Beasom (1973, 1974) used the sandy soils of South Texas to their advantages. However, environmental conditions, vehicular traffic, and unworkable substrates make widespread use of this technique impractical.

Road-killed coyotes. The number of coyotes killed by vehicles can be used, if standardized, to estimate relative abundance of coyotes. Henke (1992) drove the same 30 miles of highway roads every day for 2 weeks each season and recorded the number and location of freshly-killed coyotes. He estimated the relative abundance of coyotes from the equation:

$$[n/l)/V] \times 10{,}000$$

where: n = number of fresh road-killed coyotes; l = length of the road (km) surveyed; and V = average daily volume of traffic.

However, Henke (1992) reported this technique did not yield satisfactory estimates. Juveniles represented the majority of coyotes killed on the highway, suggesting a strong age bias. Differential vulnerability to vehicular traffic was also reported by Windberg and Knowlton (1990). Average vehicle speed, weather, season, and location of preferred areas may present additional biases (Downing 1980).

Harvest questionnaires and bounty payments. Many agencies use harvest data from questionnaires to estimate coyote population trends (Krause et al. 1969). However, these data are subject to biases arising from sample size, pelt prices, and honesty of respondents. Krause et al. (1969) suggested that many hunters reported they were hunting coyotes only if they happen to kill one, thus overestimating coyote harvest by underestimating effort. County bounty systems may overestimate relative coyote abundance because coyotes may be collected from nearby counties, but hunters may claim the kill occurred in the jurisdiction paying the highest bounty.

Conclusions

Developing techniques to assess the relative or absolute numbers of wild animals is an intriguing but complex process. In the case of the coyote, 2 techniques seem to have particular merit for assessing relative abundance: scent-station visitation rates and scat deposition rates. In addition, practical density estimates seem feasible through use of radioisotopes for long-term marking of feces of specific animals. However, reasons for enumerating a population, situations at hand, and resources available should be assessed before a technique is selected.

Before engaging in any attempt to detect trends or changes in coyote abundance, thought should be devoted to the sensitivity required of the estimator. How large or small a difference in abundance that can be detected will be a function of (1) the relative response level of the particular index being used, (2) variation inherent in the index method, and (3) the sampling effort. Little can be done about variation inherent in an indexing technique except to rigidly adhere to standardized methods, not only in terms of procedures but also to the conditions under which the methods are performed. The relative level of response presumably is a function of the number of animals present, and cannot be changed artificially, but expectations of the response rates to be encountered permit adjustments in the sampling intensity to achieve the degree of sensitivity desired. In short, the quality of "the answer", in terms of precision and accuracy, is closely related to the effort involved and the relative scale of that particular enumeration data.

Literature Cited

Alcorn, J.R. 1946. On the decoying of coyotes. J. Mammal. 27:122-126.

Andelt, W.F. 1985. Behavioral ecology of coyotes in South Texas Wildl. Monogr. 94:1-45.

_____, and S.H. Andelt. 1984. Diet bias in scat-deposition rate surveys of coyote density Wildl. Soc. Bull 12:74-77.

_____, C.E. Harris, and F.F Knowlton. 1985. Prior trap experience might bias coyote responses to scent stations Southwest Natural 30:317-318.

Andrews, R.D , and E.K. Boggess. 1978. Ecology of coyotes in Iowa. Pages 249-265 in M Bekoff, (Ed.), Coyotes: biology, behavior, and management. Academic Press, New York.

Baer, C H , R.E. Severson, and S.B. Linhart. 1978. Live capture of coyotes from a helicopter with ketamine hydrochloride J. Wildl. Manage. 42:452-454

Bailey, N T J. 1951. On estimating the size of mobile populations from recapture data Biometrika 38.293-306.

Bailey, T.N. 1971. Immobilization of bobcats, coyotes, and badgers with phencyclidine hydrochloride. J. Wildl. Manage. 35:847-849.

Balser, D.S. 1965. Tranquilizer tabs for capturing wild carnivores. J Wildl. Manage. 29: 438-442.

Beasom, S L. 1973 Ecological factors affecting wild turkey reproductive success in South Texas. Ph.D Dissert. Texas A&M Univ. 215pp.

_____. 1974. Intensive short-term predator removal as a game management tool. Trans. Am. Wildl. Nat. Resource Conf. 39:230-240.

_____, J.C. Hood, and J. R. Cain. 1981. The effect of strip width on helicopter censusing of deer. J. Range. Manage. 34:36-37.

Bowen, W.D. 1981. Variation in coyote social organization: the influence of prey size. Can. J. Zool. 59:639-683.

Cain, S.A., J.A. Kadlec, D.L. Allen, R.A. Cooley, M.G. Hornocker, A.S. Leopold, and F.H. Wagner. 1972. Predator control - 1971. Report to the Council on Environmental Quality and the Dept. of Inter., Univ. Mich Press, Ann Arbor. 207pp.

Camenzind, F.J. 1978. Behavioral ecology of coyotes on the National Elk Refuge, Jackson, Wyoming. Pages 267-293 *in* M. Bekoff, (Ed.), Coyotes: biology, behavior, and management. Academic Press, NY.

Carley, C.J. 1973. Development of coyote census techniques. Presented at Colorado Chapter, The Wildl Soc and Colo Sec. Soc. Range, Manage., Englewood, CO.

Clark, F W. 1972. Influence of jackrabbit density on coyote population change. J Wildl. Manage. 36:343-356.

Cornely, J.E. 1979 Anesthesia of coyotes with ketamine hydrochloride and xylazine J. Wildl. Manage. 43:577-579.

Crabtree, R L , F.G. Burton, T.R. Garland, D.A. Cataldo, and W.H. Rickard. 1989. Slow-release radioisotope as individual markers for carnivores. J. Wildl. Manage. 53:949-954.

Davison, R.P. 1980. The effects of exploitation on some parameters of coyote populations Ph.D. Thesis, Utah St. Univ., Logan. 120pp.

Downing, R.L. 1980. Vital statistics of animal populations Pages 247-268 *in* S.D. Schemnitz, (Ed), Wildlife management techniques manual. 4th ed., The Wildlife Society, Bethesda, MD.

Fafarman, K.R., and R.J. Whyte 1979. Factors influencing nighttime roadside counts of cottontail rabbits. J. Wildl. Manage. 43:765-767.

Fagre, D.B , B.A Butler, W.E Howard, and R. Teranishi 1981 Behavioral responses of coyotes to selected odors and tastes. Pages 966-983 *in* J.A. Chapman and D. Pursley, (Eds.), Worldwide Furbearer Conf. Proc., Frostburg, MD.

_____, W.E. Howard, D.A. Barnum, R. Teranishi, T H. Schultz, and D J. Stern. 1983. Criteria for the development of coyote lures Vertebr. Pest Control and Manage. Mater. 4:265-277.

Foreyt, W.J., and A. Rubenser. 1980 A live trap for multiple capture of coyote pups from dens. J. Wildl. Manage. 44:487-488.

Garner, G.W., J.A. Morrison, and J.C. Lewis 1978. Mortality of white-tailed deer fawns in the Wichita Mountains, Oklahoma. Proc Southeast. Assoc. Game and Fish Comm. 30:493-506.

Gionfriddo, J.P., and L.C. Stoddart. 1988 Comparative recovery rates of marked coyotes. Wildl. Soc Bull. 16 310-311

Guthery, F S , and S.L Beasom. 1978 Effectiveness and selectivity of neck snares in predator control. J. Wildl Manage 42:457-459

Hamlin, K.L., S.J. Riley, D. Pyrah, A.R. Dodd, and R.J. Mackie. 1984. Relationships among mule deer fawn mortality, coyotes, and alternate prey species during summer J. Wildl Manage. 48 489-499.

Harris, C.E. 1983 Differential behavior of coyotes with regard to home range limits. Ph.D. Diss., Utah State Univ , Logan, UT. 120pp.

Harwell, W.F , R L Cook, and J.C. Barron. 1979 The spotlight count method for surveying white-tailed deer in Texas Texas Parks and Wildl. Dept Fed Aid Proj. No. W-109-R. FA Rep. Serv No. 21. 25pp.

Henke, S E. 1992 Effect of coyote removal on the faunal community ecology of a short-grass prairie Ph.D Dissert , Texas Tech Univ., Lubbock, TX. 229pp

Jotham, N., and R.L Phillips. 1994. Developing international trap standards - a progress report Proc. Vertebr. Pest Conf. 16:308-310.

Kline, P.D. 1965 Factors influencing roadside counts of cottontails. J Wildl. Manage. 29:665-671.

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

_____, L.C. Stoddart, R.L. Crabtree, and J.W. Blatt. 1989. Evaluation of some radioisotopes as marking agents for monitoring bait consumption Pages 52-62 *in* K A. Fagerstone and R D. Curnow, (Eds.), Vertebr. Pest Control and Manage. Materials. 6th Vol., Amer. Soc. Test. Mater. Publ. 1055.

Krause, G.F., F W. Samson, and J M Orr 1969 Biased coyote harvest estimates: a paradox J. Wildl Manage 33 444-446

Laundre, J W 1981. Temporal variation in coyote vocalization rates J Wildl. Manage. 45:767-769.

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

_____, G.J. Dasch, and F.J. Turkowski. 1981. The steel leg-hold trap: techniques for reducing foot injury and increasing selectivity. Proc Vertebr Pest Conf 3:1560-1578

Nellis, C.H 1968. Some methods for capturing coyotes alive J Wildl. Manage. 32:402-405

_____, and L B. Keith. 1976. Population dynamics of coyotes in central Alberta, 1964-68. J. Wildl. Manage. 40:389-399.

Okoniewski, J.C., and R E Chambers. 1984 Coyote vocal response to an electronic siren and human howling. J. Wildl. Manage. 48:217-221

Pelton, M.R., and L C. Marcum 1975 The potential use of radioisotopes for determining densities of black bears and other carnivores. Pages 221-236 *in* R.L. Phillips and C Jonkel, (Eds) , Proc. Predator Symp., Mont. Forest and Cons. Expt. Sta., Univ Mont., Missoula.

Pond, D.B , and B.W. O'Gara. 1994. Chemical immobilization of large mammals Pages 125-139 *in* T.A Bookhout, (Ed.), Research and management techniques for wildlife and habitats. 5th ed. The Wildlife Society, Bethesda, MD.

Quinton, D.A. 1976. An evaluation of two coyote census techniques, Final rep., Contract No. 14-16-0008-1142, Texas Tech. Univ., Lubbock, TX. 31pp.

Ramsden, R.O , P.F. Coppin, and D.H. Johnston. 1976. Clinical observations on the use of ketamine hydrochloride in wild carnivores. J. Wildl. Dis. 12:221-225.

Roughton, R.D , and D. Bowden. 1979 Experimental design for the field evaluation of odor attractants for predators. Pages 249-254 *in* J.R. Beck, (Ed.), Vertebr. pest control and manage. materials. Amer Soc. Test Mater. STP 680, Philadelphia, PA

_____, and M W Sweeney. 1982 Refinements in scent station methodology for assessing trends in carnivore populations. J Wildl. Manage. 46:217-229.

Scrivner, J.H., D A. Wade, G.E. Connolly, and L.C. Howard. 1985. Cost and other effects of predation on an angora goat ranch. Rangelands 7:54-57.

Skinner, D.L , and A. W. Todd. 1990. Evaluating efficiency of footholding devices for coyote capture. Wildl. Soc Bull. 18:166-175.

Spowart, R.A., and F.B. Samson. 1986 Carnivores. Pages 475-496 *in* A.Y. Cooperrider, R.J Boyd, and H R Stuart, (Eds.), Inventory and monitor ing of wildlife habitat. U S. Dept Inter., Bur. Land Manage. Service Center, Denver, CO

Stoddart, L.C. 1984. Relative abundance of coyotes, lagomorphs, and rodents on the Idaho Nat'l Engineering Lab. Ann. Rep of Pred Ecol and Beh Proj , Denver Wildl. Res Ctr. Denver, CO. 24pp

Todd, A W., and L.B. Keith. 1976. Responses of coyotes to winter reductions in agricultural carrion. Alberta Dept. Rec., Parks and Wildl., Fish and Wildl Div., Wildl Tech. Bull. 5:1-32.

Turkowski, F J., A R Armistead, and S.B. Linhart. 1984 Selectivity and effectiveness of pan tension devices for coyote foothold traps. J. Wildl. Manage. 48.700-708.

Wagner, F.H 1972. Coyotes and sheep, some thoughts on ecology, economics, and ethics. Utah State Univ., Logan Faculty Honor Lecture 44:1-59.

Wenger, C.R , and A.T. Cringan 1978. Siren-elicited coyote vocalizations. an evaluation of a census technique. Wildl. Soc. Bull 6.73-76.

Windberg, L.A., and F.F. Knowlton 1990 Relative vulnerability of coyotes to some capture procedures. Wildl Soc. Bull. 18:282-290.

Wolfe, G.J 1974 Siren elicited howling response as a coyote census technique. M.S. Thesis, Colo State Univ., Fort Collins, CO 206pp.

Zemlicka, D. E., and K Bruce. 1991. Comparison of handmade and molded rubber tranquilizer tabs for delivering tranquilizing materials to coyotes captured in leg-hold traps. Pages 52-56 *in* S E Hygnstrom, R M. Case, and R. J. Johnson, (Eds.), Proc. 10th Great Plains Wildl Damage Control Workshop, Great Plains Agric. Council Publ 137.

Zippin, C. 1958 The removal method of population estimation. J. Wildl Manage 22:82-90.

INTERPRETING PHYSICAL EVIDENCE OF COYOTE PREDATION

JAMES E. BOWNS, Southern Utah University and Utah State University, Cedar City, UT 84720

Abstract: There are situations where it is necessary to determine the cause of death of livestock, game animals, or other wildlife. Criteria used for recognizing predator kills are well known and scientifically documented. These criteria include the attack, killing and feeding behavior of predators as well as the characteristics of their tracks, droppings, and canine teeth size and spacing. Diagnostic criteria for recognizing coyote (*Canis latrans*), domestic dog, fox (*Urocyon cinereoargenteus*, *Vulpes vulpes*), cougar (*Felis concolor*) , bobcat (*Lynx rufus*), bear (*Ursus* spp), and eagle (mostly *Aquila chrysaetos*) predation are presented in this paper.

Predation and its impacts on livestock and wildlife continue to generate interest and controversy among livestock producers, environmental groups, wildlife managers, hunters, researchers, students and the general public. An accurate assessment of the damage actually done by each predator species is prerequisite for reconciling the concerns of these diverse interests, and for developing effective predator management and control policies. Such cause-specific diagnoses require the ability to recognize predation events and the respective predators involved

Predation is usually a secretive event that occurs in areas remote from human habitation, thus it is rarely witnessed. Therefore, it is necessary to use physical evidence to document that (1) a kill has occurred and (2) to determine which predator species was involved. The purpose of this paper is to present detailed descriptions of predator characteristics and behaviors that can be used to (1) distinguish predator kills from other causes of death, and (2) identify the predator when a kill has occurred

Interpreting physical evidence of predation

Animals die from many causes, e.g., starvation, exposure, parasites, disease, bloat, suffocation, poisonous plants, and lightning, all of which can be determined by appropriate examination of the carcass and the kill site Often, however, a veterinarian or other expert is needed for an accurate determination In such a case, the carcass and nearby soil and vegetation should not be disturbed

Death caused by predation can be recognized by characteristic wounds and consumption of the carcass, as well as by the position or orientation of the carcass. Identification of specific predators assumes that each predator species follows a general pattern of killing and feeding, and therefore, leaves similar evidence. However, it must be recognized that individual predators vary in their behavioral patterns.

A suspected predator kill should be approached carefully to avoid unnecessary disturbance taking care to not disturb tracks or droppings that may be found near the carcass, along trails, fence lines, creeks, water holes or dry washes. Note the position of the carcass, look for drag trails, blood on the ground or on vegetation, and if the carcass has been covered by soil and/or plants Look for obvious wounds which are often located on the neck, head or shoulders. Examine the carcass for the feeding pattern, especially check the udder, viscera, shoulders and hind quarters Skin the carcass and look for tooth punctures, subcutaneous hemorrhaging, tissue damage, bruising and broken bones, especially broken necks. Where punctures are found, note their number, size, depth and location.

Coyotes

Coyotes are the most common and the most serious predator of livestock in the western U.S. (Wade and Bowns 1982). Connolly et al (1976) considered coyote predation on sheep as a serious economic and political problem

In attacks on adult sheep, goats and older lambs, coyotes typically bite the throat just behind the jaws and below the ear (Wade and Bowns 1982). On smaller prey, such as small lambs and kids, coyotes may bite the head, neck, or back, causing massive tissue and bone damage.

Connolly et al. (1976) considered the sheep killing technique of coyotes to be remarkably consistent. Each coyote ran alongside the fleeing sheep, clamped its jaws on the neck laterally (sometimes dorsally) just behind the ear, and braced its feet to stop the sheep The coyote's grip then shifted to the larynx region, and it simply held on and waited for the sheep to succumb (primarily by suffocation). Sheep killed by coyotes exhibited tooth marks and hemorrhaging (sometimes only subcutaneously) in the larynx region.

Bowns (1976) concluded that blood on the throat wool was *prima facie* evidence of predation Where external bleeding was not apparent, the hide should be skinned from the neck, throat, and head of the carcass. A coyote kill reveals subcutaneous hemorrhages, tooth punctures in the hide, and tissue damage. The tooth punctures are usually located below the ear and on the throat immediately behind the mandibles. On very small lambs, however, the coyote's upper jaw may penetrate the top of the neck or the skull

It is often difficult, if not impossible, to determine the cause of death if the carcass has reached an advanced stage of decomposition. However, if the head is positioned higher than the rest of the body and the bitten side has not touched the ground, evidence of the bite may still be distinguishable Blood on the ground near a long-dead animal is also indicative of predation.

Young, inexperienced coyotes may not bite the throat but tear the flank or hindquarters of the sheep. Other atypical attacks may occur in late winter or early spring when sheep are attacked frequently at the hindquarters It is assumed that this behavior occurs because the winter wool is long and thick on the neck while the hind quarters are exposed and vulnerable.

Bitten or wounded lambs are commonly observed in herds that are exposed to coyote predation. These lambs usually have blood on their neck or throat, and often trail along at the rear of the herd. These bitten lambs can be identified by drooping ears, and a stiff neck carried in a low horizontal position Actual damage may vary from little or no external blood to severed trachea, broken jaws, or hide torn from the sides or legs. These animals can be treated with a combination of antibiotics, pine tar, and insect repellents.

Coyotes normally begin feeding on lambs in the flank or just behind the ribs. They often consume the viscera first; a milk-filled stomach is a preferred item. Multiple kills are common but many carcasses are not eaten

Calves are also vulnerable to coyote predation. Evaluations are often difficult because everything but the skeleton and part of the hide may be consumed. Subcutaneous hemorrhage, blood on the ground and vegetation, and bloody drag trails help to characterize coyote predation. Some dead calves have tooth punctures in the nose or have the nose chewed off

Calves that have been bitten, but not killed, often have wounds in the flank, hindquarters or front shoulders "Bob-tailed" calves are often common when coyotes are involved. Dead calves and severe injuries to the genital organs and hindquarters of cows are characteristic when coyotes attack cows while they are giving birth. This is most common with first-calf heifers.

Deer (*Odocoileus* spp), especially fawns, are common prey for coyotes. Nielsen (1975) concluded that most mule deer fawns were killed in a manner similar to the way coyotes kill sheep Bowns (1976) examined a fawn that had extensive tissue damage to the forepart of the neck and tooth punctures in the hide. This fawn was bitten on both sides of the neck from below rather than from the side as occurs with most lamb kills. Fawn carcasses are often completely dismembered and eaten which makes verification difficult. Mature mule deer (*O. hemionus*) are often pulled down from behind, but some carcasses show bites or bruises in the neck.

White (1973) recognized coyote predation as the major mortality factor for young white-tailed (O. *virginianus*) fawns in south Texas. These fawns were frequently bitten in the head or neck, but some had bites in the back or elsewhere. Sometimes the only remaining evidence of a kill was blood, hair, and bits of flesh, bone, and fat. He concluded that coyotes started feeding at the abdomen and ate the stomach of young fawns which contained mainly milk.

Pronghorn (*Antilocapra americana*) fawns are common prey of coyotes and other predators. Neff and Woolsey (1979) used hounds to locate pronghorn kills. The hounds were able to locate buried caches of meat, scat, coyote dens and sleeping coyotes. Without hounds they would not have located the meager evidence of hair and bone chips left after a coyote had consumed a fawn. Knowlton (1968) reported that frequently there was little evidence that remains after a fawn has been killed by a large predator. Fawns killed by coyotes may be totally consumed, leaving little more than blood spots on the grass.

Tucker and Garner (1980) developed several criteria which they used to determine coyote predation on pronghorn. These criteria included (1) carcasses lying in the open with no attempt to conceal the carcass or sometimes the carcass was buried, (2) carcass remains are scattered, (3) skull punctured or crushed, (4) underside of the neck bruised but without puncture wounds, (5) broad bruises on the back of the neck and throat, and (6) the entire carcass consumed except for the scattered leg bones, bone fragments, etc

Spacing of the teeth of an average coyote is 1 1/8 to 1 3/8 inches between the upper canines and 1 to 1 1/4 inches between the lower canines. This spacing of punctures observed in the hide or tissue may be an aid in confirming coyote predation. Coyotes may also urinate, defecate and scratch after feeding

Coyote tracks are more oval and compact than tracks of dogs. Nail marks are less prominent on coyote tracks and the tracks tend to follow a straight line more closely than dogs A normal coyote track is about 2 inches wide and 2 1/2 inches long, with the hind track slightly smaller than the front

Other predators

Although this is a coyote symposium, we should also discuss the characteristics of other predators in order to illustrate the differences between them, and make verifications of predator involvement more accurate

Dogs. Domestic dogs are a serious problem when they are permitted to roam freely This problem is increasing as housing subdivisions expand into historic sheep-producing areas. Domestic dogs do not normally kill for food and their attacks usually lead to indiscriminate mutilation. True feral dogs are more apt to kill for food.

Sheep-killing dogs usually work in pairs or larger groups and can inflict considerable damage. Sheep are likely to be bitten in the head, neck, flank, ribs, and front shoulders, and the ears of mature sheep are often badly torn. Often sheep attacked by dogs are not killed but are mutilated to the point where they must be destroyed. The external appearance of some dog bites may not look serious but a necropsy reveals serious tissue damage (Bowns 1976).

Domestic dogs can also be a serious problem with wintering deer herds. Dogs often harass or attack deer that are already stressed by cold temperatures, deep snow, and lack of forage

Foxes Both red and gray foxes may prey on livestock and poultry. Foxes usually kill only young or small animals, but red foxes may kill larger lambs and kids, adult sheep and goats, and small calves Foxes usually attack the throat of lambs and kids, but sometimes inflict multiple bites to the neck and back. They do not have the size and strength to hold and immobilize adult animals, therefore repeated bites may be required to subdue their prey.

Foxes generally prefer the viscera and begin feeding behind the ribs, but some prefer the nose and tongue, and may even consume the head of small prey Red foxes are known to carry small carcasses back to their dens, which probably accounts for the disappearance of some prey.

The spacing of the canine teeth is narrower than in coyotes Upper canines are approximately 1/2 to 3/4 inches apart on gray foxes and 11/16 to 1 inch apart on red foxes. They rarely cause severe bone damage, which helps to distinguish fox kills from coyotes or other large carnivores

Fox tracks are typically smaller than coyotes and foxes have a shorter stride. Red fox tracks are normally about 1 3/4 inches wide and 2 1/4 inches long; gray fox tracks are slightly smaller (Wade and Bowns 1982)

Cougars. Cougars usually kill sheep and goats by biting the top of the neck or head. Removing the hide will expose large holes made by the canine teeth. The cougar bite often breaks the neck. Cougars may kill older ewes by biting the side of the neck or the throat. Cougars also may kill by grasping the head of a sheep, goat or deer and pulling the head until the neck is broken. Cougars kill calves in the same manner as sheep and goats.

Multiple kills of sheep and goats by cougars are common; cases of 100 or more animals in a single incident have been recorded. The U.S. Fish and Wildlife Service Animal Damage Control in Utah documented an incident in June 1985 where cougars killed 6 adult sheep and 112 lambs in one incident Usually only 1 or 2 of the sheep are fed upon by the cougar.

Larger animals such as deer, elk (*Cervis canadensis*), horses, cattle, and probably bighorn sheep (*Ovis* spp) are killed by cougars leaping on the shoulders or back and breaking the neck. Claw marks on the neck, face, back, and shoulders are characteristic of these kills The neck may be broken by the bite or when the animal falls.

Cougars often carry or drag their kills to a secluded area to feed, leaving frequently leaving drag marks at kill sites. They may feed on the viscera, neck, shoulders or hindquarters. Like most carnivores, the feeding pattern varies from individual to individual They frequently try to cover their kills with soil, vegetation, or snow The viscera, particularly the rumen, may be covered separately. "Scrapes" or "scratches" composed of mounds of soil, grass, leaves, or snow are often found around carcasses and trails

A cougar's canine teeth are massive compared to coyotes or bobcats The upper canines of an adult cougar are approximately 1 1/2 to 2 1/4 inches apart, the lower teeth are approximately 3/8 to 1/2 inch narrower

Cougar tracks are relatively round and rarely show claw marks Tracks of the front feet of a large adult male may be 4 inches or more long and about the same or slightly less in width; hind tracks are slightly smaller The rear pads of the feet are distinctly different from those of other carnivores Typically there are 2 lobes on the anterior and 3 on the posterior portion of the rear pads

Bobcats A bobcat's hunting and killing behavior is similar to that of the cougar's On small prey such as lambs, kids and fawns, they bite into the skull or back of the neck. There may be claw marks on any part of the body, but they are usually concentrated on the neck, shoulders and ribs On larger prey, they leap on the back and shoulders which also leaves claw marks

Bobcats also bite the neck or throat where they secure a lethal hold on the prey until it stops struggling. This grip over the larynx suffocates the animal quickly and there is little bleeding. They generally begin feeding on the viscera by entering behind the ribs. Bobcats, like cougars, also tend to cover their prey.

Bobcats are serious predators of pronghorn Beale and Smith (1973) found that bobcats were by far the most significant cause of mortality among pronghorn fawns in the Great Basin All fawns killed by bobcats, except the very young, had numerous tooth punctures on the neck just behind the head. Death apparently resulted from strangulation and canine tooth punctures in the neck.

Most kills (66%) took place near some type of dry wash or drainage channel In every instance fawn carcasses were either dragged or carried from the kill sites Small fawns were carried to shrub or tree cover and the only remains were the legs, bits of skin, and skull fragments. Larger fawns were dragged into or toward a wash

About half the time attempts were made to cover the carcass with vegetation, gravel, sand, and hair. Usually the head and hind quarters were the only parts covered. The carcass may be covered, moved and eaten, and covered again. The neck and hind quarters, particularly the anal area were fed upon most often Seventy five percent of the time the bobcat returned to feed again on the carcass.

Adult bobcat canine teeth are normally 3/4 to 1 inch apart and the spacing is easier to see than on fox or coyote kills because bobcats normally do not bite repeatedly

Like cougar tracks, bobcat tracks are round and lack claw marks, but are only 2 to 3 inches in diameter. The rear pad is relatively straight in front, with a lobe at each side of the posterior end (Wade and Bowns 1982).

Bears Grizzly bears (*U. arctos*) are omnivorous and consume large quantities of vegetation and wild fruits in addition to carrion and prey. They will kill any domestic animal but cattle and sheep are their most common prey.

Roy and Dorance (1976) found that grizzly bears usually kill with a blow to the anterior region of large prey which results in a broken skull, neck or shoulder bones. Cattle may have claw marks on the face or shoulders and tooth marks on their head, neck and back. Smaller prey are killed by a bite to the head or neck. Murie (1948) insisted that the grizzly bear does not attack by striking with its paws, but instead seizes and holds its victim with its "arms" so as to administer the killing bite.

Grizzly bears prefer meat over viscera They characteristically cover their prey and readily feed on carrion (Roy and Dorrance 1976).

Black bears (*U. americana*) are also omnivorous and vegetation is a significant part of their diet They attack adult cattle and horses but seem to prefer sheep, goats, calves and pigs. Griffel and Basille (1981) found that sheep killed by bears typically had 2 or more puncture wounds in the nape and/or skull accompanied by subcutaneous hemorrhage. Apparently a deep bite to the nasal or facial regions of sheep induces shock and paralysis. In this respect, the biting and killing method of a bear differ from that of other mammalian predators which involves either suffocation or brain and spinal cord damage

Griffel and Basil (1981) made reference to observations made by sheepmen and predator control agents where: 1) bears straddle and claw the backs of sheep, 2) there were bites to the neck, and 3) there was evidence of clawing and batting One agent reported that he had seen more sheep killed by powerful blows than had been killed by neck bites. They concluded that the usual mode of attack in their study had been a grasping action rather than a striking blow. All subcutaneous hemorrhages were associated with bite wounds, and every bear-killed carcass bore claw-inflicted lacerations over the cervical, thoracic or lumbar regions.

Griffel and Basil (1981) reported that the feeding point of entry was the udder (74%) or the flank (26%); on all lactating ewes the udder was consumed first The heart and liver were eaten next and then the fleshy parts. Bears tend to skin their prey, leaving the inverted skin attached to the bones

Black bears commonly bite and claw the top of the neck and back of cattle, but smaller prey are sometimes killed with a blow to the head or neck. Griffin and Basile (1981) reported more claw marks on black bear kills than grizzly bear kills, and Roy and Dorrance (1976) reported that black bears also readily feed on carrion.

Bear tracks are distinctive with 5 toes and a broad, short pad on the front foot and 5 toes with a triangular pad on the rear foot The rear foot oversteps the front foot in normal travel

Eagles Both bald (*Haliaeetus leucocephalus*) and golden eagles are known to prey on livestock. Eagles are efficient predators and can cause severe losses to livestock. Generally they prey on young animals, primarily sheep and goats, although they are capable of killing adults.

Talon punctures are typically deeper than those caused by canine teeth and are somewhat triangular to oblong in shape. Compression fractures of the skulls of small animals may occur and bruises are common. Small lambs or kids are seized anywhere on the head, neck or body; lambs are frequently grasped from the front or side. Larger animals are killed by multiple talon stabs into the ribs and back. The talons puncture the large internal arteries and/or lungs causing massive internal hemorrhage (Wade and Bowns 1982)

Eagles skin out the carcasses, turning the hide inside out On very young animals the ribs are neatly clipped off close to the backbone and eaten. Sometimes they clip off and eat the mandible, nose, and ears. Often, the palate and floor pan of the skull are removed and the brain consumed.

Eagles may defecate around a carcass, leaving characteristic white streaks of feces on the soil and their tracks may be visible in soft or dusty soil

Beale and Smith (1973) found a 12 day-old pronghorn fawn that had been killed by a golden eagle. They observed eagle feathers, wing marks and foot tracks in the sand. The fawn had talon punctures on the back and side and about 2 pounds of tissue had been eaten from the neck, chest and leg.

Goodwin (1977) observed eagles in the process of killing pronghorn fawns in Wyoming. He concluded that the fawns died from shock, exhaustion, and initial feeding attempts combined with muscle and possible spinal damage. Deep talon cuts were observed in the thoracic and lumbar regions.

Miscellaneous predators Other species including ravens (*Corvus* spp), crows (*Corvus* spp.), magpies, hawks, gulls, hogs and rattlesnakes (*Crotalus* spp) may cause localized problems. It is beyond the scope of this paper to describe these predators in detail

Conclusions

The intent of this paper has been to compile and present the killing and feeding characteristics of the major North American predators as they apply to domestic livestock and game species. The descriptions presented here can be used in conjunction with the slide series developed by Bowns and Wade (1980.Revised), and the photographs in *Procedures for Evaluating Predation on Livestock and Wildlife* (Wade and Bowns 1982).

It is often difficult to determine the cause of death of an animal and to distinguish between the killing and feeding patterns of the different predator species. However, experience and knowledge of physical evidence, such as presented here, should provide a level of proficiency and confidence in the verification of predator kills

Literature Cited

Beale, D.M., and A D Smith 1973. Mortality of pronghorn antelope fawns in western Utah J Wildl Manage 37:343-352.

Bowns, J E. 1976 Field criteria for predator damage assessment. Utah Sci. 37 26-30.

Connolly, G.E., R M. Timm, W.E. Howard, and W M. Longhurst. 1976. Sheep killing behavior of captive coyotes J Wildl. Manage. 40:400-407.

Goodwin, G.A. 1977 Golden eagle predation on pronghorn antelope. Auk. 94:789-790.

Griffel, D.E., and J.V Basile. 1981. Identifying sheep killed by bears. Intermountain For. and Range Exp. Sta Res. Note. INT-313. 4pp.

Knowlton, F.W. 1968. Coyote predation as a factor in management of antelope in fenced pastures. Proc. Bien. Antelope States Workshop. 3:65-74.

Murie, A. 1948 Cattle on grizzly bear range. J. Wildl. Manage. 12.57-72.

Neff, D J., and N.G Woolsey. 1979. Effect of predation by coyotes on survival of antelope fawns on Anderson Mesa. Spec Rep. 8. Res Branch. Ariz. Gane and Fish Dep. 36pp.

Nielsen, D.B. 1975 Coyotes and deer. Utah Sci 36:87-90.

Roy, L D., and M J. Dorrance. 1976. Methods of investigating predation of domestic livestock. Alberta Agri. Dept. Edmonton, Alberta. Can. 54pp

Tucker, R.D., and G W. Garner. 1980. Mortality of pronghorn antelope fawns in Brewster County, Texas Proc. Annu Conf. West. Assoc Fish and Wildl Agencies 12pp.

Wade, D.A., and J E Bowns 1982 Procedures for evaluating predation on livestock and wildlife B-1429 Texas Agr. Ext Serv , College Station 42 pp

White, M. 1973 Description of remains of deer fawns killed by coyotes J. Mammal. 54:29-293.

PUBLIC ATTITUDES TOWARD PREDATORS IN TEXAS

DOUGLAS REITER, Department of Forest Resources, Utah State University, Logan UT 84322-5215

MARK W. BRUNSON, Department of Forest Resources, Utah State University, Logan UT 84322-5215

ROBERT H SCHMIDT, Department of Fisheries and Wildlife, Utah State University, Logan UT 84322-5210

Abstract: A national survey of public attitudes toward wildlife damage management provided the opportunity to extract a data set from Texas respondents on predator management Texas respondents were generally more supportive of predator control for livestock protection than the rest of the U S., although the overall trends were similar. Lethal technologies scored low on a humaneness scale.

A national survey of public attitudes toward a variety of wildlife issues provided an opportunity to explore the attitudes of Texans toward predators A mail survey was sent to 1,500 randomly selected households throughout the United States The sample was stratified into 5 regions: Pacific coastal states (AK, CA, HI, OR, and WA), the intermountain west states (AZ, CO, ID, KS, MT, NE, NV, NM, ND, SD, UT, and WY), Texas and Oklahoma, the southeastern states (AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, and VA), and the northeastern states (CT, DE, DC, IL, IN, IA, ME, MD, MA, MI, MN, MO, NH, NJ, NY, OH, PA, RI, VT, WV, and WI) Each region received 300 surveys.

The population surveyed was adults (18 years and older) living in a household with a telephone Six hundred usable surveys were received, including 85 from Texas Two-hundred surveys were unusable, resulting in an overall participation rate of 47.1%. A telephone survey of 10% of the non-respondents indicated no obvious differences between respondents and non-respondents

Attitudes and beliefs of respondents from Texas were compared to the respondents from the other 49 states, plus the District of Columbia Predator management-related questions and responses are summarized below Means presented below represent the average response on a scale from 1 to 5.

1. On a scale of 1 (strongly disagree) to 5 (strongly agree), more Texas respondents believed that it was acceptable to remove predators that prey on livestock ($\bar{x}$= 4 0) than the rest of the U S ($\bar{x}$= 3.6) (p = 0 02). Asked another way (more generically, i e , "*Predator control is unacceptable*"), there was no difference in mean response scores between Texas respondents mean response 2 2) and the rest of the U.S. ($\bar{x}$= 2 4) (p = 0.09) When asked whether predators are a risk that comes with the business of livestock production, there was no difference between Texas respondents ($\bar{x}$= 3.4) and the rest of the U.S. ($\bar{x}$= 3.5) (p = 0.48).

2. When asked whether it is unacceptable to remove native predators that prey on threatened and endangered species, there was no significant difference between Texas respondents ($\bar{x}$= 2.9) and the rest of the U S. ($\bar{x}$= 2.9) (p = 0.99), again using a scale of 1 (strongly disagree) to 5 (strongly agree).

3 On a scale of 1 (strongly disagree) to 5 (strongly agree), more Texas respondents believed that the careful use of poisons was an acceptable method to control wildlife populations ($\bar{x}$= 2 5) than the rest of the U.S. ($\bar{x}$= 2.2) (p = 0.03), although the overall mean response was negative (i.e , leaning towards "disagree").

4. On a scale of 1 (strongly disagree) to 5 (strongly agree), fewer Texas respondents believed that wildlife population should not be managed by humans ($\bar{x}$= 2.1) than for the rest of the U S. ($\bar{x}$= 2 4) (p = 0 04) On a scale of 1 (strongly disagree) to 5 (strongly agree), more Texas respondents enjoyed hunting ($\bar{x}$= 3 1 vs. 2.6 for the rest of the U.S , p = 0 01)

5. On a scale of 1 (not important) to 5 (extremely important), there were no differences between Texas respondents ($\bar{x}$ = 3.0) and the rest of the U.S (3.2)

when asked how important it was that the federal government be involved in controlling predators that threaten livestock (p = 0.24). Similarly, there were no differences between Texas respondents ($\bar{x}$ = 3.1) and the rest of the U.S. ($\bar{x}$ = 3.2) when asked how important was it that the federal government be involved in removing animals preying on endangered species (p = 0.76).

7. Respondents were asked to rank a variety of wildlife damage management techniques on a humaneness scale, from 1 (not humane) to 5 (very humane). Texas respondents ($\bar{x}$ = 2.2) perceived shooting animals from aircraft as more humane than the rest of the U.S. (1.9) (p = 0.06), however the mean response was still on the "not humane" half of the scale. For calling and shooting, the Texas respondents' mean score ($\bar{x}$ = 2.9) was the same as the rest of the U.S. ($\bar{x}$ = 2.7) (p = 0.26). Although the mean response was still negative, Texas respondents were more positive ($\bar{x}$ = 2.7) than the rest of the U.S. ($\bar{x}$ = 2.2) on ranking the humaneness of poisons for predators (p = 0.004).

8. Texas respondents were very negative toward leghold traps on a humaneness scale, with a mean response score of 1.6, a perception shared by the rest of the U.S. respondents ($\bar{x}$ = 1.7) (p = 0.26). Neck snares and foot snares followed a similar pattern. Texas respondents were more positive toward human guards and livestock herders on a humaneness scale, with a mean response score of 4.4 compared to a mean response score of 4.1 for the rest of the U.S. (p = 0.04).

9. Fertility control ranked high on a humaneness scale with Texas respondents ranking fertility control more humane ($\bar{x}$ = 4.2) than the rest of the U.S. ($\bar{x}$ = 4.0) (p = 0.05). Guard dogs also ranked higher for Texas respondents ($\bar{x}$ = 4.0) than for the rest of the U.S. ($\bar{x}$ = 3.6) (p = 0.03).

Texas respondents overall were more supportive of predator control for livestock protection than respondents from the rest of the U.S. However, like the rest of the U.S., Texan respondents were negative toward lethal control techniques for managing predators. Lethal control alternatives such as shooting, poisons, neck and leg snares, and leghold traps were ranked lower on a humaneness scale than non-lethal methods.

These findings may assist decision-makers and managers in both justifying current programs and in developing a sense of how the public may respond to future programs. However, for the most part these are differences in degree of support or opposition, not in the overall preferred direction of wildlife damage policy.

Funding for this program was provided in part by the United States Department of Agriculture's, Animal and Plant Health Inspection Service (APHIS). However, this publication may not necessarily express APHIS' views.

COYOTES AS PART OF TEXAS' FUR TRADE

JERRY L. COOKE, Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, TX 78744

Abstract: One factor that potentially affects coyote (*Canis latrans*) abundance is recreational and commercial trapping for harvest of coyote fur. Herein I report how the economic impact of coyote pelts has changed from 1979-94 for landowners and trappers from the Texas. Pelt values accounted for over 50% of the variability observed during this 15-year period. The future of this economic incentive for managing coyotes is questionable because of the impending ban by the European Union of furs from North America.

Coyotes enjoy a mixed reputation in Texas. While some farmers and ranchers in Texas view coyotes as vermin (i e , obstacles to the successful operation of their property), others at the opposite extreme view coyotes in their more romantic role of rustic survivors in a mythical "west".

In reality, coyotes are efficient predators whose impacts on the range are as varied as the systems within which they exist. In some areas of Texas, their influence has resulted in stable systems that provide both long- and short-term benefits to landowners (e.g , white-tailed deer (*Odocoileus virginianus*) populations in south Texas). In other areas, coyotes may be responsible for the volatile and unpredictable nature of systems that make economic planning problematic.

The mixed reputation of coyotes is a reflection of landowners' values and the expectations that they have for their properties One way of ameliorating the perceived negative impacts of coyotes on the range is by making their management a positive economic element in a landowner's operation Historically, this has been accomplished through the fur trade.

Harvest trends

The reported harvest of coyotes in Texas has varied over the past 15 years, but has generally followed a downward trend (Fig 1) The period 1980-87 demonstrated a flat but variable harvest of pelts, while 1988-94 showed a similar pattern, but at a significantly reduced level Over this 15-year interval, income from these pelts in Texas has dwindled from over $1.6 million in 1979 to less than $200,000 in 1994 (Figure 2).

Some preservation groups have pointed to the declining coyote harvest (and fur harvest in general which reflects similar trends) as an indicator of overharvest. They often use these data to support proposals calling for increased protection of all furbearing animals. Such efforts by preservation groups have resulted in the banning of leg-hold traps in some communities, and in some cases, has resulted in the banning of all trapping within a state (e.g , Arizona).

The validity of such an argument is simple to evaluate. If the reduction of harvest was due to declining numbers of coyotes, one would expect prices per pelt to increase in the face of a stable demand and declining supply. In other words, a stable demand and a declining supply should be demonstrated by a negative correlation between price per pelt and number of pelts taken

In Texas however, price per pelt reflects a similar pattern to number of pelts taken (Figure 3), and the relationship between these 2 variables is significantly similar (X_1 is positive, $df = 13$, $F = 16.09$, $P \leq 0.001$). Price alone explains over 50% of the variation in number of pelts taken ($R_{ADJ}^2 = 0.52$). This suggests that pelt price rather than the availability of coyotes for harvest regulates the number of pelts taken in Texas. There is no indication that coyote populations in Texas are declining

Conclusions

This very simplistic analysis of Texas fur harvest suggests factors that influence price per pelt regulate coyote harvest in Texas to a large degree. Fashion, and the changing custom of wearing fur garments, may be significant among these factors Fur houses in New York and elsewhere announce the prices that will be paid for pelts from the various furbearing species, and trappers then decide whether it will be feasible to trap rather than follow some other economic pursuit.

Some have suggested that trappers have been forced to give up trapping because of this economic relationship, and may not be able to return to trapping even if prices returned to 1979 levels. While the European Union's ban on furs from North America is expected to have a major impact on the fur market in the United States, it's influence on coyote harvest in Texas may not be significant The 1994 harvest of approximately 20,000 pelts does not suggest a highly organized trapping effort.

The loss of a viable market for coyote fur may place more emphasis on coyote removal as an active or proactive management strategy for other species. This may be difficult if many who have traditionally been trappers have taken up other sports or vocations. It cannot be assumed that coyote removal will be coincidental to normal fur harvest if fur harvest is not continued as a commercial pursuit.

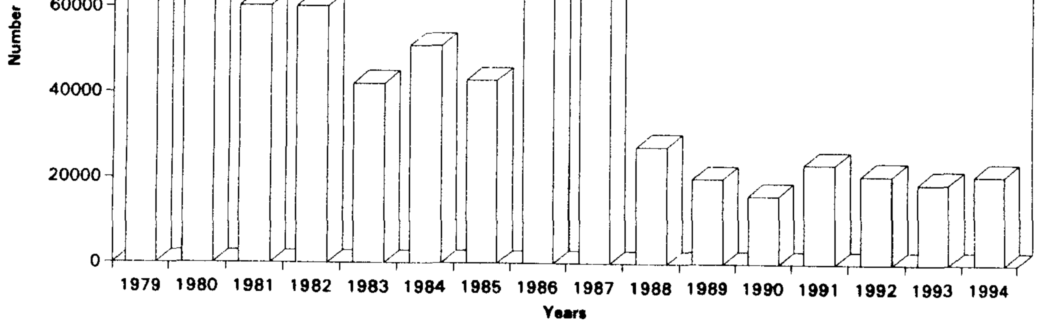


Figure 1. Number of coyote pelts sold in Texas from 1979-94.

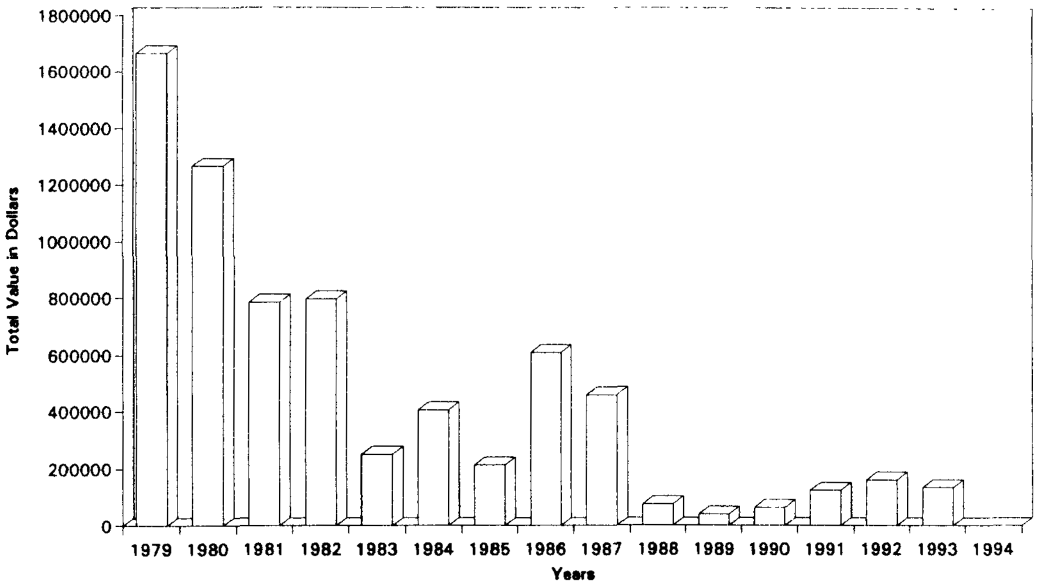


Figure 2 Value of coyote pelts sold in Texas from 1979-94.

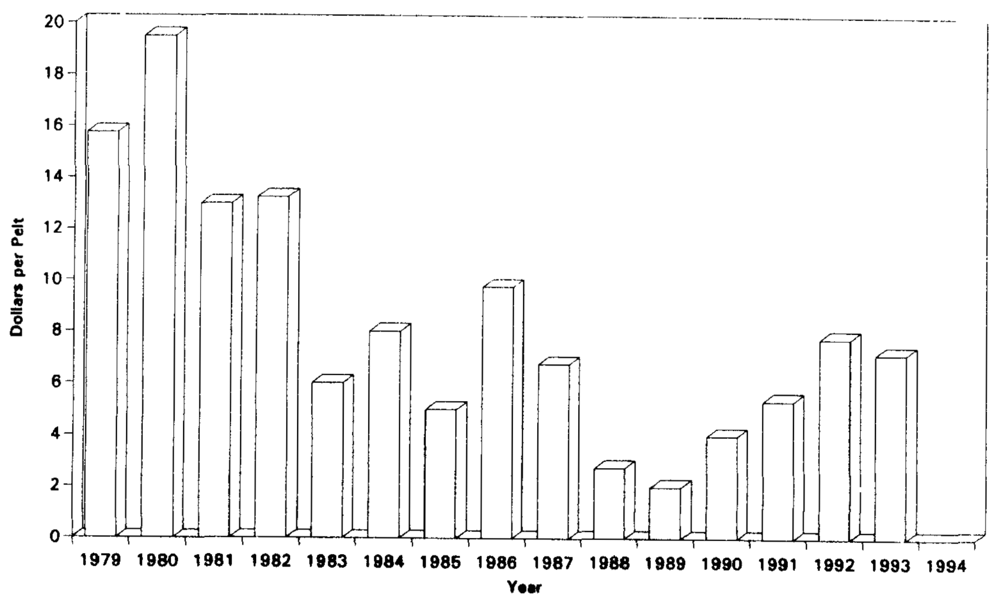


Figure 3. Average price for a coyote pelt sold in Texas from 1979-94

PRESCRIBED COYOTE CONTROL TO DEVELOP AN "OPEN WINDOW POLICY" FOR ENHANCING DEER SURVIVAL

TOMMY L. HAILEY, Texas Parks and Wildlife Department, Ivan Star Route Box 67, Breckenridge, TX 76424

Abstract: Management of white-tailed deer (*Odocoileus virginianus*) holds a high priority on many Texas ranches today The use of "prescribed aerial control" of coyotes to increase white-tailed deer productivity may provide wildlife managers with an economical management tool. I describe two case studies of ranches in the Lower Rolling Plains where prescribed coyote control has increased the deer herds

Today's wildlife managers are faced with producing a commodity that is acceptable to both landowners and hunters. The development of a productive white-tailed deer herd that can sustain an annual harvest will satisfy this need, by providing landowners with additional income and hunters with a quality recreational opportunity

However, there are many factors that affect the production of wildlife that is being managed Factors such as drought and above normal rainfall, with its associated flooding, are beyond the control of wildlife managers However, livestock grazing, harvest quotas, brush clearing and predation can be controlled, indeed manipulated, to enhance wildlife populations and their habitat.

The enhancement of wildlife habitat is of critical importance to the manager since habitat is the basis of production for any species. Other aspects of population management which are of prime importance to the wildlife manager are the genetic quality of the herd, deer density, sustained recruitment into the herd, and proper harvest quotas

I will report on two case studies (i e , ranches) where I have worked in recent years to manipulate coyote densities as a tool for increasing deer survival

Davenport Ranch-Fisher County

In September 1986, I had the opportunity to begin work with Mr Bob Davenport on a wildlife management plan for the 9,600-acre ranch he owns and operates in Fisher County, Texas. This ranch lies within the Lower Rolling Plains geographic area and is very typical of this region. The ranch is comprised primarily of low rolling hills bisected by one major drainage with numerous draws Mesquite (*Prosopis glandulosa*) is the dominant woody species inhabiting the upland, with light to moderate stands of western soapberry (*Sapindus drummondii*), chittam (*Bumelia lanuginosa*), elm (*Ulmus* spp), cottonwood (*Populus deltoides*), and associated small brush species occurring in the water courses

A helicopter survey was conducted on September 23, 1986, to determine the status of the white-tailed deer herd and turkey population (Table l; Fig. 1). A total count of the ranch indicated a deer density of 1 deer per 105 acres; a low population level considering the availability and condition of the deer habitat on this ranch During the survey, we observed 17 coyotes and only 12 white-tailed deer fawns. When we calculated the fawn:doe ratio, this ranch had only a 21% fawn survival, compared to an average 61% fawn survival on other managed ranches in the same general area (Table 1).

Deer management recommendations were made which included control of the coyote population, establishment of food plots, use of commercial high protein feed during vegetatively stressful periods and proper harvest of the deer herd A predator control program was initiated on the ranch during the winter and spring of 1986-87 which removed 54 coyotes by ground control (calling) and aerial hunting The majority of those coyotes were removed by aerial hunting

Controlling the coyote population just prior to the deer fawning period is referred to as the "*Open Window Policy*". The primary purpose is to allow deer fawns in a heavily-populated coyote area from 6 to 8 weeks of relative freedom from the coyote

Table 1. Deer population data recorded from aerial surveys on the Davenport Ranch, Fisher Co., TX, 1986-94.

Year	No. Deer Observed	Acres/Deer	Fawn Survival for: *Ranch* (%)	*Area* (%)	No. Coyotes Removed
1986	91	105	21	61	0
1987	146	66	74	65	54
1988	169	57	59	55	43
1989	168	57	56	51	62
1990	208	46	72	60	14
1991	202	48	67	59	5
1992	255	38	54	50	8
1993	-	-	-	-	-
1994	241	40	45	47	11

predation After 8 weeks, fawns are probably mature enough to start running with the does, hence less vulnerable to coyotes

The next year, a helicopter survey was conducted on November 1, 1987 This survey indicated a deer density of 1 deer per 66 acres, 74% fawn survival and a reduced coyote population, with just 7 coyotes being observed during the flight. The average fawn survival for other managed ranches in the area was 65%. The aerial hunting method, utilizing a helicopter, was again used to reduce the coyote population in April 1988, which resulted in the removal of 43 coyotes

The following fall, the aerial survey conducted on October 4, 1988, indicated a deer density of 1 deer per 57 acres, 59% fawn survival and 23 coyotes were observed during the flight The average fawn survival for other managed ranches was 55 %. Control measures, with the use of a helicopter, were again brought to bear on the coyote population during April 1989, when 37 coyotes were removed.

In the fall of 1989, due to the availability of the helicopter, aerial hunting of coyotes was implemented just prior to the aerial deer survey. On October 3, 1989, 25 coyotes were removed, bringing the yearly total for 1989 up to 62 coyotes removed from the ranch. The result of the aerial survey that fall indicated a deer density of 1 deer per 57 acres with a 56% fawn survival. The average fawn survival for other managed ranches was 51%.

In the following 3 years, 1990-92, a total of 27 coyotes were removed from the ranch by aerial hunting. This total includes 14 coyotes removed in October, 1990, 5 removed in October 1991, and 8 removed in November 1992. Aerial deer surveys conducted during 1990, 1991, and 1992 indicated deer densities of 46, 48 and 38 acres per deer, respectively The fawn survival percentages for this 3-year period were 72%, 67% and 54%, respectively. These data compare to an average fawn survival for other managed ranches in the area of 60%, 59% and 50%, respectively during the same 3-year period.

In 1993, no coyote control measures or aerial deer survey was conducted In the fall of 1994, aerial hunting of coyotes was used to remove 11 coyotes from the ranch. The aerial deer survey for 1994 indicated a deer density of 1 deer per 40 acres and a 45% fawn survival The average fawn survival for other managed ranches in the area was 47%.

Since the start of the management program on the ranch in 1986, when 91 white-tailed deer were observed (1 deer per 105 acres) and predator control measures were subsequently implemented, the deer herd has been increasing with a concomitant decrease in the coyote population. By 1994, the observed deer population had increased to 241 animals with only 11 coyotes being seen and subsequently removed from the ranch.

Hooker Ranch-Haskell County

In 1992, I received a request from Jane Hooker, of the Hooker Ranches, for management recommendations on their 7,826-acre ranch in Haskell County. This ranch also lies in the Lower rolling Plains area. A helicopter survey conducted on October 9, 1992 counted 82 white-tailed deer (1 deer per 95 acres) (Fig. 2). Seventeen white-tailed deer fawns were observed, indicating a 50% fawn survival, and 34 coyotes were seen during the same flight The average fawn survival on other ranches in the area was also 50%

Based on these data, I recommended that a 2-hour helicopter flight be conducted for coyote control during the spring of 1993 to provide the deer herd with the *"Open Window Policy"* to enhance fawn survival. The flight was conducted on April 19, 1993, with 33 coyotes being observed and 32 removed.

On October 5, 1993, an aerial survey was conducted on the ranch with 106 white-tailed deer recorded (1 deer per 74 acres), 11 coyotes were observed during the flight Deer fawn survival was 87% based on the observation of 34 fawns during the survey. This compared to an average fawn survival of 57% for other area ranches during the same year

On April 19, 1994, a 2-hour helicopter flight detected and removed 14 coyotes. On September 29, 1994, an aerial survey counted 101 deer (1 deer per 78 acres) and only 2 coyotes Fawn survival was 62 % based on the observation of 28 fawns during the survey. The average fawn survival for other area ranches was 47% The area where the ranch is located was subjected to extremely dry conditions during the period from late- May through September.

During the aerial survey conducted on October 9, 1992, 3 feral hogs were observed. However, the next aerial survey (October 5, 1993) detected 33 feral hogs with 25 of them being young of the year. Additionally, numerous occurrences of rooting activity were located throughout the ranch during the flight. The September 29, 1994, aerial survey recorded only 14 feral hogs (5 of them young of the year) with no indication of fresh rooting being observed The extremely dry summer of 1994 may have forced the hogs to move the short distance south to the Lake Stamford area.

The *"Open Window Policy"* is an attempt to enhance fawn survival through the use of an economical control method for coyotes that can be applied to ranches in the Lower Rolling Plains area.. The average yearly cost of such a control method will be in $500 to $600 range. However, this cost can easily be justified with the increased revenue generated from the harvest of additional white-tailed bucks.

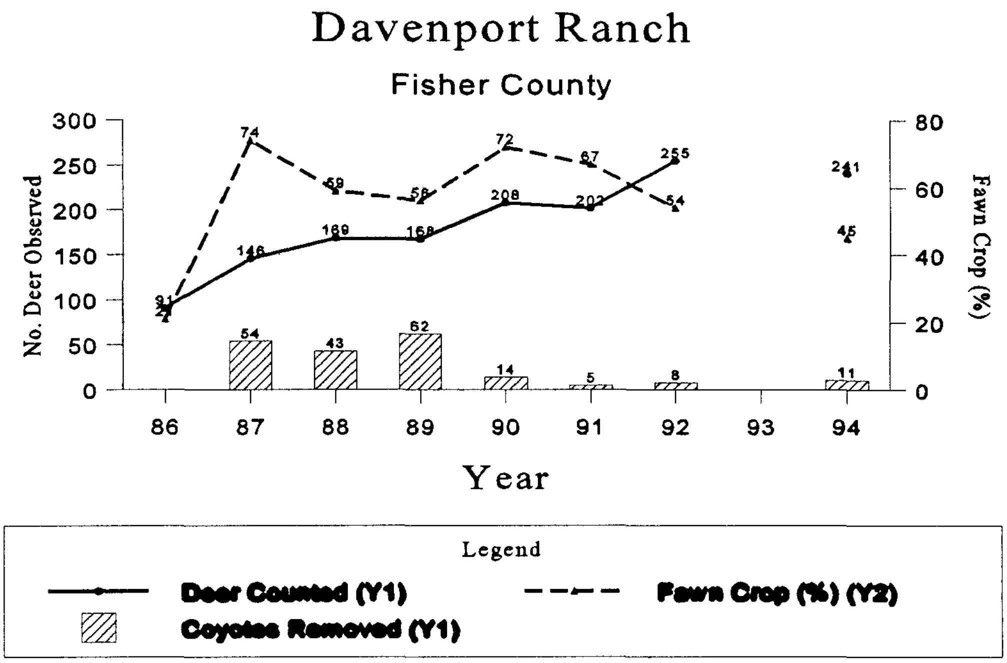


Figure 1. Deer population trends estimated by aerial surveys on the Davenport Ranch, Fisher Co., TX, 1986-94.

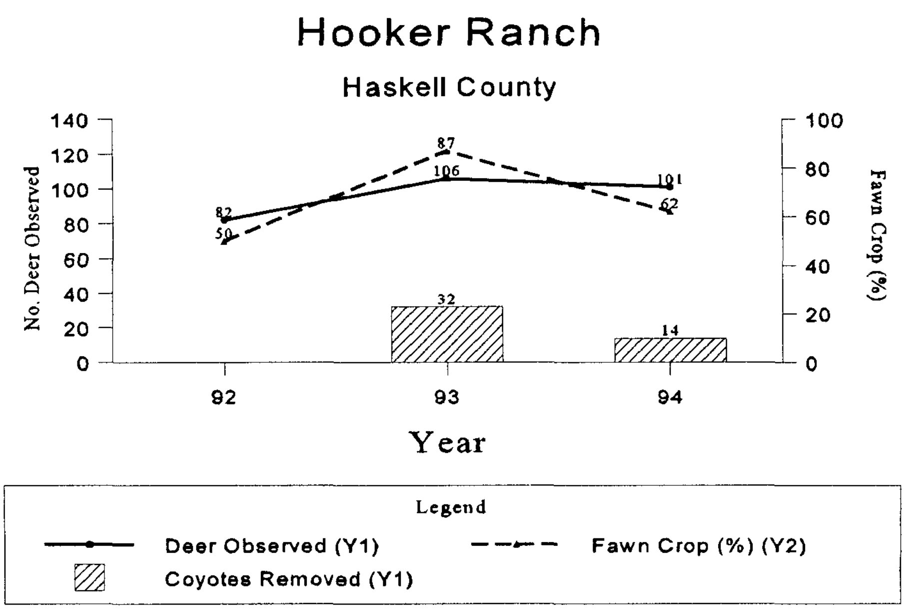


Figure 2. Deer population trends estimated by aerial surveys on the Hooker Ranch, Haskell Co., TX, 1992-94.

COYOTES: A POTENTIAL ROLE IN DEER HERD MANAGEMENT?

ROBERT E. ZAIGLIN, Harrison Interests, Ltd., 602 Dorothy Jo, Uvalde, TX 78801

Abstract: White-tailed deer (*Odocoileus virginianus*) herd control is one of the principal problems faced by private lands game managers. Private landowners unwilling to permit adequate numbers of sport hunters on their lands force deer managers to exercise other harvest strategies, one of which is natural population control by protecting the coyote (*Canis latrans*). I describe an ongoing case study in South Texas where predation by coyotes may be considered a positive tool in deer population management.

Predation by coyotes on white-tailed deer in South Texas is recognized as one of the major contributing factors to deer mortality. The combined impact of disease and predation represents the major causes of fawn mortality, with losses exceeding 50% of the fawn crops in some years (Cook et.al. 1971).

Population studies conducted on the Welder Wildlife Refuge in South Texas indicated that fawn mortality is the major factor stabilizing this dense and generally healthy herd (Knowlton, 1964).

Beasom (1974) demonstrated that deer populations in South Texas could be increased with a very intensive predator control program. Since coyotes represent the primary predator of deer (excluding man) in South Texas, and many deer herds are increasing uncontrollably, it may be wise to consider the coyote as a management tool instead of a hindrance, particularly on large land tracts The following is my personal view of the coyote and the role it plays in the intensive deer management program conducted on the Harrison Piloncillo Ranch.

Study area

An intensive deer management program was established on the Harrison Piloncillo Ranch in 1983. The objective of this program was to enhance and sustain the quality of deer on the ranch in conjunction with generating some income from deer hunting

The 107,000-acre ranch is located approximately 4 miles south of Catarina, Texas and lies at the junction of Dimmit, Webb, and LaSalle counties. The ranch is not high-fenced; however, it is divided into 2 management units: (a) the core area and (b) the peripheral unit, which takes in portions of both sides of U.S. Hwy. 83. The peripheral unit is leased or package-hunted commercially in order to serve as a buffer zone protecting the core area from external hunting pressure

Vegetation is dominated by a woody brush overstory with a diverse herbaceous association dependent upon seasonal precipitation. Associations of cenizo, guajillo, blackbrush, Texas kidney wood, and brazil occur on upland shallow, sandy loam soils. Upland areas with deep soils are characterized by honey mesquite (*Prosopis glandulosa*), prickly pear (*Opuntia* spp.), Texas hog-plum (*Colubrina texensis*), and desert youpon (*Schaefferia cuneifolia*). Woody species such as honey mesquite, whitebrush (*Aloysia gratissima*), granjeno (*Celtis pallida*), Mexican persimmon (*Diospyros texana*), and huisache (*Acacia smallii*) occur on the deep loamy, bottomland sites.

Topography varies from areas with little relief to gently rolling terrain interspersed with drainages. The dominant soil type is fine sandy loam. Average annual rainfall is 22 inches for this region.

No supplemental feeding for the deer is conducted, however, a total of 206 acres (36 plots) are planted to oats annually. These planted food plots represent a substantial amount of highly-digestible forage during the critical "late-winter" period when bucks are recovering nutritionally from the rut. The food plots also enhance selectively harvesting of deer. For example, the efficient harvest of older bucks exhibiting undesirable antler qualities, and the prevention of harvesting buck fawns during our doe harvests, are facilitated simply by allowing hunters adequate time to adequately judge their target.

Roller-chopping along roadways is conducted on an annual basis Approximately 10 miles of roadsides are chopped annually, with widths varying from 50 to 150 feet By reversing the successional stage of plant growth by roller-chopping, an additional source of high-quality forage is made available to all game species Roads are chopped on a three-year rotation.

Prescribed fire is also part of the program; however, the acreage burned is dependent on the fuel load. These fuel loads are dependent on the climate, which can vary dramatically on an annual basis.

White-tail deer are the only big game animals on the ranch. Coyotes are abundant and protected They represent a significant impact on both fawn survival and post-rut mortality in bucks

Cattle grazing (by steers) occurs, but never exceeds one animal unit per 40 acres Grazing is lightest to non-existent within the center of the core area. Depredation of cattle by coyotes has not been observed.

Deer population management

Since 1983, a total of 345 bucks has been harvested from the core area The harvest of mature bucks ranges from one adult per 1,666 acres to one adult per 4,230 acres The buck harvest is controlled at a low rate in an attempt to increase the number of bucks reaching the older age classes of 6 years or older, at which time our harvest data indicates the largest antlers are developed.

Since 1983, a total of 1,325 does has been removed from the core area. Lactation data are collected from all females harvested Percent lactation of 1 5-year-old-plus does ranged from a low of 9% in 1992 to a high of 62% in 1985.

Problems in attaining an adequate doe harvest on private land can be numerous First, the private landowner must be convinced of the necessity of a female deer harvest Second, large numbers of hunters are normally required to accomplish an adequate doe harvest on large landholdings. The problem here lies in the fact that few landowners are willing to open their gates for a large number of outsiders Thus, the manager must design the harvest to fit the landowner's goals and personal feelings By protecting the coyote, I feel that the number of doe hunters can be reduced, and the ultimate goal of herd reduction accomplished .

A genuine concern when protecting coyotes in order to enhance herd control is the indiscreet manner in which they kill Obviously, most deer managers prefer to select which animal (at least sex) that is harvested. The coyote is a non-selective predator and will kill adult post-rutting bucks as well as doe and buck fawns However, for those landholdings closed to sport hunting, the coyote may be the only population control factor (other than the climate) and thus must be understood and utilized

Population estimates are based on aerial helicopter surveys conducted on 15,000 acres (27%) of the core area Since 1982, 1 year prior to the initial doe harvest, the sex ratio has ranged from 2.4 does per buck in 1982 to 0 8 does per buck in 1986.

With the combination of a sport doe harvest, predation by a high population of coyotes, and a low harvest rate of bucks, the sex ratio was reduced to favor bucks from 1986 through 1989 As a result of the altered ratio, natural mortality, particularly post-rut mortality, increased in the bucks. For example, 3 pairs of bucks were discovered in the antler-locked position in 1987. The low probability of this occurring, combined with the even lower probability of discovering the animals on such a large land mass, forced us (by request of the landowner) to reduce our doe harvest in the core area beginning in 1990. As a result, doe numbers rebounded to 1.5 does per buck by 1994

Buck numbers continued to rise from 187 bucks counted in 1985 to 457 in 1994, based on aerial helicopter surveys Overall deer density increased from 1 adult per 36 acres in 1985, 2 years following the intensive doe harvest, to 1 adult per 13 acres in 1994.

Food for thought

Based on this information, our harvest scheme, which included coyotes as a harvesting mechanism, impacted the herd dynamics initially, i.e., doe numbers decreased and buck numbers increased However, once the doe harvest was reduced in 1990, it became obvious that coyotes alone could not hold this population at a static level

In conclusion, it is my opinion that predation by coyotes, in conjunction with low intensity doe harvests (typical in this area), can control deer numbers on large (non high-fenced) management areas Thus, on land tracts owned by individuals unwilling to allow adequate hunters on the land to reduce doe numbers, the coyote represents a viable tool in deer harvest management

Literature Cited

Cook, R. S., M White, D O. Trainer, and W. E. Glazener 1971. Mortality of young white-tailed deer fawns in South Texas. J. Wildl. Manage 35:47-56.

Knowlton, F F 1964. Aspects of coyote predation in South Texas with special references to white-tailed deer Ph D Thesis, Purdue University. Lafayette, Indiana. 189pp

MANAGEMENT OF COYOTES FOR PRONGHORN?

S. KEMBLE CANON, Division of Range Animal Science, Sul Ross State University, Alpine, TX 79832

Abstract: Coyotes (*Canis latrans*) and pronghorn (*Antilocapra americana*) have co-existed for thousands of years, but in today's production-oriented society the pronghorn may need some help periodically. Although pronghorn numbers have rebounded dramatically since the early 20th century, continued management of this species is necessary and may include "management" of its primary predator, the coyote. Pronghorn defense mechanisms offer protection from predators, but the coyote's hunting strategies overcome these mechanisms The Trans-Pecos region of Texas holds the greatest numbers of pronghorn in the state. Ranchers in the Trans-Pecos can use predictors, such as rainfall; strategies, such as proper livestock stocking rates and pasture deferment; and tools, such as predator control, to help manage pronghorn populations in the presence of coyotes.

Coyotes and pronghorn have co-existed in North America since the Pleistocene epoch In this co-evolutionary process, each of these species has evolved behavioral, morphological, and physiological mechanisms which allow both the predator and prey species to survive. However, with the influence of human expansion and associated impacts, it has become necessary to implement management practices which enhance pronghorn survival.

In the Trans-Pecos of Texas, most of the emphasis in pronghorn management has been toward population manipulation through hunting, water distribution and fencing improvements, and predator control. In recent years, predator control has been a controversial subject, largely because of the increased influence of groups concerned for the "rights" of animals The necessity of predator control in healthy prey populations also has been questioned by many in the scientific community.

The purpose of this paper is to investigate the overall relationship between the pronghorn and coyote in the southwestern United States. Hunting and survival mechanisms, and management of the pronghorn-coyote interaction will be discussed. Specific emphasis will be placed on the Trans-Pecos region of Texas

Historical perspective

The return of the North American pronghorn to much of its native range has been a success story in modern wildlife management. Estimates of pronghorn numbers prior to European settlement range from 40 to 60 million animals. However, with the arrival of settlers and more efficient methods of hunting, fueled by market demands of consumers in more populated areas, pronghorn populations in the United States declined to approximately 10,000 animals by 1900 (Yoakum 1980). By 1924, populations had increased to about 24,000, largely the result of a greater emphasis on conservation. Since that time, through proper management and translocation practices, pronghorn populations in the United States have increased to over 800,000 animals (V W Howard, New Mexico St. Univ., pers commun 1990).

Some southwestern pronghorn populations have undergone similar fluctuations, while others have not fared as well For example, American pronghorn (*A. a. americana*) populations in northern Arizona have fluctuated as described above, with major declines in the late 19th and early 20th century, and subsequent increases to a relatively stable number Conversely, those subspecies in more severe, arid regions such as the Peninsular pronghorn (*A. a. peninsularis*) of southern California and Baja California, and the Sonoran pronghorn (*A. a. sonoriensis*) of the Sonoran Desert region, have never recovered from the original declines and are currently listed as endangered Still others, such as the pronghorn of the Trans-Pecos region of Texas, which occupies overlapping ranges of both the American pronghorn and the Mexican pronghorn (*A. a. mexicana*), have maintained relatively stable numbers throughout these time periods.

The Trans-Pecos historically has been a stronghold for pronghorn populations in Texas. With the advent of the cattle industry, and subsequent installation of watering facilities in the late 1800s, many marginal areas became productive habitats for pronghorn and other wildlife species. This, coupled with the predator control efforts and protection provided by some concerned ranchers of the early 1900s, resulted in increased numbers of Trans-Pecos pronghorn from 1924 to 1939, when herds in other parts of the state remained relatively static (after suffering severe declines in earlier years).

Trans-Pecos herds were healthy enough to permit translocation of over 4,000 animals to other parts of the state from 1939 to 1956. Overall, Trans-Pecos pronghorn levels remained relatively stable from the late 1950s to the early 1990s with intermittent, long-term droughts causing the most severe fluctuations (Hailey 1986).

Pronghorn defense mechanisms

The pronghorn has evolved several defense mechanisms which enhance survival, especially as it relates to predation. Most of these mechanisms are further enhanced by, and have naturally evolved in, the open, expansive habitats preferred by pronghorn. In adults, speed may be the most important defense against predation Adult pronghorn can reach 40 mph with relatively little effort, and speeds in excess of 50 mph are not uncommon. Pronghorn have extremely acute vision at long distances and the large, protruding eyes located on the side of the head enhance peripheral vision as well. A white rump patch which flares up when the animal is alarmed provides a visual signal to other pronghorn when danger approaches Another alarm signal, the "cough", provides an auditory signal for other animals in the group. In close encounters with predators, pronghorn will also use their horns for defense, although all females do not grow horns

Strategies or mechanisms to prevent depredation of young pronghorn include both inherent morphological and physiological characteristics as well as behavioral responses of both fawns and adults. In pronghorn fawns, 4 basic strategies are effective in preventing predation: (1) cryptic coloration or camouflage, (2) lack of early scent gland development, (3) ability to lie motionless for long periods of time, and (4) selection of proper concealment in bedding behavior (Alldredge et al. 1991).

Pronghorn dams also employ strategies for protection of young such as (1) leaving fawns bedded in isolation for relatively long periods of time, resulting in less likely attraction of predators, (2) cleaning of young to eliminate fecal and urinary odors, (3) simple protective behavior involving attacks of predators by dams (and bucks), and (4) visual and auditory alarm responses as mentioned above.

Herd characteristics which enhance survival include grouping behavior when danger approaches and synchronization of fawning dates. Grouping behavior tends to enhance survival by reducing the probability of individual animals being depredated. Synchronization of birth is thought to reduce predation of newborns (Rutberg 1987) through (1) "swamping" (ie. large numbers of young born in a short period of time exceed the nutritional demands of the predator population), (2) group defense (maternal protective instincts are compounded by groups of dams with fawns), and (3) the "confusion" factor (i.e., the ability of the predator to select a specific target may be reduced in a group of dams with fawns, rather than isolated fawn/doe pairs).

Coyote hunting strategies

Although the evolved defense mechanisms of pronghorn are many and varied, coyotes have responded with hunting strategies which enhance their ability to capture pronghorn, especially fawns. Coyotes may hunt individually, in pairs, or in small family units.

When hunting individually, a coyote may employ 2 primary methods. The first, I refer to as the "-search and destroy" tactic in which an individual coyote will, apparently somewhat methodically, search an area until a prey species is found and attacked This is particularly effective on newborn fawns exhibiting cryptic behavior (lying motionless).

The second method used by individual coyotes involves seeing or smelling the fawn and simply stalking and/or chasing it. In selecting prey by age, sex, or health status, an individual coyote is more likely to select smaller or weaker individuals (fawns, seldom does, and very infrequently bucks), because coyotes are simply not equipped physically to effectively kill larger animals in an efficient manner. In selecting smaller prey species, individual coyotes are less likely to be discriminatory and more likely to be opportunistic

Coyotes also hunt in family units (i.e., packs) and in this style of hunting, attacks on larger animals are more likely. In pack behavior, coyotes may hunt by either stalking or pursuit, but generally pursuit of prey is most common. It is often suggested that coyotes will use a "relay" technique in which they alternate amongst each other to progressively wear down the prey animal. Based on the relative "intelligence" of coyotes and numerous personal communications with witnesses of this behavior, I am convinced that the coyote is capable of such teamwork.

A form of stalking is also exhibited by family units of generally 3 to 5 animals in which the coyotes surround the prey species and gradually close in to overwhelm the prey with sheer numbers. In general, coyote packs are most likely to capture smaller, weaker, or lame individuals, however healthy adults are also susceptible.

One other hunting behavior exhibited by coyotes, specifically on pronghorn, may indicate an ability to use a "tool" of sorts to aid in capture Coyotes have been observed in the Trans-Pecos "herding" pronghorn to fences, which the pronghorn will not cross if the fence is made of net-wire In this way, the coyote may actually be using the fence to facilitate capture

Pronhorn defense vs. coyote strategy

In the evolutionary and annual battle between coyotes and pronghorn, the "victor" varies among years, climatic regimes, and habitat types. The relationship between coyotes and pronghorn is extremely complex and is affected by such factors as the previous and current year's precipitation, available hiding cover, nutritional status of the dam, forage availability, alternative prey species, and other factors.

Research conducted on the effect of coyote predation on pronghorn populations generally has indicated that coyotes are very effective predators of pronghorn fawns during their first 30 to 60 days of life (Autenreith 1982, Barrett 1984, Hailey 1986). Coyote predation was the primary cause of low fawn survival on Anderson Mesa in Arizona (Neff et al. 1985), and increased fawn survival was attributed to coyote control (Smith et al. 1986). In a southeastern Colorado study, coyote predation was believed to be responsible for 71% of fawn mortality (Gese et al 1988) Mortality of radio-equipped fawns in Montana was 90 and 93% in 2 separate years in 1 portion of the National Bison Range; coyote predation was the primary cause of death (Corneli 1979). Fawn survival rates in southeast New Mexico were 14% greater in 2 of 3 years in a coyote-controlled versus non-controlled area (Larsen 1970). Other studies have also have shown evidence of coyote predation on pronghorn fawns varying from 12 to 31% of known fawn mortality (Barrett 1978, Beale 1978, Bodie 1978).

Trans-Pecos pronghorn predation

In the Trans-Pecos, predation of adult pronghorn is uncommon primarily because those predators commonly occupying pronghorn habitat (coyotes, bobcats, golden eagles) are largely incapable of killing adults. Mountain lions, although certainly capable of stalking, capturing, and killing pronghorn, do not tend to occupy the same habitat Additionally, diseases and parasites do not commonly affect Trans-Pecos pronghorn seriously because of the arid climate (Hailey 1986, Canon 1993).

Thus, with the absence of these sources of mortality, adult pronghorn in the Trans-Pecos have a high probability of living a relatively long life, except in long-term drought situations. Such d-roughts can result in large losses in isolated pronghorn herds (Buechner 1950, Hailey 1986) and can be especially detrimental where net-wire fences do not allow free movement of these herds

Pronghorn fawns in the Trans-Pecos, as in other areas, are highly susceptible to predation In a study conducted in Hudspeth County of the western Trans-Pecos, 81% of 101 radio-equipped fawns were killed by predators over 3 fawning seasons Sixty six fawns were killed by coyotes, 6 by mountain lions, 5 by bobcats, and 4 by golden eagles (Canon 1993). Eighty percent of depredated fawns were killed within the first 30 days of life and 95% within the first 60 days of life, supporting the notion that the most critical period for pronghorn is the first 30 to 60 days of life.

Coyotes were especially efficient at finding and capturing fawns, both individually, and in pairs or family units. All of the hunting strategies described previously were witnessed by the author at some point during the 3 years except the "relay" technique, which probably wasn't necessary on fawns The "search and destroy" tactic appeared to be the most common, based on the number of times coyotes were seen (Canon 1993).

Denning pairs of coyotes appeared to be particularly effective at finding and destroying fawns. Fawn remains were found near the 3 dens that were found, and the radio transmitters were near 2 of them. In "Buckhorn" valley, the center of which contained a coyote den during one of the fawning seasons, 5 fawns were killed in 1 night and several others over the course of the fawning season; (the night after we found the den, the pups were moved by the pair to another "undisclosed" location) After losing several fawns in another area, a radio transmitter was found next to an active den close to the center of the area.

Transient coyotes also appeared to be attracted to the area during fawning season based on the number of coyote sightings during the peak fawning period. Coyote scats on roads also were more frequently noted during this time period

Fawn habitat

In the Hudspeth County study (Canon 1993), fawn habitat was investigated by measuring a series of 23 micro- and macro-habitat characteristics on over 600 fawn bed-sites, and comparing these to the same characteristics on 225 randomly-selected sites. These habitat characteristics also were compared between surviving and non-surviving fawns. The purpose of the habitat evaluation was to identify characteristics of preferred bedding sites, and which of these resulted in greater fawn survival

Several of the habitat characteristics differed between actual and randomly chosen bed-sites, indicating that certain vegetative and physical characteristics were selected by fawns for bedding, rather than random selection. The comparison of most interest, however, was that between surviving and non-surviving fawns. Only a few of the 23 characteristics measured were different between these 2 groups Brush density was greater ($P<0.06$) at bed-sites of survivors than non-survivors. Surviving fawns bedded more often ($P<0.05$) in the flatter terrain where rock cover was inherently less.

Perhaps the most important variable in terms of immediate hiding cover for bedded fawns was the measurement "nearest concealing cover" (NCC). Because fawns tended to bed with their back to a vertical object (clump of grass, shrub, cacti, yucca, rock), I measured the distance from the bed-site to the closest object providing cover. Surviving fawns were more likely ($P<0.06$) to "select" bed-sites with greater immediate (close-range) hiding cover.

Although few of the habitat characteristics differed between surviving and non-surviving fawns, we found that surviving fawns were more likely to bed in flatter areas with greater brush cover (providing more cover in the surrounding macro-habitat), and closer to a tall plant or object (providing more cover in the immediate micro-habitat). Bed-sites next to clumps of taller grasses and yuccas appeared to be favored. Although grass cover in the area surrounding the bed-site was not considered an important factor separating surviving and non-surviving fawns, taller grasses did appear to provide hiding cover As part of the Chihuahuan Desert region, grass cover was extremely variable on the study area. Relative to fawn fate, grass cover was essentially identical among survivor bed-sites, non-survivor bed-sites, and random sites

Management of pronghorn-coyote interactions

The Trans-Pecos region, specifically that portion in the Chihuahuan Desert, does not provide the type of low shrub cover found in most pronghorn habitat in the western U.S However, pronghorn fawn survival in the Trans-Pecos can be enhanced when micro- and macro-habitat cover is available. Micro- and macro-habitat cover may be provided by brush and taller grasses, as in the Hudspeth County study (Canon 1993), or any combination of short- and long-range cover which serves to conceal fawns from predators, primarily coyotes.

Although brush provided macro-habitat cover in that study, such cover can be provided by tall, bunch-type grasses as well. Livestock management practices which promotes taller grasses will allow more compatible co-existence of pronghorn and livestock. Periodic and timely deferment of livestock from known, preferred pronghorn fawning habitat will produce the type of taller, bunch-type grasses that provide better fawning areas.

Unfortunately, the weather of the Chihuahuan Desert is too variable and alternative strategies may be necessary in times of prolonged drought. In order to survive such drought periods, ranchers in this part of Texas may not have the luxury of deferring livestock (primarily cattle in the Trans-Pecos) from fawning habitat. When the grass gets short, and the rain has not come, the rancher has 2 options, either sell (usually in a down market) or move them where there is still some grass left. This situation has occurred over the last couple of years in west Texas

In terms of pronghorn populations, poor nutritional status of adults resulting from the lack of forage, scarce cover remaining in preferred fawning habitat and subsequent poor fawn crops, and other factors, have resulted in substantial declines in Trans-Pecos pronghorn populations Texas Parks and Wildlife surveys show a gradual decline from a high of almost 15,000 pronghorn in the Trans-Pecos region in 1992 to barely half that (7,525) in 1995 (Richardson 1994, M. Hobson, Texas Parks Wildl. Dept., pers. commun) Although a couple of good precipitation years can this decline, a recovery from a decline of this magnitude will take some time

In such situations, on both a local and regional scale, 1 alternative strategy is coyote control. An investigation of pronghorn fawn crops over an 8-year period on University of Texas Lands properties in the Trans-Pecos (S. Sullenger, U.T Lands, unpubl data; Canon 1993) revealed that intensive, relatively short-term control of coyotes in the 2- to 3-month period prior to and during fawning season can result in major increases in the number of fawns surviving beyond the critical 30- to 60-day period following birth

Aerial surveys on the Double U and Baylor ranches in Hudspeth County showed large increases in fawn crops in the first few years following initiation of coyote control (S Sullenger, U.T Lands, unpubl data). Although coyote control continued after these initial years, the effectiveness of control efforts declined. Subsequently, fawn crops began to decline as well, from a high of 61% on all of U.T. Lands in 1985, to a low of 16% on the same areas in 1990.

On the Baylor Ranch, 1990 estimated fawn crops were down to 10%. In early 1991 and again in 1992, the Baylor Ranch hired a trapper to supplement the annual helicopter gunning provided by U.T Lands. The resulting intensive control efforts yielded 78 and 104 coyotes prior to and during the 1991 and 1992 fawning seasons. Fawn crops subsequently increased to 61% and 75% in 1991 and 1992 respectively (approximately 6- and 7-fold increases, respectively, compared to 1990 estimates)

Although increased precipitation in 1991 and 1992 undoubtedly aided in this increase, on the nearby Double U Ranch, where coyote control efforts remained similar to previous years, fawn crops only increased from 16% in 1990 to 35% and 30% in 1991 and 1992, respectively (approximately 2-fold increases each year compared to 1990)

On U T Lands overall, fawn crops increased from 16% in 1990 to 43% and 40% in 1991 and 1992 respectively. (Much of this increase was the result of the large increases from the Baylor Ranch.)

It is apparent, therefore, that timely and intensive coyote control can substantially increase pronghorn fawn crops However, such control efforts are not necessarily required on an annual basis. Further investigation of the effects of precipitation on fawn crops on U.T. Lands revealed that 54% of the variation in current-year fawn crops ($P<05$, $r^2=0.54$, $y = 0.08 + 2\ 97x$) can be explained by the previous year's precipitation total (Canon 1993) In other words, there is a fair correlation between current year's rainfall and next year's pronghorn fawn crop. Thus current-year precipitation may serve as a predictor of sorts to determine the need for coyote control prior to next year's fawning season

Management Implications

Current population estimates in the Trans-Pecos show the lowest total number of pronghorn since before 1977 (Richardson 1994, M. Hobson, Tex. Parks Wildl. Dept., pers. commun.). Barring continued drought, ranchers in the Trans-Pecos may be able to hasten the recovery of these populations by initiating an intensive coyote-control program in the 2- to 3- month period prior to and during fawning season for at least 2 consecutive seasons. Such a program should be a 2- to many pronged approach (2 or more methods of control are employed) Coyote control is not a panacea for pronghorn populations, but it can be used to restore populations to former levels more rapidly

The following management recommendations are suggested:

(1) Proper stocking rates (of cattle, not sheep or goats in pronghorn habitat) will provide an adequate forage supply for pronghorn in most years, and ensure adequate nutrition for lactation. Stocking rates should be remain flexible in these arid environs.

(2) Defer livestock from pastures containing preferred pronghorn fawning habitat for a period long enough to provide hiding cover (tall growth of bunch-type grasses) for fawns. Continue deferment for 30 to 60 days beyond the peak of fawning season. Ideally, such deferment should be provided at least every 2 to 3 years

(3) Monitor annual rainfall to aid in determining the necessity for coyote control the following year If this year's rainfall is well below average, coyote control is recommended prior to (and possibly during) the following fawning season. (The assumption here is that next year's rainfall will be better, which is not always the case of course.)

(4) In declining populations, or in populations below the estimated carrying capacity, intensive coyote control (as above) may speed recovery, or growth, to desired levels "Intensive" control must effectively reduce coyote populations until at least 30 days after the peak of fawning season

(5) In most "normal" years, coyote control is probably not necessary except for the control of specific depredating individuals

Literature Cited

Alldredge, A.W., R.D. Deblinger, and D. J Peterson. 1991. Birth and fawn bed site selection by pronghorns in a sagebrush-steppe community. J. Wildl Manage. 55:222-227.

Autenreith, R.E 1982. Pronghorn fawn habitat use and vulnerability to predation. Proc. Pronghorn Antelope Workshop 10:112-131.

Barrett, M W. 1978. Pronghorn fawn mortality in Alberta. Proc. Pronghorn Antelope Workshop 9:429-444.

______. 1984. Movements, habitat use, and predation on pronghorn fawns in Alberta. J. Wildl. Manage. 48:542-550.

Beale, D.M. 1978 Birth rate and fawn mortality among pronghorn antelope in western Utah. Proc. Pronghorn Antelope Workshop 8:445-448

Bodie, W L. 1978. Pronghorn fawn mortality in the Upper Pahsimeroi River drainage of central Idaho. Proc Pronghorn Antelope Workshop 8:417-428

Buechner, H 1950 Life history, ecology, and range use of the pronghorn antelope in Trans-Pecos, Texas. Amer. Midl. Nat 43:257-354

Canon, S.K 1993. Fawn survival and bed-site characteristics of Trans-Pecos pronghorn Ph D. Thesis, Texas Tech Univ., Lubbock. 133pp.

Corneli, P S. 1979. Pronghorn fawn mortality following coyote control on the National Bison Range. M.S. Thesis Univ Montana, Missoula. 69pp.

Gese, E M., O J Rongstad, and W.R. Mytton 1988. Relationship between coyote group size and diet in southeastern Colorado J. Wildl Manage. 52:647-653

Hailey, T L. 1986. A handbook for pronghorn antelope management in Texas. Texas Parks Wildl Dept. FA Rep. Ser. No. 20. 59pp.

Larsen, P 1970. A six year study of antelope productivity and survival in southern New Mexico. Proc. Antelope States Workshop 4:97-103.

Neff, D.J., R.H. Smith, and N.G. Woolsey. 1985. Pronghorn antelope mortality study. Final Rept. Ariz. Game and Fish Dept.Fed. Aid Proj. W-78-R. 22pp.

Richardson, C. 1994. Big Game Research and Surveys. Performance Report. Texas Parks Wildl Dept. Fed Aid Proj. W-127-R-2

Rutberg, A.T. 1987. Adaptive hypotheses of birth synchrony in ruminants: an interspecific test. Am. Nat. 130:692-710.

Smith, R.H., D.J. Neff, and N.G. Woolsey. 1986. Pronghorn response to coyote control--a benefit:cost analysis. Wildl. Soc. Bull. 14:226-231.

Yoakum, J 1980. Habitat management guides for the American pronghorn antelope. U.S. Dept. Int , Bur. Land Manage. Tech. Note No. 347. 77pp.

COYOTES AND UPLAND GAMEBIRDS

FRED S. GUTHERY, Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX 78363

Abstract: That coyotes (*Canis latrans*) destroy nests and individuals of bobwhites (*Colinus virginianus*) and wild turkeys (*Meleagris gallopavo*) is well documented. In many situations, however, the removal of coyotes would have little observable effect on gamebird recruitment and population dynamics. This counterintuitive result occurs because (1) renesting reduces the hen failure rate and (2) loss sources other than coyotes become stronger when coyotes are removed from a predator-prey system.

Coyotes destroy nests of northern bobwhites and wild turkeys Coyotes also depredate adult quail and turkeys. One automatically assumes, therefore, that removal of coyotes would increase production and survival of these gamebirds. The assumption is not necessarily correct.

My purpose is to review selected literature on the relationship between gamebird populations and coyotes in Texas and elsewhere. I will focus on the nesting season and show nest depredation by coyotes and other predators accounts for a substantial percentage of nest losses. Then I will review field research that compared quail and turkey abundance on areas with and without suppression of coyotes and other predators. These results will show that intensive predator control may increase standing populations of wild turkeys, but that it has little if any effect on quail populations. Finally, I will discuss theoretical circumstances that lead to counterintiutive outcomes when a predator species, such as the coyote, is removed from a predator-prey system.

Nest loss

Lehmann (1984:91-93) determined the fates of 532 bobwhite nests. He collected data during 1936-1952 in the Coastal and Rio Grande Plains of Texas. The first point to make about Lehmann's results is that they are biased high, because he did not use appropriate statistical procedures. Nevertheless, his results provide an overall picture of nest depredation.

Forty-five percent of Lehmann's (1984) sample nests hatched successfully and 55% were destroyed by some agent. Predators caused 84% of the losses, i.e., about 46% of nests in the sample were depredated. Coyotes were responsible for 36% percent of nests destroyed by predators, which amounted to about 17% of all nests.

Vangilder (1992) summarized nest success rates for different races of wild turkeys. Success rates ranged between 31-62%. The bulk of nest failures were due to predators, but in some cases coyotes were not involved in nest depredations.

On the Welder Wildlife Refuge near Sinton, Texas, predators destroyed 12 of 31 radio-tagged hens and all of 10 nests initiated by radio-tagged hens (Ransom et al. 1987). Ransom et al. concluded predation limited juvenile recruitment and, hence, predation kept wild turkey populations at low levels in the study area

Effects of predator control

Beasom (1974) analyzed the effects of intensive predator control on bobwhite and turkey populations in the eastern Rio Grande Plains. He removed 188 coyotes, 120 bobcats (*Lynx rufus*), 65 raccoons (*Procyon lotor*), 46 striped skunks (*Mephitis mephitis*), and 38 other mammalian predators from a 9-square mile area over 2 years. His results indicated moderate gains in the abundance of bobwhites and strong increases in turkey production as gauged from poult:hen ratios.

Guthery and Beasom (1977) conducted a

similar study in the western Rio Grande Plains. They took 132 coyotes, 18 bobcats, 15 raccoons, 22 striped skunks, and 40 other mammalian predators from a 6-square mile area This intensive level of control had no effect on population trends and abundance of scaled quail (*Callipepla squamata*) and bobwhites.

Predation and gamebird population dynamics

Results of the studies cited above lead to the notion that suppression of coyotes and other predators may or may not affect the abundance of gamebirds. The failure of predator suppression to increase gamebird populations is counterintuitive, because of the documented heavy losses of gamebird nests and to a lesser extent adult birds. Removal of a major loss source should reduce losses and thereby increase abundance. In this section, we explore reasons for the counterintuitive outcome

Renesting. Both turkeys and bobwhites may renest if a clutch is destroyed. Turkeys are weak renesters compared to bobwhites, which may lay 3 to 4 nests in an attempt to hatch at least 1 nest. Renesting has the effect of reducing the hen failure rate while the nest failure rate remains constant Consider flipping a coin. If you want to get 1 head you have a much better chance in 3 flips than in 1 flip. The chance of a head on 1 flip is 0.5, but the chance of at least 1 head in 3 flips is 0 875. From Lehmann's (1984) data with a nest failure rate of 0.55, the hen failure rate is 0.17 and the hen success rate is 0 83, given 3 nesting attempts. This means that 83% of hens would be expected to hatch a brood, even though more than half of all nests are destroyed.

Turkeys are less likely to renest if a first nest is destroyed. This means that the nest failure rate is approximately equal to the hen failure rate. Weak renesting behavior of turkeys is 1 reason why suppression of coyotes and other predators may increase poult:hen ratios, as observed by Beasom (1974). Turkey counteract lower production rates with higher annual survival rates than bobwhites.

Competing risks Suppose we study a predator-prey system and measure with high accuracy the loss rates owing to different predator species; e g., coyotes destroy 10% of nests, raccoons 10%, skunks 10%, and snakes 10%. Now suppose we remove skunks from the system We *do not* save 10% of nests by taking skunks out of the system. Rather, we save some smaller fraction of nests (say 2%) because those nests not destroyed by skunks become available to coyotes, raccoons, and snakes. The percentage of nests taken by coyotes, raccoons, and snakes would increase with the removal of skunks. These competing risks provide the general expectation that a nest saved from 1 predator does not necessarily mean the nest will be successful. The general expectation means there is not a 1:1 relation between predator suppression and nest success We might expect, for example, that 4 or 5 or 6 of every 10 nests saved from loss to a particular agent would eventually result in chicks or poults

Combined effects of renesting and competing risks. Here we set up a predator-gamebird system and isolate the effects of coyote predation. The background circumstances are as follows: nonpredation losses account for 15% of nests if no predators are present; noncoyote predators destroy 50% of nests if no coyotes are present and no nests are lost to other causes. We will model the system with variable rates of coyote predation where there are no other predators and no other loss sources The above circumstances may be combined under the union rule of probability and we can isolate and estimate the effects of coyote predation on hen failure rate

In the system described above, removal of all coyotes would yield about a 60% hen failure rate for turkeys (1 nesting attempt) and a 20% hen failure rate for bobwhites (Fig. 1). Note that as the coyote predation rate increases, the hen failure rate increases at a lower rate. This occurs because, somewhat ironically, an increasing coyote predation rate reduces the predation rate of other predators.

Figure 1 reveals that in a reasonable range of expected coyote predation rates on nests (0 to 20%), the effect of coyote predation on the hen failure rate is low Analysis of fall age ratios and percent summer gain in populations under different rates of coyote predation supports the above assertion. For quail and turkeys, there is little difference in recruitment whether coyote predation is low (0%) or high (20%) (Table 1) in the system we have created.

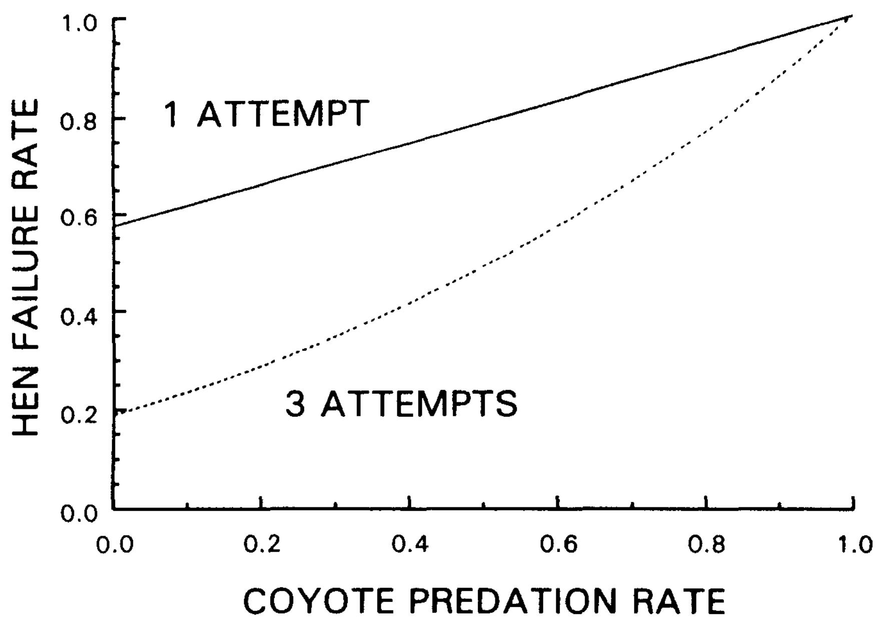


Fig. 1. Relationship between hen production failure rate and coyote predation rate with renesting efforts and competing risks present. The curve for wild turkeys is approximated under 1 nesting attempt and the curve for bobwhites under 3 nesting attempts. See text for explanation and definition of competing risks.

Table 1. Modeled responses of bobwhite and wild turkey population variables to different coyote predation rates. Number of nesting attempts is given in parentheses.

Coyote predation rate[a]	Bobwhite (3 attempts)			Turkey (1 5 attempts)		
	J/A[b]	PSG[c]	Survival (%)[d]	J/A	PSG	Survival (%)
0 00	3 96	174	20.2	2 76	107	26.6
0 05	3 85	167	20.6	2 64	101	27.5
0 10	3.73	161	21.1	2.52	94	28.4
0.15	3 62	155	21.7	2.39	87	29.5
0.20	3.49	147	22.3	2.27	80	30.6

[a]*Rate of nest destruction by coyotes in the absence of all other causes of nest loss.*
[b]*Age ratio in juveniles/adult 6 months after the first egg of the nesting season is laid.*
[c]*PSG = percent summer gain in abundance.*
[d]*Annual survival rate that will lead to population stability given recruitment.*

The general findings on nests would also hold for coyote predation on adult birds, i.e., the existence of coyote predation must reduce losses to other causes and, conversely, the removal of coyote predation would increase losses to other causes.

Discussion

Natural systems, including predator-prey systems, are quite complex. This very complexity tends to stabilize systems by virtue of biological checks and balances such as competing risks. Whereas I reviewed the effects of renesting and competing risks, other balances exist. For example, suppression of coyotes tends to increase their productivity (larger litter sizes, better pup survival) Coyote suppression may also remove competition for non-coyote predators and result in increased density for these species Prey species may be resilient to predation by virtue of density-dependent production and survival. This means that as the density of a prey species declines, its survival and production rates increase

Whereas we seek general principles of wildlife management in general and predator-prey management in particular, we must be aware of special exceptions to general outcomes. Processes in nature are intrinsically variable; this variability insures different effects of coyote predation on bobwhite and turkey populations at different times and places. Places may have special properties that render general expectations invalid. For example, intensive agriculture may force predators and prey to use the same isolated tracts of permanent cover. This may result in higher than normal predation and rates and may render predator suppression a viable alternative for increasing gamebird abundance.

Let me conclude this discussion with an observation on the truth of the following statement. "*Suppression of coyotes and other predators increases abundance of gamebirds.*" In a simple world, we could say the statement is true or false, however, the world is not simple. So in any situation the statement is likely to be true to some extent and false to some extent. The role of the wildlife manager is to *scientifically* determine (no art, please) the truthfulness and falseness of the statement under a particular set of circumstances, and to apply predator management according to scientific analysis and well-defined management goals

Literature Cited

Beasom, S L 1974. Intensive short-term predator removal as a game management tool. Trans North Am Wildl. Conf. 29:230-240.

Guthery, F. S., and S L. Beasom. 1977 Responses of game and nongame wildlife to predator control in south Texas. J Range Manage. 30:404-409.

Lehmann, V W 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A&M Univ Press, College Station. 371pp.

Ransom, D , Jr., O J. Rongstad, and D. H. Rusch. 1987. Nesting ecology of Rio Grande turkeys. J. Wildl. Manage. 51:435-439.

Vangilder, L. D. 1992. Population dynamics. Pages 144-164 *in* J G. Dickson, (Ed.) The wild turkey Stackpole Books, Harrisburg, Penn

MANAGING FOR COYOTES TO ENHANCE WATERFOWL PRODUCTION: AN ALTERNATIVE PERSPECTIVE

TERRY A. MESSMER, The Jack Berryman Institute, Department of Fisheries and Wildlife, Utah State University, UMC 5210, Logan, UT 84322-5210

***Abstract*:** The Prairie Pothole Region (PPR) of North America produces about half of the continent's duck population. Predation on hens, young, and eggs severely impacts duck production in the region decreasing fall flights. Recent studies conducted in the region suggest that management efforts to increase duck production need to consider both habitat and predator effects. Research indicates that managing on the landscape level to protect coyotes in sufficient numbers to exclude red foxes should be encouraged in PPR areas suitable for duck production and where the risks of damage to domestic livestock and other wildlife species are minimal

Over the past century, migratory waterfowl hunting in North America has undergone a transition from a subsistence activity with recreational overtones to a recreational activity with subsistence overtones (USFWS 1986). Concurrently, hunting of migratory waterfowl has become more intensively managed. Since 1948, waterfowl hunting in the United States has been managed on the basis of migrational units, called "Flyways" (Figure 1)

Lincoln (1935) classified the migratory routes across North America into 4 flyways, based on analysis of banded birds and their movements These flyways, the Pacific, Central, Mississippi, and Atlantic, correspond to major migrational routes followed by millions of waterfowl and other birds (Bellrose 1976) Although the boundaries between the routes are not exact, and several species of ducks regularly cross from one flyway to another, the 4 flyways serve as administrative units for managing continental waterfowl populations. The southwestern states of Texas, Oklahoma, and New Mexico are part of the Central Flyway administrative unit.

In 1985, over 5 million U S. residents spent over 41.7 million hunter-days in pursuit of waterfowl. During this same period, 691,000 Texans spent 4.88 million hunter-days hunting waterfowl. This figure constitutes over 10% of all days spent hunting waterfowl in the U.S. during 1985. Total expenditures for migratory bird hunting in the U S. during 1985 were $1.1 billion (USFWS 1988).

The Prairie Pothole Region: duck factory for the Southwest

The Prairie Pothole Region (PPR) of North merica (Figure 2) is the primary breeding ground for many of the waterfowl that are hunted in the Central Flyway and subsequently winter in Texas. Although the PPR represents only 10% of North America's duck breeding grounds, about half of the continent's ducks fledge there (Smith et al 1964, Bellrose 1976). Hence, factors affecting duck production in this region are of special interest to waterfowl populations, wildlife managers and to those that participate in associated recreational activities (Bellrose 1976, Turner et al. 1987, Sargeant et al. 1993).

Studies of nesting ducks conducted in the PPR indicate that duck production has been reduced because of low nesting success attributed to predation on hens, ducklings and eggs (Cowardin et al 1985, Greenwood et al. 1995). Predation severely limits duck production in the region, ultimately affecting the size of the fall flights (Johnson et al 1992)

Effects of predator community composition on nest success

Prairie ducks exhibit evolutionary adaptations (large clutches, renesting, antipredator behaviors, and cryptic coloration) designed to minimize the effects of predation However, alteration of the

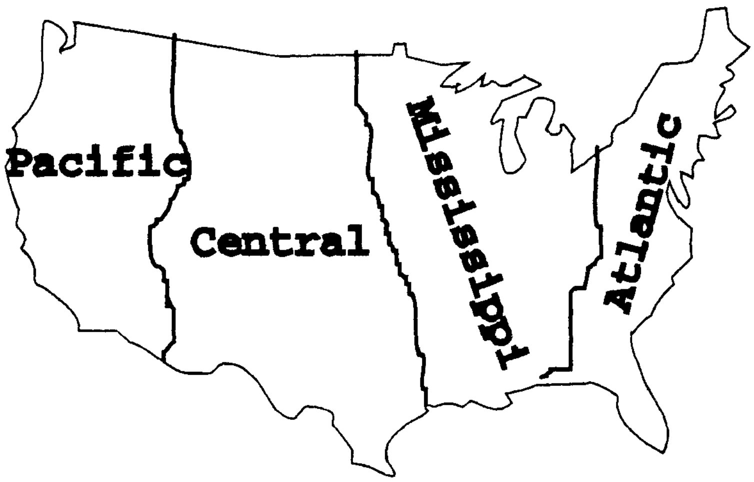


Figure 1. Major waterfowl flyways of North America.

Figure 2. The Prairie Pothole Region of North America.

prairie landscape has resulted in significant changes in the composition of the predator community which can have severe effects on waterfowl populations (Sargeant and Raveling 1992).

During the past 120 years, the PPR has been transformed from a largely pristine ecosystem to on that is farmed intensively (Turner et al. 1987). These changes have contributed to the degradation and fragmentation of duck nesting habitat Further, land use changes also have exposed nesting hens, their eggs and ducklings to different types of predator communities than existed during pristine times (Cowardin et al 1983, 1985, Greenwood et al. 1987).

Predators that were common and widely distributed before settlement of the region disappeared from all or most of the area These include the swift fox (*Vulpes velox*) and the gray wolf (*Canis lupus*). Other species that were scarce and distributed narrowly, such as the raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), red fox (*Vulpes vulpes*), and the coyote (*Canis latrans*), clearly benefitted from habitat changes in the region Sargeant et al. 1984)

These "new" mammals are the principal predators currently affecting duck production in the region (Keith 1961, Johnson and Sargeant 1977, Sargeant et al. 1993). The red fox has emerged as the major predator affecting duck production, preying on both ducks and eggs (Duebbert and Lokemoen 1976, Higgins 1977, Sargeant et al 1984, Klett et al 1988, Greenwood et al 1995, Sovada et al. 1995) Recent evidence suggests that coyotes may have less impact on nesting ducks than red foxes, raccoons, and striped skunks (Johnson et al. 1989, Sargeant et al 1984, 1993, Greenwood et al. 1995, Sovada 1995)

Factors affecting predator abundance and distribution in the PPR

Major habitat changes affecting predator populations in the region include the conversion of wetland/grassland complexes to annually-tilled cropland and the establishment of farmsteads with associated windbreaks, food sources, water, and human presence (Sargeant et al. 1993) These changes increased habitat structural diversity, favoring many predator species More diverse and stable food supplies became available to coyotes, red foxes, and raccoons. However, changes in the abundance of these species, particularly the canids, cannot be attributed solely to habitat changes.

Extensive killing of predators in the PPR by humans not only resulted in the extirpation of some species, such as the gray wolf, but probably prevented the expansion of new predator populations for several decades. High fur prices prior to the 1940s, coupled with rural residents' dislike for predators, held populations at low levels. When fur prices collapsed during the 1940-60s, the animal damage and control-of-disease programs resulted in the deaths of tens of thousands of mammalian predators These programs, however, failed to reduce red fox populations to low levels, while having a considerable effect on coyote abundance, particularly in intensively farmed areas (Adams 1961)

Interspecific relations of canids appear to be another dominant factor affecting the current distribution and abundance of the canid species in PPR (Sargeant 1982). Although habitat changes also allowed raccoons to expand their range, incompatibility with other predator species probably impeded raccoons from expanding their range earlier.

Inter- and intraspecific predator interactions: duck production consequences

Predator community composition can impact duck nesting success (Sargeant et al. 1993, Greenwood et al 1995, Sovada et al. 1995) Of particular consequence to duck production in the prairie pothole region are interactions between (among) specific predator species

Coyotes suppress the abundance of red foxes (Criddle 1929, Sargeant 1982, Voight and Earle 1983, Sargeant et al. 1987, Harrison et al. 1989) Sargeant et al. (1993) reported a strong inverse relationship between coyote and red fox numbers. Circumstantial evidence also suggests that coyotes may suppress raccoon populations in the PPR (Cowan 1973, Stelfox 1980, Clark et al. 1989, and Sargeant et al. 1993) Coyotes also occasionally prey upon striped skunks (Godin 1982).

Several authors have suggested that coyotes can affect the abundance of predators other than red foxes sufficiently to the extent that duck nesting success is enhanced. However, there is little evidence in the literature to support this contention. Klett et al. (1988) initially suggested that differences in predator communities from east to west in the PPR, particularly the canids, may have been the reason for observed higher nest success in western portions of the region. Coyotes were more common than red foxes in the western portion of the region than in the east.

Greenwood et al. (1995) and Sovada et al. (1995) attributed differences observed in nest success between coyote-dominated areas and fox-dominated areas to coyote suppression of red foxes. Sovada et al. (1995) reported that average nest success in coyote-dominated areas was 15% higher than in fox-dominated areas. This difference in nest success is important because the higher rate exceeds nest success threshold levels suggested by Cowardin et al. (1985) for maintaining stable populations of several species of dabbling ducks.

Greenwood et al. (1995) and Sovada et al. (1995) suggest that, in areas where coyotes densities are relatively low, coyotes may benefit ducks by reducing nest predation by foxes. However, in areas where coyotes are abundant, they can prey extensively on nesting hens and duck nests (Glup and McDaniel 1988).

Management Implications

Greenwood et al. (1995) and Sovada et al. (1995) reported a high degree of variability in nest success among study sites and among years. Both studies also reported that predation was the cause of most nest failures, and predator indices also varied considerably among areas and years. These results support Johnson et al.'s (1989) contention that predator numbers alone are not the sole determinant of nest success. Other factors also affect nest success, such as the abundance of buffer species, habitat quality and quantity, the abundance of other predators species, and waterfowl nest densities.

Variability in nest success among coyote-dominated and fox-dominated areas indicates that the presence of coyotes alone may not ensure high nest success (Sovada et al. 1995). Their work was conducted during a drought period, primarily on Conservation Reserve Program lands that had been seeded to perennial grass cover. The additional grassland may have resulted in greater dispersion of duck nests which reduced their risk to predation. The drought also may have contributed to a reduction in duck abundance and nesting effort (Smith 1969, Krapu et al. 1983). Low nest density may have a positive influence on nest success by reducing predator efficiency (Marshall 1967, Weller 1979, Hill 1984).

Long-term management efforts designed to increase duck production must be applied at the landscape level in full consideration of the species' habitat requirements, habitat quality and quantity, predator composition and abundance, and predation risks. Consideration also should be given to encouraging sufficient coyote numbers to exclude red foxes in areas of the PPR where the potential exists to increase duck production without consequence to domestic livestock production or other wildlife species (Greenwood et al. 1995, Sovada et al. 1995).

Literature Cited

Adams, A.W. 1961. Furbearers of North Dakota. North Dakota Game and Fish Dept., Bismarck. 102 pp.

Bellrose, F.C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pa. 544 pp.

Clark, W.R., J.J. Hasbrouck, J.M. Kienzler, and T.F. Glueck. 1989. Vital statistics and harvest of an Iowa raccoon population. J. Wildl. Manage. 53:982-990.

Cowan, W.F. 1973. Ecology and life history of the raccoon (*Procyon lotor hirtus* Nelson and Goldman) in the northern part of its range. Ph.D. Thesis, Univ. of North Dakota, Grand Forks. 161 pp.

Cowardin, L.M., A.B. Sargeant, and H.F. Duebbert. 1983. Problems and potentials for prairie ducks. Prairie Nat. 34:4-11.

Cowardin, L.M.., D.S. Gilmer, and C.W. Shaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildl. Monogr. 92. 37pp.

Criddle, N. 1929. Memoirs of the eighties. Canadian Field-Nat.. 43:176-181.

Duebbert, H.F., and J.T. Lokemoen. 1976. Duck nesting in fields of undisturbed grass-legume cover. J. Wildl. Manage. 40:39-49.

Glup, S.S., and L.L. McDaniel. 1988. Bullsnake predation on waterfowl nests on Valentine National. Wildlife Refuge, Nebraska. Proc. Great Plains Wildl. Damage Control Workshop. 8:149-152.

Godin, A.S. 1982. Striped and hooded skunks. Pages 674-687 *in* J.A. Chapman and G.A. Feldhamer, (Eds.) Wild mammals of North America. Johns Hopkins Univ. Press, Baltimore, MD.

Greenwood, R.J., A.B. Sargeant, D.H. Johnson, L.M. Cowardin, and T.L. Shaffer. 1987. Mal lard nest success and recruitment in Prairie Canada. Trans. North Am. Wildl. Nat. Resourc. Conf. 52:298-309.

______ . , A.B. Sargeant, D.H. Johnson, L.M. Cowardin, and T.L. Shaffer. 1995. Factors associated with duck nest success in the Prairie Pothole Region of Canada. Wildl. Monogr. 128. 57pp.

Hill, D.A. 1984. Clutch predation in relation to nest density in mallard and tufted duck. Wildfowl 35:151-156.

Harrison, D.J., J.A. Bissonette, and J.A. Sherburne. 1989. Spatial relationships between coyotes and red foxes in eastern Maine. J. Wildl. Manage. 53:181-185.

Higgins, K.F. 1977. Duck nesting on intensively farmed areas of North Dakota. J. Wildl. Man age. 41-232-242.

Johnson, D.H., and A.B. Sargeant. 1977. Impact of red fox predation on the sex ratio of prairie mallards. U.S. Fish and Wildl. Serv. Wildl. Res. Rep. 6. 56 pp.

______., A.B. Sargeant, and R.J. Greenwood. 1989. Importance of individual predators on duck nesting success in the Canadian Prairie Pothole Region. Can. J. Zool. 67:291-297.

______ . , J.D. Nichols, and M.D. Schwartz. 1992. Population dynamics of breeding waterfowl. Pages 446-485 *in* B.D. Batt, A.D. Afton, M.G. Anderson, C.D. Ankrey, D.H. Johnson, J.A. Kadlec, and G.L. Krapu, (Eds.) The ecology and management of breeding waterfowl. Univ. Minn. Press, Minneapolis.

Keith, L.B. 1961. A study of waterfowl ecology on small impoundments in southeastern Alberta. Wildl. Monogr. 6. 88pp.

Klett, A.T., T.L. Shaffer, and D.H. Johnson. 1988. Duck nest success in the Prairie Pothole Region. J. Wildl. Manage. 52:431-440.

Krapu, G.L., A.T. Klett, and D.J. Jorde. 1983. The effect of variable spring water conditions on mallard reproduction. Auk 100:689-698.

Lincoln, F.C. 1935. The waterfowl flyways of North America. U.S.D.A. Circ. No. 342. 12 pp.

Marshall, I.K. 1967. The effects of high nesting densities on the clutch size of the common eider *Somateria mollissima* (L.). J. Ecol. 55:1-59.

Sargeant, A.B. 1982. A case history of a dynamic resource - the red fox. Pages 121-137 *in* G.C. Sanderson, (Ed.) Midwest furbearer manage ment. Midwest Fish and Wildl. Conf., Wichita, Kans.

_____, A.B., S.H. Allen, and R.T. Eberhardt. 1984. Red fox predation on breeding ducks in midcontinent North America. Wildl. Monogr. 89. 41pp.

_____., _____., and J.O. Hastings. 1987. Spatial relations between sympatric coyotes and red foxes in North Dakota. J. Wildl. Manage. 51:285-293.

Sargeant, A.B., and D G. Raveling. 1992. Mortality during the breeding season Pages 396-422 *in* B.D.J.Batt, A.D. Afton, M.G. Angerson, C.D. Ankey, D.H. Johnson, J.A. Kadlec, and G.L. Krapu, (Eds.) The ecology and management of breeding waterfowl. Univ. Of Minn. Press, Minneapolis.

_____., R.J. Greenwood, M.A. Sovada, and T.L. Shaffer. 1993 Distribution and abundance of predators that affect duck production - Prairie Pothole Region U.S. Fish and Wildl. Serv Resourc. Publ. 194. 96pp

Smith, A G., J.H. Stoudt, and J.B. Gollop. 1964 Prairie potholes and marshes. Pages 39-50 *in* J.P. Linduska, (Ed.) Waterfowl Tomorrow. U.S Fish and Wildl. Serv. Washington, D.C.

_____. 1969. Waterfowl-habitat relationships on the Lousana, Alberta waterfowl study area. Pages 116-122 *in* Saskatoon wetlands seminar. Can. Wildl Serv Rep. Ser 6

Sovada, M.A. , A.B Sargeant, and J. W. Grier. 1995. Differential effects of coyotes and red foxes on duck nesting success. J. Wildl. Man age. 59:1-9

Stelfox, H A 1980. Wildlife changes in southeastern Saskatchewan. Blue Jay 38:69-79.

Turner, B.C., G S. Hochbaum, F.D. Caswell, and D.J. Nieman. 1987. Agricultural impacts on wetland habitat on the Canadian prairies, 1981-85. Trans. North Am. Wildl. and Nat. Resour. Conf. 52:206-215.

U.S. Fish and Wildlife Service. 1986. Use of lead shot for hunting migratory birds of the United States - Final supplemental environmental impact statement. Office of Migratory Bird Manage., Washington, D.C.

_____ 1988 1985 National survey of fishing, hunting, and wildlife associated recreation. Washington, D.C 167 pp.

Voight, D R. and B D. Earle. 1983. Avoidance of coyotes by red fox families. J. Wildl. Manage. 47:852-857.

Weller, M W. 1979. Density and habitat relationships of blue-winged teal nesting in northwestern Iowa. J. Wildl. Manage. 43:367-374.

SHEEP AND GOAT LOSSES IN RELATION TO COYOTE DAMAGE MANAGEMENT IN TEXAS

GARY L. NUNLEY, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Texas Animal Damage Control Program, P.O. Box 100410, San Antonio, TX 78201-1710

Abstract: The average reported sheep and goat loss to coyotes (*Canis latrans*) in 1992 on those properties worked by the cooperative animal damage control program were relatively low. Sheep and goat losses were not evenly distributed among the producers. Geographical distribution of the losses reflected a positive relationship between relative coyote density and livestock losses. The sheep and goat industry is adversely affected by the cumulative losses of those producers suffering high levels of predation.

The Texas Animal Damage Control Program (ADC) is a cooperative wildlife damage management agency comprised of the Animal Damage Control Program of USDA's Animal and Plant Health Inspection Service, the Texas Animal Damage Control Service of the Texas A&M University System, and the Texas Animal Damage Control Association One of the functions of the cooperative program is to conduct direct control operations for the protection of sheep and goats from depredation by coyotes and other predators Historically, the program's primary control strategy has been to attempt to prevent the infiltration of coyotes into the major sheep and goat production areas (Nunley 1995)

Through its management information system, the Texas ADC program collects livestock loss information from the individual producers who receive direct control assistance from Texas ADC. The program also documents the number of coyotes and other predators taken from each property worked This paper describes the analysis of the interrelationships of producer- and industry-level livestock loss data, relative coyote densities, and coyote damage management efforts for the year 1992.

Coyote predatory behavior

Coyotes are predators that are equipped physically and behaviorally to locate, pursue, and kill small- and medium-sized prey (Knowlton 1980, 1989) Rodents and lagomorphs generally make up the bulk of the coyote diet, but they are capable of killing prey 6-8 times their own size under appropriate circumstances, which includes sheep and goats While they are innately programmed to kill, the recognition of suitable prey and the ability to capture it at least partially reflects skills derived from experience and practice. Like many predators, coyotes frequently kill more than required for their immediate needs This may be partially due to innate responses to specific stimuli, but also because there are survival values in practicing capture techniques and caching their prey.

Wade (1981) described four conditions that further characterize the limits within which coyote predation occurs: (1) anything that is palatable, available, and of a suitable size is "natural" food to coyotes, (2) if only wild prey, fruits, and berries were available these would comprise the entire coyote diet, (3) if only domestic prey, fruits, and berries were available these would comprise the entire coyote diet, and (4) in the absence of coyotes there cannot be coyote predation.

In studies of the sheep killing behavior of captive coyotes, 8 of 11 pen reared coyotes individually killed 35 to 70 pound lambs (Connolly et al. 1976). These pen-reared, and thus naive, coyotes possessed the inherent inclination and ability to kill sheep. In this study, food deprivation had no discernible effect on the killing behavior of coyotes but did influence feeding activity on kills. These observations suggested that hunger is not always the primary motivation for predatory behavior. In a similar study, 18 of 19 pen-raised coyotes, and 38 of 54 wild-caught adult coyotes, killed sheep when placed in a 2.5-acre pen with sheep (U.S. Fish and

Wildl Serv. 1978).

These studies indicate that not all coyotes kill sheep, but most will learn to kill sheep, particularly lambs, if regularly given the opportunity (U.S. Fish and Wildl. Serv 1978). We can assume that the same applies for goats, especially kids.

Livestock loss survey

In early 1993, Texas sheep and goat producers provided the program with estimates of their 1992 livestock losses to specific predators as well as all other causes. These livestock losses were reported only from properties where coyotes or other predators where being taken by ADC at various levels of intensity for the protection of sheep and goats. These producers indicated that there were:

885,000 adult sheep,
628,000 lambs,
721,000 adult mohair goats,
282,000 mohair kid goats,
93,000 adult spanish goats, and
66,000 spanish kid goats

being protected by ADC on their properties Coyotes were responsible for 64% of the sheep losses and 56% of the lamb losses caused by predators (Fig. 1) Coyotes were also responsible for 63% of the goat losses and 42% of the kid losses attributed to predators (Fig. 2). Note also the differential vulnerability among livestock from predation. Lambs were more apt to be killed by coyotes than adult sheep. However, the differential was less of a factor between adult goats and kids.

The best overall estimates available for sheep losses to coyotes on properties without damage control are 4.5% for sheep and 17% for lambs (USDA 1994). On properties with damage control, losses to coyotes are estimated at 1.2% for sheep and 4% for lambs (USDA 1994). Figure 3 indicates the percent of Texas sheep and goats protected by the program in 1992 that were lost to coyotes, other predators, and causes other than predation This data reflects that a relatively small 0.4% of the sheep, 1.7% of the lambs, 0.9% of the goats, and 2.4% of the kids were lost to coyotes.

Frequency distribution of loss rates

To understand the relevance of this average loss data, the frequency distribution of the losses at varying loss rates was analyzed. One of the disadvantages of "average" loss data is that losses are not equally distributed (Wade 1982) Some producers suffer losses which jeopardize economic survival, some suffer losses that they can survive, and some sustain no losses Figure 4 illustrates this point in that 12% of the lamb producers reported losses in excess of 10% while 54% reported no losses to coyotes Similarly, 19% of the kid goat producers reported losses in excess of 10% while 57% reported no losses to coyotes (Fig 5)

Geographical distribution of losses

The geographical distribution, by county, of the reported losses throughout the major sheep and goat production area was examined next Rather distinct regional areas of "low", "moderate", and "high" lamb and kid losses were delineated from this analysis (Figs 6,7) When comparing the distribution of these regions to the suspected relative abundance of coyotes within each region, a positive correlation exists (Fig 8). This positive correlation between sheep and goat losses and coyote numbers in the area of the Edwards Plateau has also been documented by other authors (Shelton and Klindt 1974, Pearson and Caroline 1981).

Predator-prey ratios and loss rates

The correlation between predator numbers and livestock losses reflects the impact of the predator-prey ratio which prescribes that a population of predators will kill at some rough per-predator rate times the number of predators in the population (Wagner 1988). A more dense coyote population will impose a higher kill rate on a specific sheep and goat population

On the other side of the equation, we can see that even with a constant coyote population, the percent of animals lost will be higher on a small sheep and goat operation than a large one. Thus, the concentration of sheep and goats, and/or sheep and goat producers in a given area, is an important factor in explaining some of the differences in losses

(Nielsen 1977, Pearson and Caroline 1981). The counties with the highest percentage losses to coyotes are those with medium- and low-density sheep and goat populations located on the edges and adjacent to the Edwards Plateau. These are also the areas of higher coyote densities.

Impact of sheep and goat losses to coyotes

Economic survival is improbable for those producers suffering the higher level of losses to coyotes, and especially in those cases compounded by additional livestock losses to other predators. Producers who fail to survive are replaced in the high-loss category by others whose operations then bear the brunt of predator populations Utilizing the previous data (Fig 4), if lamb producers with at least a 10% loss to coyotes went out of business, then 221 or 19% of the producers would cease operation. In the case of lamb producers with at least a 25% loss, 72 or 6% of the producers would terminate production Consequently, the average coyote loss statistics of 1.7% for lambs and 2.4% for kids means little to those producers leaving the industry because of high predation losses.

The cumulative impact of the loss of these producers is not adequately recognized since they are not reflected in future loss surveys Loss surveys usually do not measure the effects of a producer's inability, due to predation or the threat of predation, to graze appropriate rangelands with sheep and goats

Industry or state average survey data of livestock losses is important. However, it is also necessary to examine the frequency and geographical distribution of the magnitude of loss among the individual producers In this way we can better understand the interrelationships of coyotes, coyote predation, coyote damage management, individual producers, and the sheep and goat industry as a whole.

Literature Cited

Connolly, G. E., R. M. Timm, W. E. Howard, and W. M. Longhurst. 1976. Sheep killing behavior of captive coyotes. J Wildl. Manage 40.400-407

Knowlton, F. F. 1980. Statement of Frederick F. Knowlton at Hearing before the Comm. on Environ. and Public Works. U.S. Senate 96th Congress. Apr 24, 1980. 231pp.

_____. 1989 Predator biology and livestock depredation management. Proc. West. Sect. Amer. Soc. of Animal Sci. 40:504-509.

Nunley, G. L. 1995. The re-establishment of the coyote in the Edwards Plateau of Texas. Pages xx-yy *in* D Rollins, T. Blankenship, S. Henke and K. Canon, (eds.) Proc. Coyotes in the Southwest: a compendium of our knowledge. San Angelo, TX. xxpp.

Pearson, E. W. and M. Caroline 1981. Predator control in relation to livestock losses in Central Texas. J Range Manage 34:435-441

Shelton, M., and J. Klindt 1974. Interrelationship of coyote density and certain livestock and game species in Texas. Texas Agric. Expt. Stn. MP-1148. 12pp

U.S. Department of Agriculture 1994. Final Environmental Impact Statement. Animal Damage Control Program. Animal and Plant Health Inspection Service, Washington, D. C.

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

Wade, D. A. 1981. Population reduction in coyote management Pages __ in Proc. Situation Management of two intermountain species: aspen and coyotes. Utah State Univ , Logan. 53pp.

_____. 1982. Impacts, incidence and control of predation on livestock in the United States, with particular reference to predation by coyotes Council for Agric. Sci. and Tech. Spec. Public. No. 10. Ames, IA. 20pp.

Wagner, F W 1988. Predator control and the sheep industry: the role of science in policy formation. Regina Books, Claremont,CA. 240pp

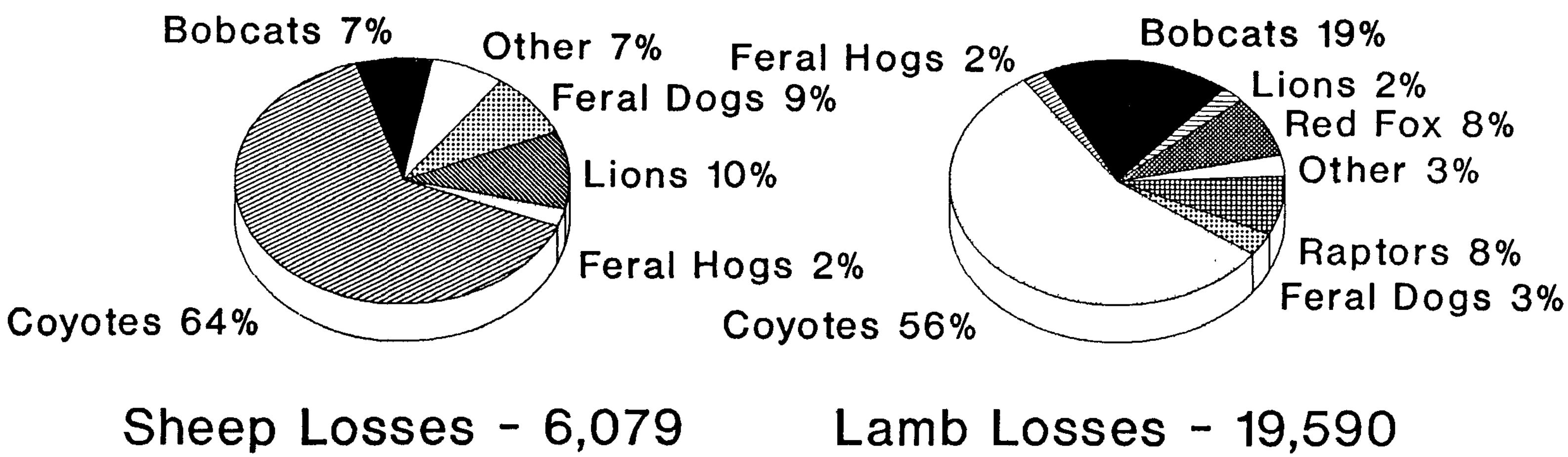


Fig. 1. Sheep and lamb losses to predators in 1992 on properties protected by the cooperative animal damage control program.

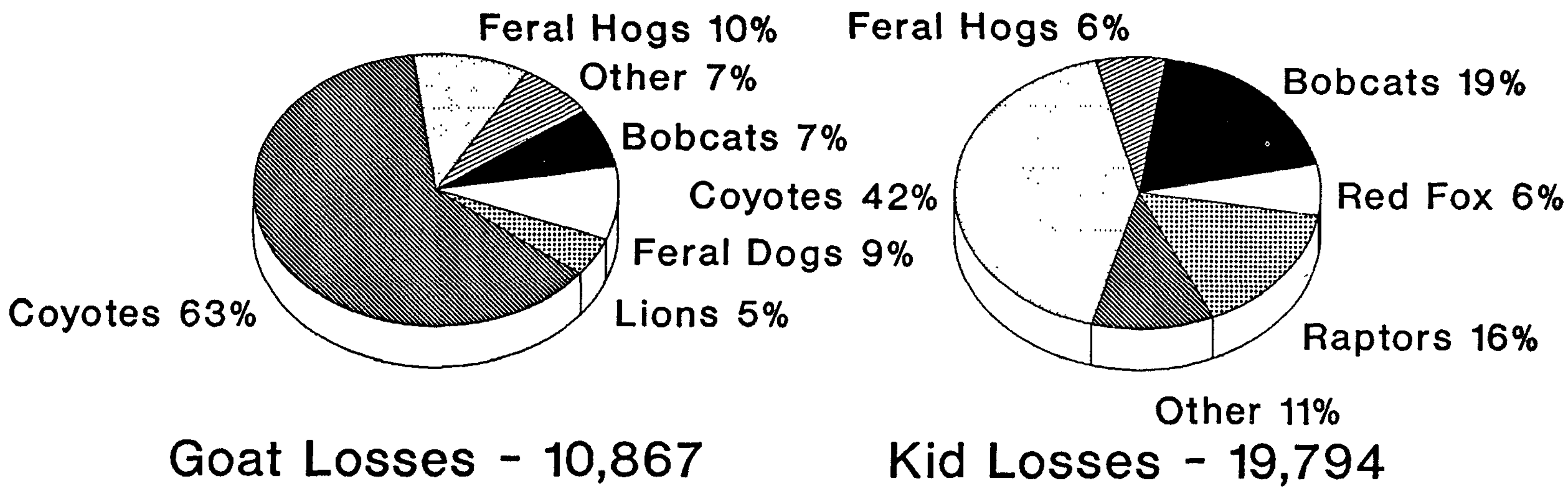


Fig. 2. Goat and kid losses to predators in 1992 on properties protected by the cooperative animal damage control program.

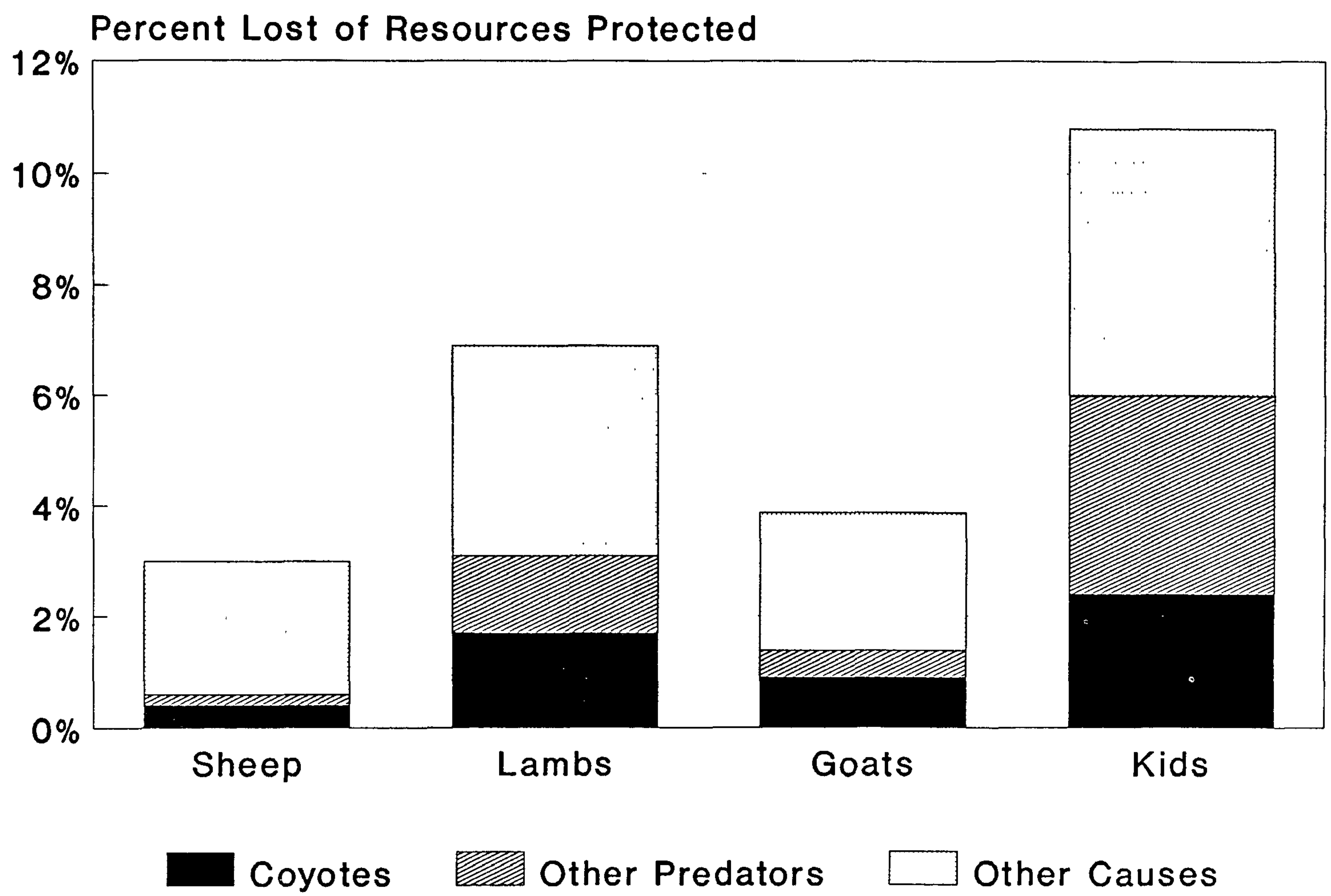


Fig. 3. Percent loss of the total livestock protected in 1992 by the cooperative animal damage control program.

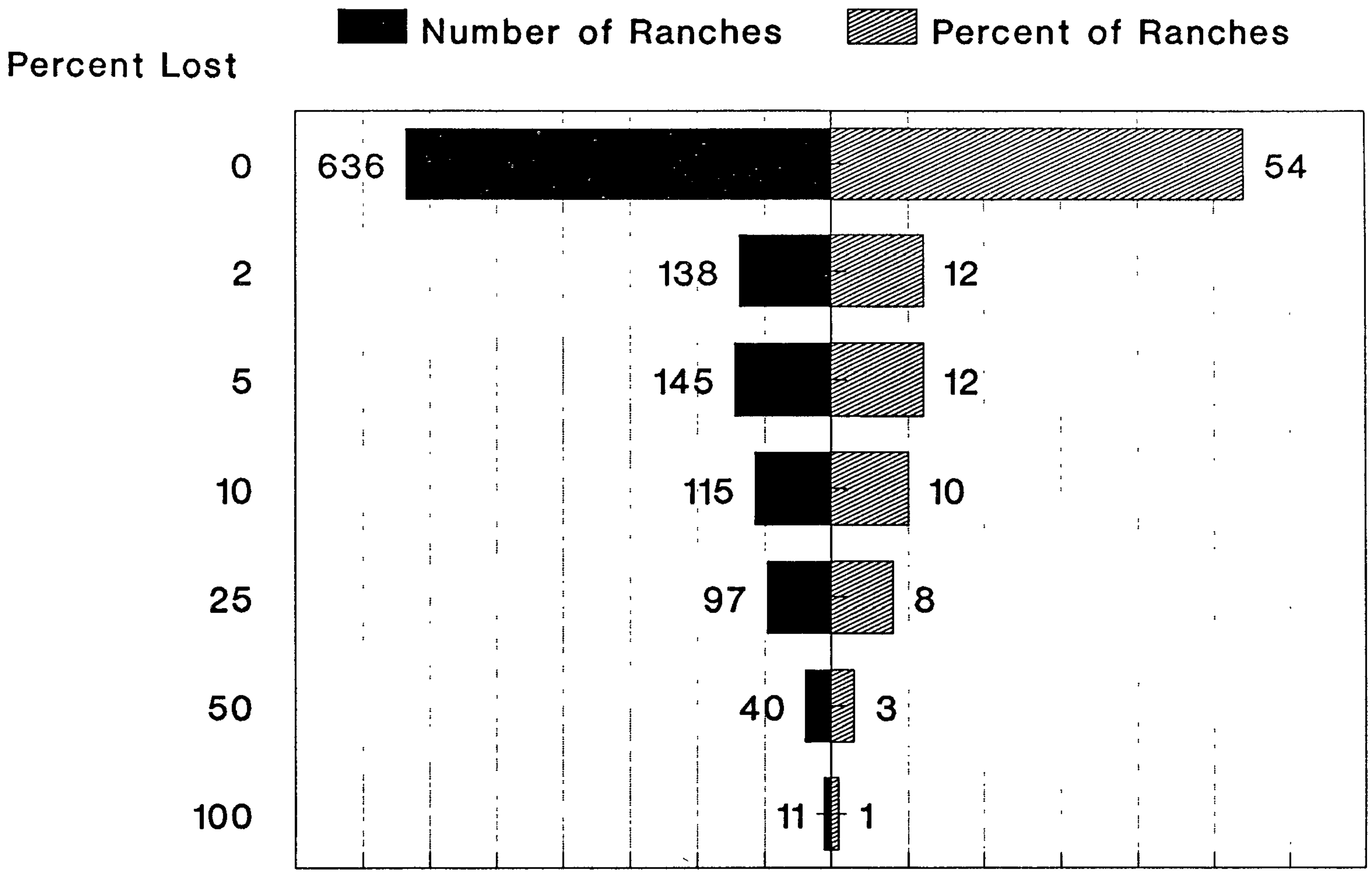


Fig. 4. Percent lamb loss to coyotes in 1992 on 1,182 ranches protected by the cooperative animal damage control program.

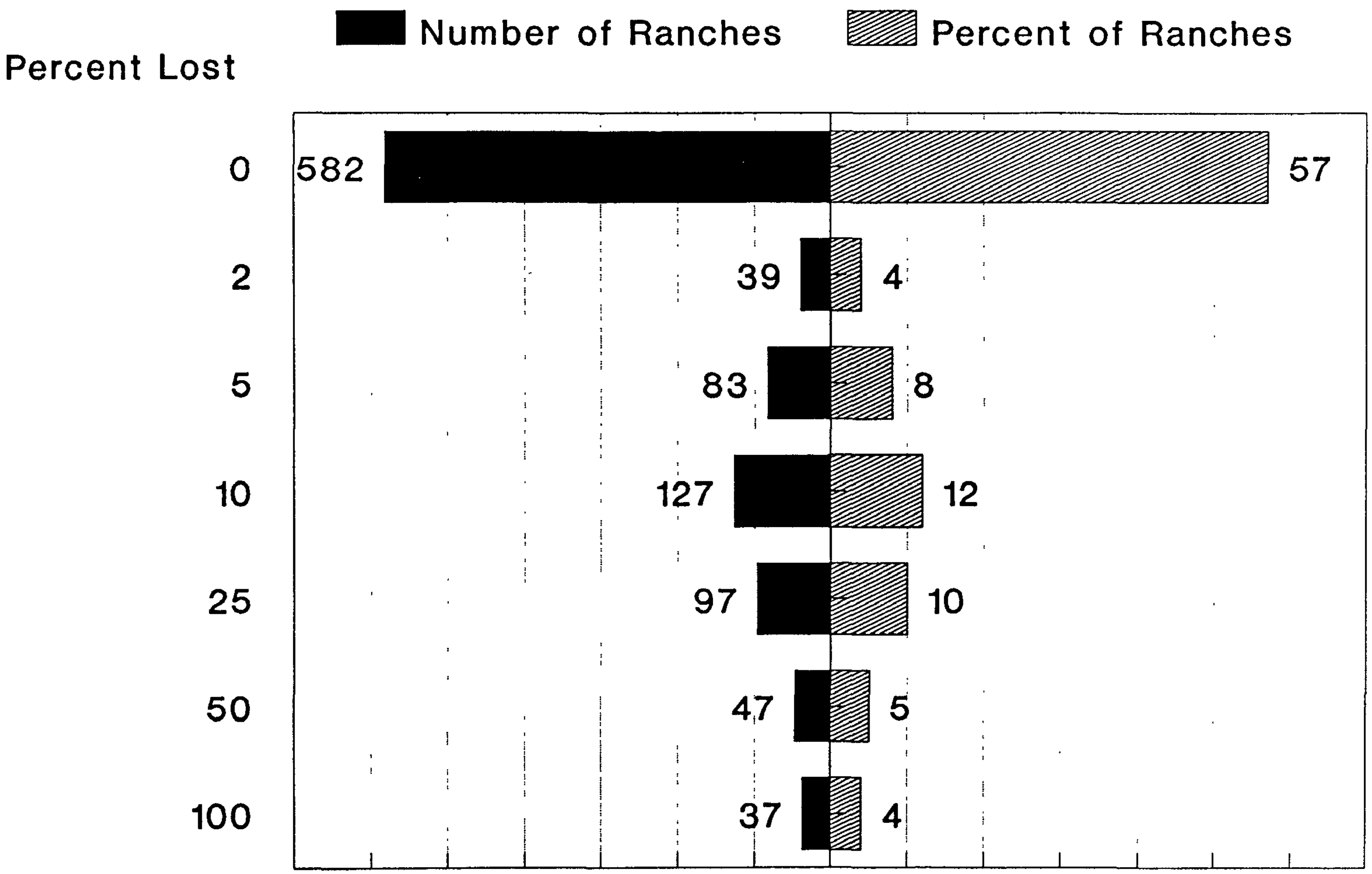


Fig. 5. Percent kid goat loss to coyotes in 1992 on 1,012 ranches protected by the cooperative animal damage control program.

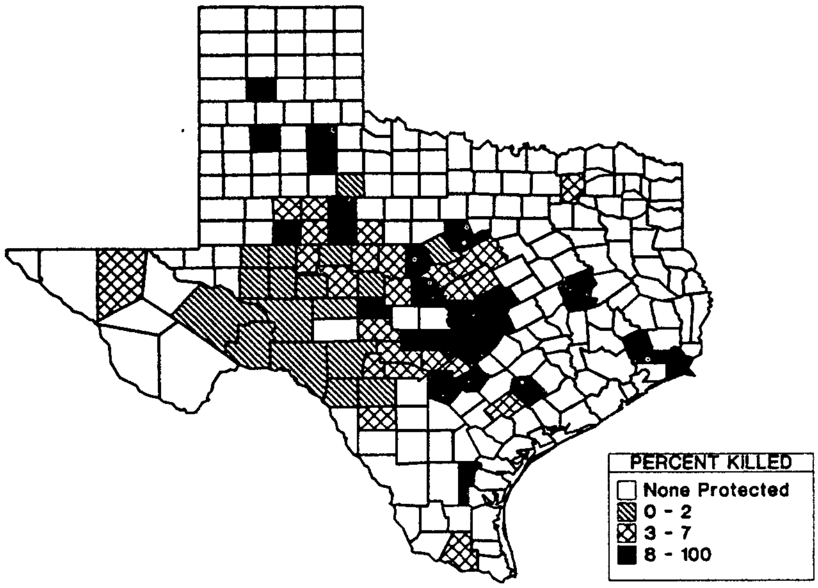


Figure 6. Geographical distribution of lams lost to coyotes in 1992 on 1,182 ranches protected by the cooperative animal damage control program.

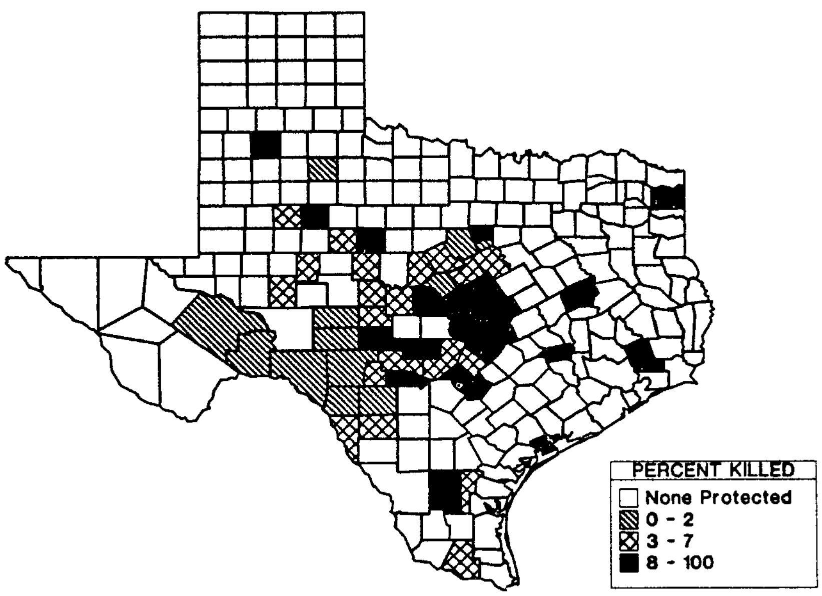


Figure 7. Geographical distribution of kid goats lost to coyotes in 1992 on 1,012 ranches protected by the animal damage control program.

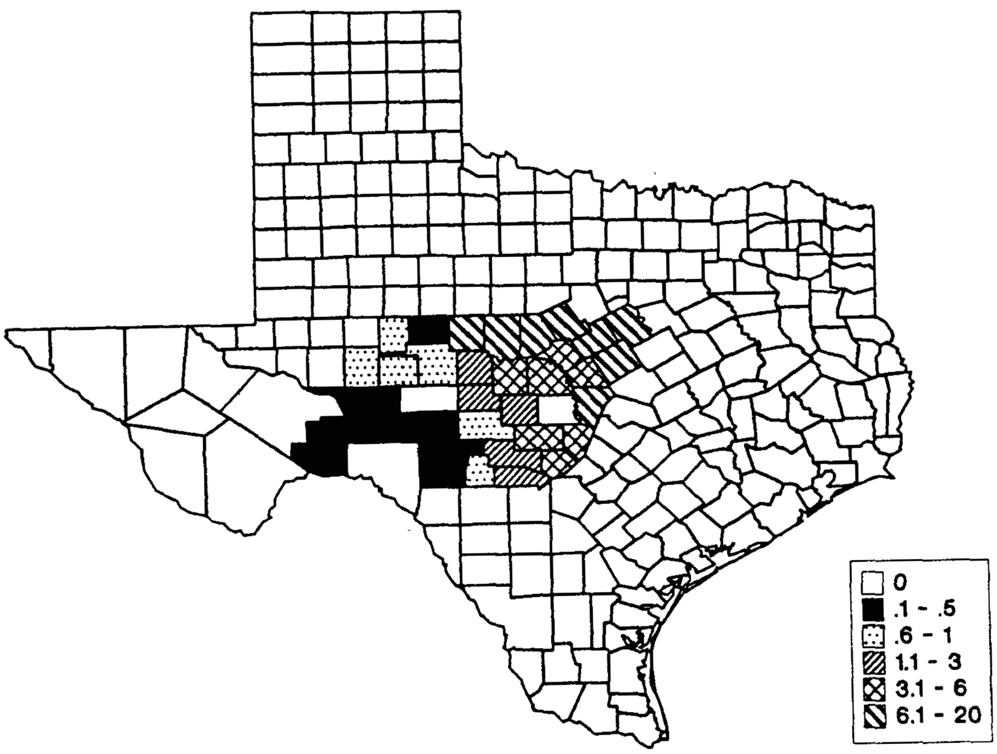


Figure 8. Coyotes taken in 1994 by the cooperative animal damage control program per 10 square miles of area worked

PREDATION IMPACTS AND MANAGEMENT STRATEGIES FOR REDUCING COYOTE DAMAGE TO CATTLE

RICKEY L. GILLILAND, District Supervisor, Texas Animal Damage Control Service, Box 277, West Texas A&M University, Canyon, TX 79016

Abstract: Loss of cattle to predators influences productivity of many livestock operations. Statistics indicate that coyote (*Canis latrans*) predation is a principle threat. Impacts to livestock resources by coyotes are appraised. Implementation of control strategies which capitalize on coyote dispersion and social interactions are discussed. Predator management to reduce livestock losses and promote a younger age structure in coyotes is suggested as a long term solution.

Coyotes have been part of rangeland ecosystems for thousands of years. Historically, their predatory niche took a subordinate position to larger predators such as wolves (*Canis* spp), large cats (e g., mountain lions, *Felis concolor*) and bears (*Ursus* spp.). Land use within the last 125 years has altered predator composition, favoring the highly adaptable coyote This intelligent animal has flourished in the absence of competition with larger predators.

Behaviorally, the coyote has succeeded as an opportunist, exploiting a variety of food sources made available by man's agriculture and habitation. During this century, eastern habitats have supported high deer populations commingled with human settlement situated throughout agricultural and forested landscapes These factors have contributed to a greater food base for coyotes (Thurber and Peterson 1991).

Presently, coyotes are expanding across much of continental North America. In Texas, coyotes continue to populate intensely-managed, low predator density areas through normal population dispersion and compensatory reproduction.

Predation impacts on cattle

Since 1970, numerous studies have been conducted to determine the magnitude of livestock losses to predators, particularly coyotes (Andelt 1987). Texas leads the nation in cattle, sheep, and goat production According to the Texas Agricultural Statistic Service (1995), there were 15.1 million total cattle in Texas in December, 1994 The calf crop for 1994 totaled 6.2 million head.

Cattle production in Texas occurs among diverse operations which include range cattle, fed cattle (in feedyards), and dairy cattle. Overall, cattle distribution across the state is fairly uniform

According to a survey by the National Agricultural Statistics Service (1992), calf losses in Texas to predators during 1991 totaled 23,400 head. This represents an estimated $7.84 million loss to Texas producers. Predators accounted for 106,400 head of cattle and calves lost in the United States during 1991. Texas lost 26,400 head of cattle and calves to all predators accounting for an estimated value of $9.865 million The value of the 17,200 cattle and calves lost in Texas to coyotes alone was $6.102 million (NASS 1992, Texas ADC Service 1993).

Predation to cattle occurs statewide with heavier impacts felt in the areas of high coyote densities. Generally speaking, higher coyote densities are found within the ecological areas surrounding the Edwards Plateau. Ranching operations within the Edwards Plateau principally support more sheep, goats, and exotic wildlife than cattle, as compared to the rest of the state. Consequently, intensive predator management is necessary to curb livestock losses. As a result, cattle production within this area benefits from a lower coyote population and is less likely to be impacted by predation than in areas of higher coyote density

The South Texas Plains, Trans-Pecos, Cross Timbers, Rolling Plains, and the High Plains typically support more coyotes These areas are home to many large ranching operations. Cattle production is generally cow-calf and seasonal stocker/yearling operations. Obviously, calving operations are more vulnerable to predation Historically, cow-calf operators managed herds for early spring or fall calving during milder weather. Today, modern ranching operations vary in management strategies from seasonal to year round calving.

Coyotes preying on cattle generally attack newborn to 500 pound calves. However, most calves killed by coyotes are within the first few weeks of birth. Adult cows are occasionally killed or seriously damaged by coyotes during complications arising from calving. Problems associated with calving can hinder a cow's defense abilities (e.g , temporary paralysis), increasing vulnerability to predation Livestock husbandry practices (e.g., close confinement during calving) have the potential to reduce coyote predation (Voigt and Berg 1987). However, practicality of range cattle management often precludes protection from predation (i e , large pastures, remote areas)

Prey selection

Factors that influence prey choice by predators are absolute abundance, relative abundance, and relative value of potential prey types (Estabrook and Dunham 1976, Windberg and Mitchell 1990) Winter calving, which usually occurs during normal declines of natural prey (i e , late winter), increases vulnerability of calves to coyotes. Decreases in natural forage stress coyotes into alternate feeding patterns. Winter diet contains larger items such as deer (either prey or carrion), livestock carrion, or locally abundant lagomorph species (Voigt and Berg 1987). Extended winter stress periods place high nutritional demands on coyotes and often result in cattle depredation and carcass scavenging.

Predation losses are often highest in spring and summer correlating to pup-rearing Pup-rearing may stimulates predation on larger prey during a time of high nutritional demands of adult and juvenile coyotes. In some instances, group behavior (i e , pack formation) can be related to pup-rearing, predation on large prey that may require group hunting strategies, or defense of carrion (Camenzind 1978, Bowen 1981, Voigt and Berg 1987)

During whelping season, parents consume high protein food items which are returned to the pups and regurgitated for their consumption. In areas experiencing calf losses, body parts may be discovered at den sites. Such evidence is key to identifying and removing offending coyotes. High nutritional demands on coyotes during spring and summer pup-rearing normally coincide with the peak of natural prey availability (e g , fawns, rodents) Additionally, cattle operations employing spring and summer calving schedules augment natural prey choices and scavenging opportunities through the calving process

It is presumable that cattle may be a preferred prey choice by depredating coyotes as related to abundance, and reduced avoidance strategies common of domestic prey. In many situations, a depredated calf more efficiently feeds a coyote family, as compared to feeding on smaller prey Additionally, the exploitation of larger prey animals decreases hunting and foraging intervals Further, larger prey allow adult coyotes more time to safeguard pups and denning areas against threats

Indirect influences

Because of the opportunistic behavior of coyotes, predation to cattle can occur year round Predation by coyotes in a diverse prey community has not been evaluated in relation to fluctuations in abundance of prey (Windberg and Mitchell 1990). However, factors influencing natural prey availability other than weather (e g , diseases to rodent populations and other decimating variables) are probable indirect influences contributing to livestock depredation in some circumstances.

Coyotes in certain situations can depend heavily on fruit production of native plants Meinzer et al. (1974) evaluated the diet of coyotes in the Rolling Plains ecological area during 1971-73 They observed that fruits of native shrubs, as a group, were the coyote's major dietary item. They further concluded that coyote predation on cattle or calves might be a problem in years when high coyote density coincided with low native fruit production.

Undoubtedly, natural forage abundance and nutritional value can buffer or minimize livestock depredation However, habitual livestock depredation by coyotes can be a *specialized behavior* that must be dealt with on an individual basis. Extreme livestock depredation situations (i.e., surplus killing) provide additional evidence of aberrant behavior that defy the norm. Although such behavior is more prevalent involving resources other than cattle (i.e., sheep and goat), evidence to support this behavior involving cattle has been observed

Population dynamics and interactions

Much of what is known today about coyote populations and movement is due to research conducted within the past twenty-five years Knowledge gained in studies during the 1970s has resulted in a much better understanding of the variability and adaptability of coyotes across North America (Voigt and Berg 1987). Population density, home range, dispersal and reproduction questions continue to be studied to refine damage management objectives Social behavior and coyote demographics (specifically population age structure) have become key factors influencing damage management strategies for protecting cattle resources.

Observations across high coyote density areas of the High and Rolling Plains have revealed that middle (3 to 5 years old) and older (>5 years old) age classes of coyotes are primarily responsible for cattle depredations. This is further supported by examination of target coyotes removed from within and near areas of confirmed calf losses. Aerial hunting observations of coyotes attacking or consuming freshly killed calves are common. Further ground truth examination of stomach contents and aging by tooth wear (Gier 1957) corroborate age of offending coyotes To simplify classification, age groupings of young (<3 years), middle age (3 to 5 years) and old (>5 years) are commonly used among management technicians.

The size and weight of coyotes are commonly overestimated, perhaps because their long pelage masks a bone structure that is lighter than that of dogs (Voigt and Berg 1987). Adult coyotes normally weigh 20 to 35 pounds, with males usually about 4 pounds heavier than females (Gier 1968, Andrews and Boggess 1978, Berg and Chesness 1978, Todd 1978, Voigt and Berg 1987). Predation of large animals such as calves, often defended by aggressive cows, require considerable strength, agility and execution of skillful tactics Coyotes that successfully prey on cattle have attained the necessary predatory prowess and strength through age.

Post-mortem examinations of fresh quarry often indicate masterful kills by coyotes that are much smaller than their prey. Subcutaneous hemorrhaging from attacks in the throat region is further evidence of kills made by experienced coyotes. In contrast, incidence of bobbed tails on calves and mutilation associated with inept, rear end attacks is often indicative of younger, inexperienced coyotes or domestic dogs Such evidence is construed as an indicator of impending losses. Rampant occurrences may further indicate a maturing and threatening population of coyotes in problem areas.

Management Implications

Presuming that coyotes $\geq$3 years of age are responsible for most calf losses, it reasons that damage management objectives should initially focus control efforts toward middle- and older-aged coyotes Control efforts that specifically target older coyotes in areas of calf losses have a demonstrated effectiveness of resolving conflicts. However, targeting and removing specific, offending coyotes can be challenging In addition to aerial hunting, proper application of control methods that entice dominant behavioral responses has been used successfully

Implementing general population suppression can assist long term damage management objectives. The removal of coyotes from high density problem areas can influence population dispersion The dynamics of coyote populations depend on natality, mortality, emigration and immigration (Knowlton 1983, Voigt and Berg 1987) Dispersal is generally from high to low density areas but is complex (Davison 1980, Knowlton 1983, Voigt and Berg 1987). Knowlton (1972) suggests that dispersal of animals seeking to establish themselves in new areas is perhaps the most important movement pattern in management schemes. It is further stated that immigration (i.e., a one-way movement into an area) provides the mainspring for restocking where removal has been the primary objective of coyote management Recurring control efforts that remove primarily subadult and young adult coyotes (<3 years of age) imply immigration by younger coyotes.

Conclusions and Recommendations

It concludes that the older, more experienced segment of the coyote population is responsible for most calf losses. Therefore, losses may be significantly reduced by initially targeting those animals. A maintenance program of general population suppression which consequently influences dispersion of younger, less threatening coyotes into lower density areas is often necessary to ensure long term reductions of livestock losses.

Acknowledgments: I wish to thank Gene Miller (Texas Parks and Wildlife Department), Ronnie Smith and Karen Dulaney (Texas Animal Damage Control Service), and Cindy Gilliland for their helpful review and suggestions

Literature Cited

Andelt, W F 1987 Coyote Predation Pages 128-140 *in* M Novak, J A Baker, M.E. Obbard, B. Malloch (Eds) Wild Furbearer Management and Conservation in North America The Ontario Trappers Assn , Prov of Ontario, Ministry of Natural Resources, Ontario.

Andrews R.D., and E.K Boggess. 1978. Ecology of coyotes in Iowa Pages 249-265 *in* M Bekoff (Ed), Coyotes biology, behavior, and management Academic Press, New York, N.Y.

Berg W E., and R A. Chesness. 1978. Ecology of coyotes in northern Minnesota Pages 229-247 *in* M. Bekoff (Ed), Coyotes biology, behavior, and management. Academic Press, New York, N.Y

Bowen W.D., 1981 Variation in coyote social organization: the influence of prey size. Can. J Zool. 59 639-652

Camenzind F.J., 1978 Behavioral ecology of coyotes on the National Elk Refuge, Jackson, Wyoming. Pages 267-294 *in* M. Bekoff (Ed.) Coyotes: biology, behavior, and management. Academic Press, New York, N.Y

Davison R.P., 1980. The effect of exploitation on some parameters of coyote populations. PhD Thesis, Utah State Univ., Logan 153pp.

Estabrook G.F., and A.E. Dunham. 1976. Optimal diet as function of absolute abundance, relative abundance, and relative value of available prey. Am. Nat 110:401-413

Gier H.T., 1957 Coyotes in Kansas. Kans. Agric Exp. Stn Bull. 393 , Manhattan. 97 pp

_____ 1968. Coyotes in Kansas Revised Kansas State Univ , Agric. Exp Stn Bull. 393 118pp.

Knowlton F F, 1972. Preliminary interpretations of coyote population mechanics with some management implications J Wildl. Manage 36:376-377.

____. 1983. Coyote population dynamics: another look Pages 93-111 *in* F L Bunnell, D.S Eastman, and J M Peek (Eds.), Proc Symp. on the Natural Regulation of Wildlife Populations. Univ. Idaho For., Wildl., and Range Exp Stn., Moscow.

Meinzer W P., D N. Ueckert , and J T. Flinders. 1975 Food niche of coyotes in the Rolling Plains of Texas J. Range Manage. 28:22-27.

National Agricultural Statistics Service 1992. Cattle and calves death loss. U.S D A., Washington, D.C 20pp.

Texas Animal Damage Control Service 1993 Activity Report FY 1993 San Antonio, Tx 65pp.

Texas Agricultural Statistics Service, 1995 Cattle and calves inventory. U.S D A , Texas Dept. of Agric , Austin, Tx.

Thurber J M., and R.O. Peterson 1991. Changes in body size associated with range expansion in the coyote. J. Mamm 72 750-755.

Todd A.W., 1978 The coyote. Bull. Can Assoc. Humane Trapping 1978 (Summer): 3-5.

Voigt D R , and W.E. Berg. 1987. Coyote. Pages 345-357 *in* M. Novak, J.A. Baker, M.E. Obbard, B Malloch, (Eds.), Wild Furbearer Management and Conservation in North America. The Ontario Trappers Assn., Prov. of Ontario, Ministry of Nat Res., Ontario.

Windberg L A , and C D. Mitchell 1990. Winter diets of coyotes in relation to prey abundance in southern Texas. J Mamm. 71:439-447.

ESTIMATING LIVESTOCK LOSSES

CHARLES DRAIN, Agricultural Statistician, U.S.D.A. National Agricultural Statistics Service, Texas Agricultural Statistics Service, P.O. Box 70, Austin, TX 78767-0070

Abstract: Most information published by the Texas Agricultural Statistics Service (TASS) is based on data gathered through a system of Sample Surveys. TASS regularly surveys sampled farms and ranches and agricultural businesses in order to make statistical inference (estimates) for a total population. The alternative to using a sample survey would be to make a complete enumeration or count of the entire population. Both cost and timely results favor the survey approach. This discussion is an attempt to explain the concepts and sampling methods TASS employs in conducting basic surveys, for both inventory and death loss data for cattle, sheep and goats The discussion will include how estimates were developed for sheep and goat losses to predators and other causes during 1994.

Sampling frame

Every sample survey requires the availability of a sampling frame. The population to be sampled (for our discussion, cattle, sheep and goat operations in Texas) must be divided into sampling units. The sampling frame defines the population and identifies the operations that are available to be sampled Sampling units can be names of people representing farm or ranch operations, or units of land as delineated on photographs or maps. The basic requirements of an effective sampling frame are that its sample units, when aggregated, contain the entire population and that individual sample units do not overlap.

TASS surveys use 2 kinds of frames, the "Area Frame" and the "List Frame." The concept of area frame sampling is simple The land area to be surveyed (in this case the state of Texas) is divided into small blocks called segments, with unique and identifiable boundaries that can be delineated on aerial photographs or maps No segment has more than one chance of being selected The sample is a random selection of segments

The area frame provides a sampling vehicle for an unlimited variety of surveys The survey population can be composed of reporting units that are farm households, farm headquarters, animals, plants, grain storage facilities, or any other identifiable units that can be associated with segments of land. The primary advantage of area frame sampling is that it provides a complete frame; that is every acre of land in the state has a known chance to be selected, so all items being surveyed have a chance of being selected by their association with a unique segment An area frame does not grow out of date in terms of coverage of the population. With the area frame, extremely large samples are required to provide estimates for commodities that (a) appear in less than 20% of the segments, (b) are produced on less than 20% of the farms and ranches, or © if the farms and ranches vary widely in size.

The list frame is a list of farm or ranch operators or agribusinesses. The list frame contains names and addresses, along with control data that identify the relative size and type of the items of interest. The list frame has several advantages over the area frame. It permits the use of data collection by mail and telephone. It also allows the use of more efficient sampling methods, especially for items produced on a small percentage of farms and ranches or where there is extreme variability in size of operations, as for livestock. If the list frame of farm or ranch operators contains information on relative size, the extremely large operations can be selected with high probability, or certainty to minimize their impact on the sampling variability

A basic disadvantage of a list sampling frame is that it is nearly impossible to maintain a complete list that covers the entire population of interest, and has current classification data. In addition, maintaining a complete list frame with current names, addresses and control data for sampling purposes is very costly.

Multiple frame sampling is a survey technique that uses a combination of list and area frames to gain the advantages of both The list frame is extremely efficient for large operations and operations that produce rare items. The area frame ensures complete coverage and can be used as an independent estimator and also to estimate incompleteness of the list frame

Sample selection

A typical multiframe sample selection procedure for a commodity requires that a "frame of interest" be established for that commodity within the overall list frame For example, a cattle frame is established by identifying names with control data indicating the presence of cattle, or a sheep frame is established by identifying names with control data indicating the presence of sheep Names that do not have cattle control data are not members of the cattle frame.

The same is true for the sheep frame The classification process assigns sample units to size groups (strata) based on the relative size of previously-reported control data For example, all extremely large units are assigned to a different stratum than extremely small units An optimum allocation procedure distributes the list sample to the various strata This means that strata containing operations with large numbers of cattle may be sampled much more heavily than those having small herds The area frame segments selected are used for a measure of incompleteness.

For the January 1, 1995 cattle, sheep and goat survey, a random sample of 4,842 Texas cattle, sheep and goat producers were selected from the list frame and 5 19 tracts of land from the area frame. Survey procedures ensured that all cattle, sheep and goat producers, regardless of size, had a chance to be included in the survey The sample was selected to provide sufficient data to estimate the items of interest at the state level only Large operations were sampled more heavily than small operations (Table 1).

The survey was conducted during December 30, 1994 -January 16, 1995 by mail, telephone, and personal interview. Livestock operators were asked to report inventory data as well as total death losses for cattle and calves, and death losses by cause for sheep, lambs and goats for the 1994 calendar year.

Estimation methods and procedures

The computations and procedures for translating survey data into estimates involve technical considerations. Usually more than one method is available, but the choices are largely dictated by survey design. There are distinct differences between the way estimates are derived from probability and nonprobability surveys.

Probability surveys Probability surveys are designed on the premise that every unit in the population has a known probability of being selected The probabilities do not have to be equal, but they must be known and used in the selection process.

Estimates can be made from probability surveys without depending on prior survey information or benchmark data. Because probabilities of selection associated with the sample units are known, data collected from them can be used to obtain unbiased estimates of current agricultural activities such as sheep and goat losses to predators. Also sampling errors can be computed for probability surveys, providing the statistician with a tool for evaluating the reliability of the estimates

The factors involved in evaluating survey reliability are the sampling frame, survey design, and sample size Each is important in maintaining sampling errors at acceptable levels, although constraints on sample size are frequently imposed by budget limitations National Agricultural Statistics Service (NASS) minimizes potential nonsampling errors through survey training programs, questionnaire design and testing, simplified and uniform survey procedures, and comprehensive editing systems. The estimation model used in preparing estimates of cattle, sheep and goat death losses from the January 1, 1995 multiple frame livestock survey (area and list frame) is:

$$X = X_a + X_L$$

where:

X_a = the expanded total for the portion of the population included only in the area frame;

X_L = the expanded total for the portion of the population included only in the list frame.

Analysis of data

Outlier reports can influence survey expansions considerably Outlier reports are sampled operations that report either very small or very large answers that lie apart from the rest of the reports. In practice, only the extremely large reports are of concern. These reports present problems if not detected Detection is primarily limited to identifying operations with answers that vary a great deal from control data

Outliers (both list and area frame) are first identified in the machine edit List frame outliers are identified again in a special analysis summary which excludes these reports. The summary is used to measure the outliers' impact on the estimate The statistician evaluates the sampling errors associated with each estimate, with and without outliers, when establishing a range for the final estimate

Obtaining estimates of death losses

Once the survey has been conducted, data edited, summarized, and analyzed, the estimates are prepared for the items of interest, i.e., death losses by all causes for various kinds of livestock. Only total death losses were estimated for cattle and calves from the January 1, 1995 survey The survey questionnaire was not designed to obtain losses of cattle and calves by cause

Total sheep (1-year old and older) losses from all causes were estimated first using the multiple frame direct expansion and ratio to all sheep 1-year old and older inventory. The survey ratio of losses by all predators was then applied to total sheep losses to arrive at an estimate for losses by all predators The survey ratio of sheep losses by type of predator was applied to the estimate of losses by all predators to arrive at estimates by type of predator. Estimates of nonpredatory losses were prepared using the same procedure (Table 2).

Total estimates of lamb (under 1 year old) losses from all causes before and after marking, docking, or branding were prepared utilizing the multiple frame direct expansion and ratio to the 1994 lamb crop. The survey ratio of predator losses to all losses of lambs before marking, docking, or branding, and after marking, docking, or branding was applied to their respective estimate of losses from all causes to arrive at estimates of losses from predators and nonpredators. The survey ratio of losses by species of predator was applied to the estimate for each of the parts to arrive at estimates by predator species, and by cause for nonpredatory losses (Table 2).

Estimates of goat losses were not made at the state level by predator species. However estimates were prepared at the state level for all losses to predators, losses to other causes and total losses (Table 4). Combined estimates of losses by predator species were prepared for 5 states (Arizona, Michigan, New Mexico, Oklahoma and Texas) by our headquarters office in Washington, D C. (Table 3)

Literature Cited

NASS Staff Report. 1995. Sheep and Lambs Death Losses 1994.

Scope and Methods of the Statistical Reporting Service of the United States Department of Agriculture Misc. Publ No 1308.

Table 1. Texas sample allocation; 1 Jan 1995 cattle, sheep and goat survey.

Survey Strata	Strata Boundaries	Population	Sample Size	Interval	Total Reps	Sample Reps	Units per Rep
2	Cattle 1-49, Dairy 1-49	39,066	280	139.521	12	8	35
3	Cattle 50-99	14,348	216	66.425	12	8	27
4	Cattle 100-499	11,398	688	16.566	12	8	86
6	Dairy 50-199	1,125	104	10 817	12	8	13
7	Goats 1-499	2,901	160	18.131	20	16	10
13	Goats 500-2,499	272	128	2.125	20	16	8
15	Sheep 1-499	5,520	1,088	5.073	20	16	68
18	Cattle 500-2,999	2,411	560	43.305	12	8	70
19	Cattle on Feed 100-999	187	40	4.675	12	8	5
20	Sheep 500-2,499	814	640	1.271	20	16	40
21	Cattle 3,000-9,999	156	156	1.000	8	8	19
22	Dairy 200-499	451	64	7.046	12	8	8
30	Dairy 500-999	91	91	1.000	8	8	11
32	Goats 2,500-9,999	169	169	1 000	16	16	11
33	Sheep 2,500-4,999	135	135	1.000	16	16	9
34	Sheep on Feed 500-1,999	23	23	1.000	8	8	3

Table 1. (Con't.)

35	Cattle 10,000	22	22	1.000	1	1	22
36	Cattle on Feed 1,000+	137	137	1.000	1	1	137
37	Dairy 1,000	41	41	1.000	1	1	41
38	Sheep 5,000+ or Goats 10,000+	80	80	1.000	1	1	80
39	Sheep on Feed 2,000+	20	20	1 000	1	1	20
	Total List	79,367	4,842				
	Area Sample		519				
	Total Sample		5,361				

Table 2: Texas Losses of Sheep and Lambs From Predators and Other Causes, 1990 and 1994

Causes	Sheep				Lambs							
					Before marking, docking or branding				After marking, docking or branding			
	1990		1994		1990		1994		1990		1994	
	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
	Head	*Percent*	*Head*	*Percent*	*Head*	*Percent*	*Head*	*Percent*	*Head*	*Percent*	*Head*	*Percent*
Total losses from predators	27,000	29.3	16,400	35.7	NA	--	57,000	63.1	80,000	66.7	31,000	58.4
Coyotes	16,000	59.2	7,400	45.1	NA	--	22,750	39.9	40,000	50	19,700	63.5
Dogs	4,000	14.8	2,300	14	NA	--	1,225	2.2	4,000	5	1,100	3.5
Mountain lions	1,500	5.5	3,300	20	NA	--	1,975	3.5	1,000	1.2	1,600	5.2
Bears	0	--	0	--	NA	--	75	0.1	0	--	100	0.3
Foxes	500	1.9	500	3.0	NA	--	4,175	7.3	6,000	7.5	2,000	6.5
Eagles	500	1.9	200	1.2	NA	--	13,525	23.7	8,000	10	3,200	10.3
Bobcats	500	1.9	1,400	8.5	NA	--	9,775	17.2	8,000	10	2,300	7.4
All other animals 1/	4,000	14.8	1,300	7.9	NA	--	3,500	6.1	13,000	16.3	1,000	3.2
Losses from other causes	65,000	70.7	29,600	64.3	NA	--	21,000	26.9	40,000	33.3	22,125	44.6
Digestive problems 2/	NA	--	4,575	15.5	NA	--	1,375	6.6	NA	--	2,700	12.2
Respiratory problems 3/	NA	--	325	1.1	NA	--	1,800	8.6	NA	--	800	3.6
Metabolic problems 4/	NA	--	375	1.3	NA	--	400	1.9	NA	--	200	0.9
Weather related causes 5/	NA	--	1,200	4.1	NA	--	4,250	20.2	NA	--	1,600	7.2
Theft	NA	--	500	1.7	NA	--	0	--	NA	--	700	3.2
Poisoning 6/	NA	--	925	3.1	NA	--	125	0.6	NA	--	400	1.8
Lambing problems 7/	NA	--	1,475	5.0	NA	--	--	--	NA	--	3,125	14.1
Other causes 8/	NA	--	9,700	32.8	NA	--	2,000	9.5	NA	--	3,300	14.9
Unknown causes	NA	--	10,525	35.6	NA	--	7,925	37.7	NA	--	9,300	42.1
Losses from all causes	92,000	100	46,000	100	NA	--	78,000	100	120,000	100	53,125	100

Table 2. Con't.

	Value of Losses From Predators			
	-- *Dollars* --		-- *Dollars* --	
Value per head 9/	59.00	55.00	35.00	39 00
Value	1 6 mil	0 9 mil	2.8 mil	1.2 mil

1/ Includes wolves, ravens, crows, pigs, etc
2/ Incudes bloat, scours, parasites, enterotoxemia, acidosis, etc
3/ Includes pneumonia, shipping fever, etc
4/ Include milk fever, twin lambs disease, pregnancy toxemia, etc
5/ Includes chilling, drowning, lighting
6/ Includes nitrate poisoning, noxious feed, noxious weeds, etc
7/ Includes all lambs before and after marking, docking and branding
8/ Include lameness, old age, on back, diseases not reported earlier, etc
9/ Sheep value per head based on a two-year straight average of the value of ewes one year old and older from the 1 Jan 94, and 1 Jan 95, NASS surveys Lamb value/head based on the USDA annual average price received by farmers and ranchers for 60-pound lambs

Table 3: Losses of All Goats by Specific Predators and Total Value, Five States, 199O and 1994[1]

Year	Coyotes	Dogs	Mountain lions	Bears	Foxes	Eagles	Bobcats	All other predators	Total predators	Value 2/
					-- Head --					Dollars
1990	64,900	9,700	2,900	0	4,100	16,300	20,600	10,900	129,400	5,661,250
1994 .. .	41,000	15,000	5,000	1,000	7,000	25,000	21,000	25,000	140,000	5,481,000

[1] Includes Arizona, Michigan, New Mexico, Oklahoma and Texas. 2/ Goat value is based on a straight average of the value per head of all goats from 1990-91 and 1994-95 NASS surveys.

Table 4. Texas losses of all goats by cause, 1990 and 1994.

Year	Lost to Predators	Other causes[1]	Total losses
		No. head	
1990	121,000	45,000	166,000
1994	137,000	73,000	210,000

[1]Includes diseases, weather, theft and unknown.

COYOTES: A SHEEP AND GOAT RANCHER'S PERSPECTIVE

ELLIS HELMERS, P O Box 200, Sanderson, TX 79848

The dictionary defines perspective as "a view of things or facts in relation to other facts and realities".

When asked their views about coyotes and coyote damage, the words used by producers to describe their perspectives and comments are less than kind. It is difficult for a producer to find anything good to say about an animal that has cost him and the sheep and goat industry so much

Most producers will admit that the coyote is smart and cunning; that it is an animal with tremendous adaptability which earns him the respect of producers They will also admit that the price tag on coyote predation during the past 30 years is probably greater than that of drouth and weak markets combined

The facts pretty well dictate what most sheep and goat producers' perspective on coyotes will be. We see a lot of reports and studies on predation that show numbers of livestock lost, and figures on the economic impact of these losses. Such figures are tremendous, but they are only a small part of the losses hurting production

The figures don't show the loss of years of productive potential, the loss of sheep and goat ranges when producers are forced out of business, the expense of predator control and management practices, the necessity of altering sound ranch management practices and schedules to prevent predation, and they don't show the amount of time lost on predator management

One of the worst losses that a producer must face is the mental anguish of seeing animals that he has raised and cared for, destroyed day after day. Most producers are in the ranching business because it is a way of life that they wish to pursue; they like to see their livestock prosper and do well They have a large investment in this endeavor and usually see a very small percent return on their investment

When you add up all the losses caused by coyote predation, it is probably the number one barrier to profitable sheep and goat production in Texas

I was raised on a ranch in Pecos County, where my family has raised sheep and goats for over 50 years During this time, the county has gone from a leader in sheep production to a county that can produce these animals on about 20% of its area. This change is almost entirely a result of coyote predation. The northwestern two-thirds of the county has such large numbers of coyotes today that we probably will never see sheep and goats in that portion of the county again.

These are the facts that shape a producers perspective on coyotes

Another definition of perspective is "from a particular mental point of view". This is a good definition because I know of several producers, trappers and bankers who have developed mental problems because of the coyote

In the past 40-50 years, there has been a rapid transition of the state's population from a rural to an urban way of life. People have moved away from the rural or agricultural point of view, changing their perspective about what goes on around them. This urban movement has made the producer's perspective a small part of the overall picture.

Most producers are devout conservationists They have to be good resource managers. They are not out to wipe the coyote off the face of the earth But in the back of their minds, and deep in their hearts, they would like to see the coyote eliminated from that small percentage of the earth where sheep and goats are raised

AUDUBON'S PERSPECTIVE ON COYOTES

DEDE ARMENTROUT, Regional Vice President, Southwest Region, National Audubon Society, 2525 Wallingwood, Suite 1505, Austin, TX 78746

The National Audubon Society

The National Audubon Society is a charitable, non-profit citizens' scientific and education organization. We were formed in the early 1900s as a coalition of independent outdoor nature groups who banded together to conserve many species of birds which were being destroyed by an unregulated market on meat and feathers.

In 1904, feathers from some of the long legged wading birds were literally worth their weight in gold: $32 00 an ounce. As a consequence of the high price, no education programs, and no regulatory apparatus, parent birds were being hunted year round, including when they had young in their nests. Especially during nesting seasons they were easy prey because of their reluctance to leave their young Nesting colonies of birds were rapidly destroyed

By hunting nesting birds, the profiteers of the feather trade were inadvertently, but seriously affecting the likelihood that subsequent generations of those species would survive

The Audubon Society used 4 tactics in its campaign to protect long legged wading birds from the plume trade. First, they used education and publicity; publishing notes, articles, editorials, adds, and poems; giving speeches, taking decision makers and opinion leaders to the sites of concern Second, they used land stewardship, buying important roosting sites or informing coastal states of the importance of coastal nesting sites when sites were publicly owned. Third, they used market pressures, urging consumers not to buy products that hastened the extinction of the beautiful bird species of concern Finally, they used legislation to provide a regulatory apparatus of protection.

The wild bird plume trade has been gone from the United States since the early 1900s Decorative feathers now come from domestic or pen-raised birds and have for almost a century. The egrets, spoonbills, and herons, once in such peril, recovered and provide Texans and millions of tourists with thrilling sights along the Texas coast and elsewhere

The Audubon member

Audubon members are still outdoor nature enthusiasts. They spend a lot of time in the field. They are active outdoor people who supplement what they see with studies and readings in areas of interest to them

Our average member is in his/her early 40s, has a few years of college past a Bachelor's degree, has a combined household income just over $60,000, and is active in church and/or a civic organizations in addition to Audubon In Texas, 20% of our members are rural or in small towns. The rest reside in or near one of Texas' major municipalities.

Audubon staff

Audubon's staff in the Southwest are predominantly young adults with middle-aged supervisors. Professional staff have a Master's Degree or higher. Most are only one generation (or less) removed from a farm or ranch background The new president of the National Audubon Society grew up on a dairy farm in Minnesota Many staff are still engaged in agriculture. I raise Angora goats and my partner and I are among very few Texas certified organic peach growers. I came from a family which was agrarian on both sides until my parents' adult lives. Most of my peers in the mainstream environmental community in Texas have similar backgrounds.

How Audubon views coyotes

Audubon has a membership which probably spans all views of coyotes (*Canis latrans*) Audubon's staff views coyotes as biologically appropriate predators in most of the Southwest. We believe that they can be an asset to a well-managed ranch, but that they can also cause localized depredation which must be answered.

Our members value predators, including coyotes, for their natural role in ecological systems, including their influence on prey species. Many of our members travel broadly and spend money to view wildlife, and consider it a treat to see and hear coyotes.

Politics and coyotes

The points that I would like to address relative to this predator's politics include both real and perceived problems. A general outline to my discussion is attached (Table 1)

Table 1. An outline of political issues related to coyotes.

I. People's perceptions of coyotes
  A. What gives value to wildlife (or anything)
    1. Market system (what's it worth?)
    2 Economic value of coyotes
      a Ecotourism
      b. Film & photographs
      c. Elimination of competitors for range resources
      d Fur
      e. Souveniers
    3. Totem value of coyotes
      a Romantic symbol of wild west
      b. Symbolic of cleverness and resourcefulness
      c. Symbolic of the beleagured but unconquered
      d. Value by rarity
        (1) Hard to see
        (2) Perceived to be diminishing
        (3) Perceived to be disappearing (i.e., *"can't do it now, but soon will be able to"*)
    4 Valued for perceived "place" in the system
      a "Place" is dynamic, but often not perceived as such
      b Valued because it is "owned" in common

II. Political versus biological decisions
  A. Do coyotes deserve the expenditures to control them?
      1. Should those expenditures be borne by the general public?
  B. Do coyotes deserve the energy to protect them?
  C. Are there vigorous efforts to eliminate/protect them?

III. Topical political issues related to coyotes
  A Coyotes are publicly-owned resources (issues of public responsibility as well as public rights)
  B Coyotes may affect privately-owned resources (adversely or positively)
  C Coyote control may impact other publicly- owned resources (e g , other wildlife, water quality, safety, local, state and national budgets)
  D. Coyotes may be scapegoats for other problems (e g., other sources of mortality and economic woes beyond the control of the producer)

IV. Perception issues with coyotes
  A Perception is reality
  B. Depredation disagreements in perception
    1. Whether there is depredation by coyotes or not
    2 Degree of depredation
    3 Significance of depredation (mortality versus compensatory mortality)
    4 Degree of responsibility for the depredation
      (a) To be borne by the producer/ public
  C Which control is appropriate
    1 Prophylactic versus reactive
    2 Lethal versus non-lethal)
  D Degree to which control is possible
    1 Importance in its niche (biological)
    2. Importance as a totem (social)
  E. Bias in data
    1. Data collection is political
    2 Data interpretation is political

PREDATOR POLITICS IN TEXAS

HONORABLE BILL SIMS, State Senator and formerly Executive Director, Texas Sheep and Goat Raisers Association, P. O. Box 2290, San Angelo, TX 76902-2290

The coyote (*Canis latrans*) is certainly one of the most destructive predators affecting the livestock industry, particularly sheep and goats. In fact, title of this session is very appropriate, because when you talk about "politics", coyotes seem to have more politicians working for them than any other animal!

It seems to me that many people who speak up for the coyote don't really know anything at all about the extent of its destructive ways. They don't realize that the coyote takes 15-20% of the sheep and goats lost to predators in the western United States. This amounts to a huge monetary loss to the ranchers affected, not to mention the loss of food and fiber for our nation.

Also, our wildlife are extremely vulnerable to coyote predation. I have seen several research projects where as much as 60% of the fawn crop was taken by predators Such high levels of predation are obviously a very serious problem to livestock - producers and wildlife managers alike.

What can we do about it? All of us in the livestock and wildlife industries must work together to educate other segments of our population (especially the urban public). They need to recognize the fact that we must be allowed to take some coyotes in order to preserve domestic as well as wildlife species. When you have large livestock and/or wildlife populations, it is impossible to operate profitably with an active coyote population.

I have worked with the sheep and goat industry professionally for the last 40 years, and I have seen the coyote population explode all over the sheep- and goat-raising areas Areas that were once coyote-free are now overrun with them, and livestock production and the wildlife population in those areas have been hit hard.

When I was a County Agent in the mid-1960s, much of this area had no coyote problem. I think 1 of the factors that caused the spread of coyotes was the drought of the 1950s. The drought forced many ranchers to get rid of their sheep and goats and some of their cattle, thus nothing was done about predators during that time. When people started re-stocking after the drought broke, the coyotes had become well entrenched.

Another factor in the explosion of the coyote population was President Richard Nixon's 1972 ban on the use of Compound 1080 and sodium cyanide, 2 of the main toxicants used in predator control At the time these toxicants were banned, it was estimated that 80% of all coyotes removed were taken with sodium cyanide and Compound 1080. So, in one day you might say we lost 80% of our animal damage control.

Shortly after we lost these toxicants, I talked to Congressman Bob Poage about how to pursue regaining the use of the 2 chemicals. He asked me which one would have the fewer people against it, and I said that it would be sodium cyanide for use in the M-44 Device. With Congressman Poage's help, we went to work on regaining the restricted use of sodium cyanide, and we were able to accomplish this in about a year. The Texas Department of Agriculture (TDA) was very helpful in this effort, assisting with re-registration and conducting operator training programs across the state, and in about 3 years the M-44 program was in place again.

Then we went to work on Compound 1080 for use in the Livestock Protective Collar (LPC). After about 5 years, and again with a great deal of help, we were granted a permit for carefully restricted use of Compound 1080 in the LPC. None of this would have been accomplished if it had not been for the hard work, knowledge and experience of Extension predator specialist Dr. Dale Wade, LPC inventor Roy McBride, State Representative Dudley Harrison and a great many Extension, ADC and TDA folks.

Although we were successful in regaining use of

1080 in the LPC and sodium cyanide in the M-44, I do not believe we will be able to reduce coyote numbers to a level of profitability until we are allowed more extensive, although restricted, use of these 2 toxicants. Snares and traps alone will not get the job done with the extremely high numbers of coyotes we have across the sheep and goat raising area of the state today.

Another factor which could prove to be extremely detrimental to livestock producers is the proposed re-introduction of the Mexican wolf (*C. lupus baileyi*) into New Mexico and Big Bend National Park. The mountain lions in the Park have already made huge inroads on the wildlife population, and the coyotes have pushed on into the livestock-producing areas in search of easier, more abundant prey If the wolves are re-introduced into the Park, they, too, will be hard pressed to find a "natural" food source, and will also move on. The coyotes will keep expanding their territory as the pressure from the wolves and lions shrinks the food supply.

If this problem is not addressed and resolved satisfactorily, I believe we will see a huge amount of good sheep, goat and cattle country taken out of production by extensive coyote/wolf/lion predation. Seminars such as this one today can go a long way toward educating the public about coyotes and working toward long-term goals of profitable co-habitation of livestock and wildlife with much smaller numbers of predators.

We have no desire to eliminate any species, but we do feel we have the right to make a living from of our land. Coyotes rob us of that right just as surely as the thieves who rob our homes and businesses do.

PREDATOR POLITICS: PERSONAL THOUGHTS AND PERCEPTIONS

MILO J. SHULT, Vice-President for Agriculture, University of Arkansas, 1123 S. University Ave., Suite 608 Little Rock, AR 72204

Abstract: My career as an extension wildlife specialist and a university administrator has allowed me to monitor both the public and private sectors' perspectives on coyotes (*Canis latrans*) and their associated management policies. Selected experiences described herein illustrate the problems (current and future) that characterize emotionally-charged conflicts like those typified by coyote control efforts.

When Dale Rollins first approached me with an invitation to participate in this symposium, I was unsure about other commitments, but hopeful that I could return to Texas, see old friends and be a part of the program. By the time we got around to finalizing the arrangements in early August, Dale let the other shoe drop by saying "Oh, by the way, you have to write a paper and it has to be in no later than September 1 "

In our first discussion, he described a panel with Bill Sims and Dede Armentrout. Naturally, I assumed we would each deliver some prepared remarks and then share experiences and observations which, if worthy of note, would be recorded in some form of a panel summary statement. Apparently not so.

As I set about the task of preparing this manuscript, I began to rummage through papers, contact colleagues whom I had "bequeathed" my old predator files to when I moved into administration full time, and go through old calendars from my specialist days. It didn't take long to realize that I could spend a great deal of time chronicling events and laws that have already been recorded by others. In fact, Dr. Dale Wade, whom I consider to be 1 of the best experts on wildlife damage control anywhere, has already done this extremely well in at least two of his publications (Wade 1980, 1982)

With that in mind, I decided to address events and activities that I have personally been a part of with respect to predator politics and to share thoughts and perceptions as related to current issues facing agriculture across our nation. As the saying goes "these are my own opinions and do not necessarily reflect those of anyone I have ever worked for."

Early career influences

In 1964, I began my graduate career at Iowa State University. The Leopold Committee Report on "Predator and Rodent Control in the United States" was made public, declaring that the U.S. Fish and Wildlife Service-Animal Damage Control program was indiscriminate, nonselective and excessive in its predator control programs. The report did, however, view Compound 1080 as a relatively humane and effective means of coyote control (Leopold 1964).

I must admit that, as graduate student of the 1960s, I was not particularly impacted by the Leopold Report except as a source of intellectual debate. I had grown up in a family where wildlife was a source of food for the table as much as anything else. One of my prized possessions today is a membership card for my great grandfather in the Illinois Federation of Sportsmen's Clubs from 1930, on the back of which is a Sportsman's Creed. The Creed exhorts members to obey laws, show respect for property, protection of wildlife and, as a last entry "I will do my best to kill a pest." That was the natural order of things from the time I was a child.

In 1971, the Cain report, "Predator Control-1971" was produced. This report indicated that chemical controls were likely inhumane and nonselective and recommended that individuals with predator problems be instructed on the use of leghold traps as the major method of damage control (Cain et. al. 1972) I remember being struck by the fact that both the Leopold and Cain reports condemned existing predator control programs, but came to somewhat different conclusions on the relationship between chemical and non-chemical controls.

Some of my colleagues in graduate school with different backgrounds than mine took these reports at face value Today, many of them are full professors in wildlife departments at major universities. I have often wondered whether or not these early career experiences influenced their attitudes towards predator management as a part of their profession.

1970s and toxicants

On Feb 8, 1972, President Nixon issued Executive Order No 11643, cancelling the use of specific chemicals for predator control on federal lands and in federal programs (Nixon 1972) This action was followed by EPA registration cancellation and suspension notices for Compound 1080, strychnine, sodium cyanide and thallium sulfate (Ruckelshaus 1972).

On May 16, 1972, I began employment as an area wildlife specialist with the Texas Agricultural Extension Service in Uvalde, Texas. Needless to say, the reaction of ranchers concerned about protection of their livestock, particularly sheep and goats, was dramatic As a newcomer it was clear that the loss of control techniques was viewed as a threat to the existence of the ranching industry and, of perhaps greater importance, a way of life

On October 31, 1972, Charles Ramsey, Extension wildlife specialist headquartered at Texas A&M, and I met with San Angeloans Bill Sims and John Cargile at their request to discuss what could be done about the situation I have often thought in recent years how they must have walked out of that meeting with no sense of accomplishment, and probably the perception that the university was deserting them At that time, there was little we could do from a research and extension standpoint.

From 1972 until 1974, there was much talk and little action at both the state and federal levels. A number of congressional hearings on predator and rodent control were conducted. Many requests were prepared and submitted for reregistration of various toxicants. Finally in February of 1974, an experimental use permit for sodium cyanide in the M-44 Device was granted to Texas by EPA

I recall the implementation meeting held at the Texas Department of Agriculture headquarters in Austin on January 23, 1974 Representatives of TDA, the Texas Agricultural Extension Service, the Texas Agricultural Experiment Station and EPA were all present. The plan presented by EPA was, in the opinion of several of us, flawed at best. Nevertheless it was presented as a "take it or leave it" proposition. In retrospect, I believe that posture was a bluff--which worked.

In February 1974, we completed development of the training materials for the program in selected counties We could not totally complete the materials until final approval was received from EPA. Charles Ramsey, Wallace Klussmann and I had divided up responsibility for the counties and had scheduled meetings in late February and March to get the tools in the hands of applicators as quickly as possible

On February 28, 1974 the first meeting for which I had responsibility was held in Bexar County The Extension Service was charged with conducting the training and TDA was to certify the applicators and allocate numbers of devices to be purchased on an acreage formula

At the outset, there was a fair amount of confusion We completed the meeting in Bexar County and moved to Uvalde County for a March 1 meeting. This was followed the next week by training on March 4 in Sterling county and March 5 in Mitchell and Taylor counties That is as far as I got.

We were instructed to call the administrative offices of the Extension Service at Texas A&M twice a day to determine the status of the program. When I completed training in Mitchell County I called in and was told there was an injunction against the program filed by the Humane Society of the United States and that we would train in Abilene, but could not certify anyone to purchase the materials That cancelled the training I had in 13 other counties in March

Frustration mounts

While there are a lot of "war stories" to be told about the whole area of predator control, one sticks out in my mind because it truly reflects the frustration felt by the producer community. When I arrived at Abilene, the meeting was in the old courthouse in the main courtroom. Mr. H.C. Stanley was the county Extension agent, a man well respected in both his community and his profession.

As a side attraction, a local young man had provided the newspaper with emotional (but upon review inaccurate) descriptions of the dangers of the M-44 Emotions were high in the rancher community and the knowledge that they would be trained but not certified put the group in a fairly ugly mood

As I passed out materials before the meeting, I noticed that one individual in a suit was not taking any. At one point as he passed the papers to his neighbor, his coat fell open and revealed a 45 semi-automatic in his belt. I felt compelled to advise Mr. Stanley of the situation. He calmly replied "Yes, that fellow's a deputy sheriff. There are several scattered around the room in case things get out of hand " As you might imagine, this bolstered my enthusiasm for getting up in front of the group.

As I began my presentation (which we had very carefully scripted to avoid any legal challenges to the training) I commented that the "M-44 is a spring-operated device designed for use with a toxicant in the control of coyotes. It is the most humane device yet developed----." At that point, someone in the audience said "We don't give a damn if it's humane " Another said "Let's use one on that G-- D--- hippie " I presumed he was talking about the local fellow and not me.

The point of this story is to demonstrate that these people, most , if not all, of whom were/are God-fearing, upstanding citizens of the community had reached a level of total frustration with regulations being thrust upon them by individuals who had never experienced firsthand the interactions between predators and livestock

Reflections

As a wildlife biologist, the entire set of experiences related to the M-44 training program gave me a broader set of perspectives of the complicated interface between politics, biology, and the social systems of our population. Since that time, a number of milestones in predator-livestock management have been reached.

All of the research and political activity surrounding the Livestock Protection Collar using Compound 1080 has resulted in the availability of this tool, along with the M-44 Device with sodium cyanide. Mis-guided projects like the use of sodium cyanide in toxic collars have gone by the wayside The use of husbandry practices including guard animals and fencing, once ridiculed as poor solutions, have taken their place in the total management scheme to suppress damage. More positive dialogue has taken place in recent years than in the past among groups with widely divergent interests And, from a personal standpoint, this author has moved on to worrying about farm bill issues, boll weevil eradication and waste management on livestock and poultry operations.

Nevertheless, there are still areas of major concern in dealing with the "politics" of predator management. Some which concern me most are as follows.

1. Professional image. The wildlife profession (my disciplinary home) has failed to actively embrace wildlife damage control (including the control of predators) as a legitimate part of its portfolio. A cursory review of the Journal of Wildlife Management or the Wildlife Society Bulletin (the "flagship" publications of professional wildlife managers) reveals some fair amount of work on predator-prey relationships, but little if any on the management/control measures needed to alleviate damage.

This situation is exacerbated by the seemingly low level of esteem in which the majority of the profession holds those individuals who chose to confront wildlife damage problems head on. We haven't moved far enough away from the demeaning term of "gopher choker" in recognizing the hard work and dedication of those in the animal damage arena.

2. *Supercivilized public.* We are moving farther away from a societal "land ethic" whereby our citizens not only appreciate the land but also recognize that managment of our resources (including wildlife) is essential to our survival. The production of food and fiber is increasingly a remote concept in the minds of urban and suburban dwellers who have no vision of where their daily bread comes from. If we are not successful in stemming this trend we will face more, not less, land use conflicts in the future

3. *Man and Nature.* Too many people today ignore or refuse to accept the fact that man, as a species, must be included in any discussions of natural resource management and agriculture It is simply not possible to "step outside of nature" and make value judgments as if man was not both a force and a species impacted on by natural resource management decisions The current debate on the Endangered Species Act highlights the concerns for social and economic implications as well as environmental ones

4. *Life and death.* As a society, we have become so captured by a safe environment supported by food and medical sciences that we have perhaps lost our appreciation for a basic concept--that death is a part of life At times we have to kill other animals for reasons of our own welfare--food, protection of property, and health In my job I come in daily contact with people who have no concept that, at times, animals must die that others will live and thrive If they do accept it, they want it to be shut out of their consciousness To me, that is a serious concern

Epilogue

Finally, let me comment on perspectives, using the coyote as an example I remember watching coyotes hunt prairie dogs in South Dakota and admiring their skills. I have raced them horseback across the Dakota prairie and seen them with steamy breath on cold Arkansas mornings. In those situations, I respect and admire the animal When, however, I encounter a coyote on my property near Doss, TX, I will destroy it if possible Not because I have any hatred for the coyote, but because my neighbors are in the angora goat business and I want to help protect their livelihood I've always felt comfortable with those seemingly contradictory attitudes Hopefully I recognize the perspectives of others in the same situation

Should we wish for the elimination of all predators? Not unless we wish to include ourselves in that process. Is there room for both sheep and coyotes in the world? Absolutely . . . but not in the same pasture!

Literature Cited

Cain, S A , J A. Kadlec, D L Allen, R.A.Cooley, M.G Hornocker, A.S. Leopold, and F.H. Wagner 1972 Predator Control-1971, Rept. to the Council on Environ Quality and the Dept. of Interior by the Advisory Comm. on Predator Control, Inst. for Environ. Qual., Univ of Michigan, Ann Arbor. 207pp.

Leopold, A.S., S.A. Cain, C.M. Cottam, T.N. Gabrielson and T L Kimball. 1964 Predator and rodent control in the United States. N. Am. Wildl and Nat. Res Conf. 29:27-49

Nixon, R M. 1972. Executive Order 11643. Environmental safeguards on activities for animal damage control on federal lands. Fed Reg 37(27):2875-2876.

Ruckelshaus, W D 1972. Notice to manufacturers, formulators, distributors and regisrants of economic poisons, suspension of registrations for certain products containing sodium fluoroacetate (1080), strychnine and sodium cyanide. PR Notice 72-2 March 9, 1972. Environ. Protection Agcy., Washington, D.C.

Wade, D.A 1980. Predator damage control, 1980: recent history and current status. Paper presented 9th Vert Pest Conf., March 4-6, 1980, Fresno, Calif. 19pp + Appendices

_____ 1982 Impacts, incidence and control of predation on livestock in the United States, with particular reference to predation by coyotes Council Agric. Sci. and Tech. Special Publ. No. 10. Ames, Iowa.

THE COYOTE IN SOUTHWESTERN FOLKLORE

WYMAN P. MEINZER, P.O. Box 195, Benjamin, TX 79505

Perhaps one of the first mentions of the coyote (*Canis latrans*) by Anglos in early-day journalism was from Mark Twain's notes during his travels through the plains frontier in the early- to mid-19th century. Touring the frontier region before its inevitable subjugation to ranching and farming, Twain wrote of the coyote and its larger more infamous cousin, the wolf (*C. lupus*), in words which left no doubt to the reader the popular sentiments for such predators of the day Although derrogatory in some respects, Twain did concede respect for *Canis latrans* and made mention of the tricks the coyote would play on domestic dogs as the wagons lumbered across the pristine landscape.

Although the wolf has since passed into the twilight of extinction (at least in the Plains), the coyote made a successful transition into the 20th century, proving to settlers for the first time, its extraordinary character and tenacity. Such characteristics have made the coyote well deserving of its role as "top dog" in folklore of the southwest.

Centuries before the appearance of Anglo settlers on the ranges of the southwest, the coyote had already isolated himself as a prominent figure in the lore of Native Americans. Long facinated with the cunning nature of *C. latrans*, many Native tribes believed that the coyote appeared on earth before man. Although not denying the fact that the coyote exhibited a lack of morals in its bid to survive, many tribes acknowledged great respect for the coyote and considered *C. latrans* somewhat sacred in his mythological role

Almost as colorful as the tales of the Native Americans are the many stories involving the coyote in Anglo folklore. From *C. latrans*' ability to hypnotize chickens into falling from their roost into his waiting jaws to the creature's baleful stare actually causing fruit from palm trees to fall to the ground, the coyote has fully established itself as an icon to students of southwest folklore. Largely misunderstood for over a century, but thumbing its nose in the face of all ridicule, *C. latrans* stands above it all as perhaps the most popular villian in our history.

In the words of J. Frank Dobie, "extraordinary folklore develops around only extrarodinary characters, though not all extraordinary characters inspire it". No doubt the coyote has been an inspiration for exaggarated tales about its ability to connive, dupe, and chase its way into the heart of the Southwest

HISTORICAL PERSPECTIVE ON COYOTE CONTROL METHODS IN TEXAS

ROBERT L. PHILLIPS, U S Department of Agriculture, Animal and Plant Health Inspection Service, Animal Damage Control, Denver Wildlife Research Center, P.O. Box 25266, Denver, CO 80225-0266

GARY L NUNLEY, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Texas Animal Damage Control Service, P.O. Box 100410, San Antonio, TX 78201-1710

Abstract: A variety of control methods used over an 80-year period (1915-1995) contributed to the effective and successful coyote (*Canis latrans*) damage management program that exists in Texas today. Traps, toxicants, shooting, denning, and dogs were important during the early years of the Texas Animal Damage Control Service (TADCS) program Aerial hunting and snares evolved as important control tools following the ban on strychnine and Compound 1080 in 1972 The livestock protection collar (LPC) has received increased use in recent years and has been useful in resolving difficult depredation problems ADC policy along with changing state and federal regulations and public opinion will dictate how specific control tools are used in the future

Texas leads the nation in the production of domestic sheep and goats Although the total number of these livestock has declined in recent years, there were 1,700,000 sheep and 1,950,000 goats present in the state during 1995 (USDA 1995) (Fig. 1) The Edwards Plateau and adjoining ecological areas contain the highest concentration of both species (Fig 2)

Organized predator control sponsored by the U S Bureau of Biological Survey began in Texas with the hiring of 8 hunters in November 1915 Their work was concentrated in the sheep producing areas of the Edwards Plateau and expanded to other areas in later years (Nunley 1986) Traps, shooting, and strychnine baits were the primary control tools used As the sheep industry expanded, so did federal and state government efforts to protect livestock producers Today there are 142 employees involved in coyote predation control efforts in 140 of the 254 counties in Texas

This paper describes the history of coyote control as conducted by the TADCS since the beginning of the program Primary emphasis is given to the period from 1972 to the present We also evaluate how public attitudes and political events have influenced the use of control tools in the past and how they may influence the use of tools in the future

Coyote control methods

Perhaps no other area of the United States (U S) can boast of a more effective and successful coyote predation control program than the Edwards Plateau region of Texas This area has been under intensive predator management since at least1915. The use of a variety of control tools eventually led to the extirpation of coyotes, red wolves (*C. rufus)*, and gray wolves (*C. lupus*) from the major sheep production areas Exactly how this task was accomplished is unknown, but Shelton and Klindt (1974) suggested that it resulted from a "massive human effort using all of the tools and techniques which could be brought to bear."

By the early 1920s, all red wolves and nearly all coyotes were eliminated from the interior sheep and goat producing counties of the Edwards Plateau (Nunley 1986) It wasn't until the 1970s that coyotes began to re-establish, red wolves have not reinvaded the area

Over the years many control tools have been used, including toxicants, shooting, aerial hunting, calling, dogs, traps, cyanide ejectors, snares, denning, and more recently the LPC. A historical review of each major control method is provided below

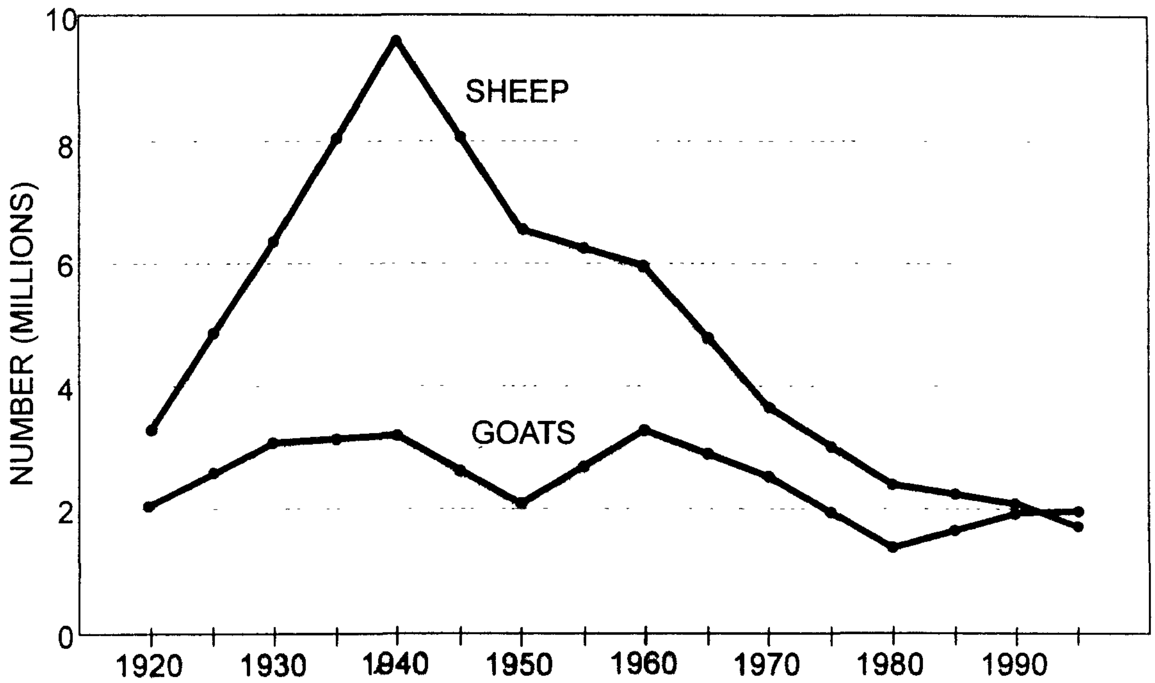


Figure 1. Trends in sheep and goat numbers in Texas (1920-95).

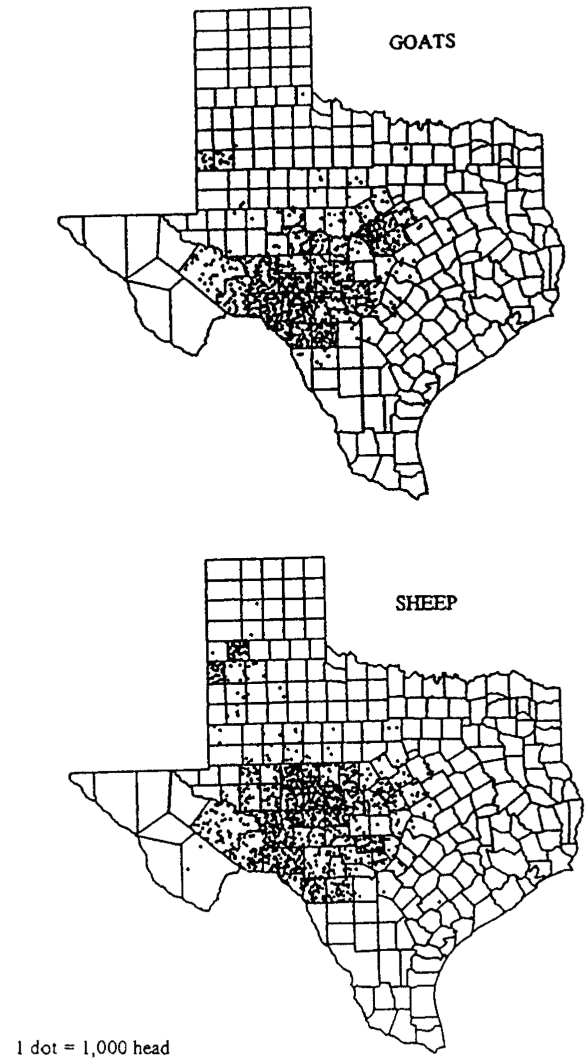


Figure 2 Distribution of sheep and goats in Texas (Texas Crop and Livestock Reporting Service 1994).

Toxic baits. Strychnine placed in meat and tallow baits was widely distributed in all sheep- and goat-raising areas when organized control efforts began in 1915. No records on the number of baits used are available for the early years, but in FY 1950, over 182,000 baits were used to reduce coyote populations. In FY 1960, over 328,000 baits were distributed, and by 1971 this number had increased to 408,000. Undoubtedly, strychnine played a major role in suppressing coyote numbers in buffer areas and reduced the possibility of reinvasion into major sheep and goat raising areas.

Compound 1080 was first used in Texas in 1949 Like the rest of the West, large meat baits were treated and placed in strategic locations during the winter months During the peak of 1080 use in the 1960s, approximately 1,000 baits per year were used (Fig 3) Compound 1080 was used in all regions of the state except east Texas, but most frequently in the counties adjacent to the Edwards Plateau and Panhandle regions The use of 1080 and strychnine ceased in 1972 following Executive Order 11643 and the cancellation of predacides by the Environmental Protection Agency (EPA).

Traps. Steel foothold traps were an important tool when organized wolf and coyote control efforts began. The No. 4 Newhouse has been the trap of choice by Texas trappers since the program first started purchasing traps. The TADCS has over 9,000 traps in its inventory today and 86% are No 3½ or 4 Newhouse. ADC field personnel relied heavily on traps following the cessation of 1080, strychnine, and M-44 cyanide ejector use. In FY 1973, TADCS personnel used traps to take 10,058 coyotes which represented 67% of the coyotes taken by all control methods. By comparison, in 1994, only 1,666 coyotes were taken in traps; this equaled 8% of the coyotes taken by all methods (Fig. 4)

A similar pattern showing the declining use of traps is prevalent in many other western ADC programs The reduced use of traps has come about for several reasons Perhaps the most significant is the increased effectiveness and use of the M-44 device which became available for experimental use in 1974, and was subsequently improved substantially and reregistered Traps will continue to be an important tool in coyote control, but with availability of other less labor intensive methods, they will not receive the use they have in the past.

Snares. Although snares were always available as a control tool, they were not widely used in the TADCS program until 1959. As woven ("net") wire fences became more common in sheep and goat producing areas, the potential effectiveness of snares as a "first line of defense" against coyotes invading pasture was recognized.

Snares are typically set in "crawl holes" under fences. The most common fence snare used by TADCS personnel is about 34 inches (86 cm) in length and constructed with 5/64 inch (2.0 mm) diameter aircraft cable using a "sure lock". By 1972, snares were responsible for taking 1,576 coyotes. Their use has expanded since then and in 1994, snares were used to capture 5,879 coyotes or 28% of the coyotes taken by all control methods (Fig. 5). Guthery and Beasom (1978) working in South Texas reported that neck snares were about 12 times more selective than leghold traps for capturing predatory mammals.

Aerial hunting. Although aerial hunting with fixed-wing aircraft and helicopters was used prior to 1972, this control method was not common until toxicant uses were canceled Both fixed-wing aircraft and helicopters are used in the Texas program. Fixed-wing aircraft are typically used in the more rolling and open areas of the Trans-Pecos, Panhandle, and the western portion of the Edwards Plateau while helicopters are used in the rougher terrain around the Edwards Plateau.

The TADCS program currently owns 1 helicopter and 2 fixed-wing aircraft. Two helicopters are used on a contractual basis. These aircraft are used in all areas of the state (except east Texas) as specific needs occur The number of coyotes taken by aircraft peaked in 1975 with 5,983 animals taken that year. Since 1982, there has been a gradual increase in the number of coyotes taken each year by aircraft with 3,692 taken in 1994 (Fig. 6).

Coyote-getters/M-44 devices. The Coyote-Getter, a primer-powered cyanide ejector using a sealed .38 special casing, was widely used in Texas after it was introduced into governmental predator control around 1940. Young and Jackson (1951) reported that in October 1946, A. B. Bynum, a TADCS employee took 536 coyotes using 325 "getters" in Maverick County. The coyote getter proved to be an effective control tool for the next 30 years and was widely used by TADCS personnel For example, in FY 1960, 21,526 coyotes were taken by "getters" in the Texas program

After years of development and testing, the M-44 device cyanide ejector officially replaced coyote getters in the ADC program (Bacus, 1969, n.d.). M-44s were immediately used in the Texas ADC program and in 1972 were responsible for taking 7,567 coyotes. Use of this tool was suspended following the EPA cancellation of all predacide registrations in 1972. Use was resumed under experimental permits in 1974 Registration by EPA occurred in 1975 and reregistration under the new guidelines, in 1994

Despite early mechanical problems with ejectors and sealants, there has been a progressive increase in M-44 use since 1975. The highest number of coyotes taken with this device was 8,250 in 1993 (Fig 7) M-44s receive their greatest use during the winter months but can be effective during all times of the year

During the period 1976-86, more coyotes were taken by M-44s in Texas than in all other states combined. Connolly (1988) attributed this to the following reasons: (1) the Texas ADC program is much larger than the others, (2) most Texas grazing lands are in private ownership, which is appropriate for M-44 use, (3) dense vegetation in many areas of Texas precludes effective aerial hunting, which is a primary technique in most other states, and (4) much control work in Texas is done in livestock pastures, where livestock interfere less with M-44s than with steel trap sets

Livestock Protection Collar The Livestock Protection Collar (LPC) was invented by Roy McBride as a method to take "problem coyotes" that were difficult to take with conventional control tools. The LPC is the most selective and specific of all control tools because it removes only the individual animal responsible for killing livestock Although 5 states have established programs to use the LPCs, only Texas has made substantial use of this new control tool The LPC has been used by state-certified rancher applicators since 1988 and by ADC field personnel since 1990.

Connolly (1993) summarized use of the collar by the TADCS program for the period FY 1990 - 1992. He reported 2,348 collars were placed on livestock which resulted in 46 being punctured by coyotes. J. Dorsett, TADCS District Supervisor (pers. commun.) reported that since 1992, an additional 3,196 collars were placed on livestock resulting in 63 coyote punctures.

Nonlethal control methods

Texas sheep and goat producers have used a variety of nonlethal techniques to protect their livestock from coyote predation. When sheep were first established on the Edwards Plateau, herders were used extensively to guard sheep In the 1920s, a major effort was made to fence individual ranches into large pastures with woven wire fences Many of the fences were equipped with wire aprons to make them "predator proof". The elaborate fence network on the Edwards Plateau probably contributed more than any other factor to reducing or, in many cases, eliminating predator losses

In recent years, many livestock producers have experimented with different types of guarding animals to protect their flocks. One of the most popular techniques has been the use of guard dogs such as the Great Pyrenees, Komodor, and Akbash breeds. In 1993, TADCS estimated that 5 to 10% of the sheep and goat producers were using guard dogs. The use of guard donkeys has also increased in popularity in recent years. Walton and Feild (1990) estimated that approximately 9% of the sheep and goat producers were using donkeys in 1989 Most of the donkeys being used are single jennies or geldings.

The TADCS and Texas Department of Agriculture advocate and promote the use of nonlethal techniques to reduce conflicts between predators and livestock producers. In 1994, Texas ranchers spent an average of $0 51 per head (breeding ewe) annually on nonlethal predator control measures (USDA 1995). This effort will most likely continue in the future.

Public opinion and coyote control methods

A historical review of the use of coyote control methods has demonstrated the importance of public opinion in dictating the availability of specific tools. During the early years of predator control in the West, there was public support for removal and elimination of large predators such as wolves and coyotes. This was because a large percentage of the American public lived on the land or had a close association with relatives that made their living from farming or ranching. The movement of people from rural environments to urban areas in the past 50 years has brought about substantial change in public attitudes towards predator control.

The most significant events that brought immediate changes to the use of coyote control methods were the Cain Committee Report (Cain et al. 1972) and the cancellation of predacide registrations by EPA. Toxicants were important in the TADCS program and were very effective in suppressing coyote predation in many areas of the state. The use of Compound 1080 bait stations was believed to be extremely effective in reducing coyote numbers on the fringe areas of the Edwards Plateau.

Despite the lack of 1080 and strychnine baits over the past 23 years, the TADCS has been able to minimize predator losses by shifting to and improving the use of other control methods. Aerial hunting, although more costly and hazardous to ADC personnel, has been effective in removing coyotes from many problem areas. Improvements in the use of snares and M-44s have been helpful in resolving depredation problems. Lastly, the LPC has proved effective in removing coyotes that were difficult to take with other methods.

Public sentiment against the use of foothold traps to capture animals has increased in recent years (Gentile 1987). An effort is underway through the International Organization for Standardization (ISO) to develop an international standard with criteria for the humane use of traps for capturing particular species (Jotham and Phillips 1994) Recent testing of several types of traps suggests that only padded jaw traps among the traps currently in use would meet proposed criteria for capturing coyotes with minimal injury The future of the ISO standards is unknown at this time, however, some type of national or international standard, reflected in state laws, appears likely in the next few years.

Within the past 2 years, 2 western states (Arizona and Colorado) have made major changes that affect how traps can be used for capturing coyotes. Arizona currently prohibits all trapping on public lands. Colorado has passed regulations which allow only padded traps to be used in land sets. Because most of the land in Texas is under private ownership it appears unlikely that such changes affecting the use of traps for predator control in Texas will occur in the near future We expect all current tools for managing coyote predation will continue to be used in Texas into the foreseeable future and that some new techniques will become available.

Acknowledgements: We thank K Gruver for his assistance in compiling historical data from the TADCS annual reports and G. Connolly for contributing ideas and numerous unpublished materials which were useful in preparing this paper. M Fall and G Connolly kindly reviewed the manuscript and provided helpful suggestions. K Flynn prepared most of the figures and typed the paper.

Literature Cited

Bacus, L C. 1969. Introducing the M-44. Field Training Aids, FTA-9, Div of Wildl. Serv , U S Bureau of Sport Fisheries and Wildlife, Denver, CO 2pp.

_____. n.d. [1971] Modifications of the M-44. Field Training Aids, supplement to FTA-4, Div. of Wildl Serv., U.S. Bureau of Sport Fisheries and Wildlife, Denver, CO 5pp

Cain, S. A., J A. Kadlec, D L Allen, R. A. Cooley, M. G. Hornocker, A. S Leopold, and F. H Wagner. 1972 Predator control -- 1971 -- rept. Council on Environ Qual.and Dept. Interior by the Advisory Comm on Predator Control Inst for Environmental Quality, Univ Mich., Ann Arbor. 207pp

Connolly, G. 1988 M-44 cyanide ejectors in the Animal Damage Control Program, 1976-1986. Proc. Vertebr. Pest Conf 13 220-225.

Connolly, G 1993 Livestock protection collars in the United States, 1988-1993. Proc Great Plains Wildl Damage Control Workshop 11:25-33.

Gentile, J R 1987. The evolution of antitrapping sentiment in the United States: a review and commentary Wildl Soc Bull. 15:490-503.

Guthery, F. S and S L Beasom. 1978. Effectiveness and selectivity of neck snares in predator control J Wildl Manage 42:457-459.

Jotham, N and R L Phillips 1994 Developing international trap standards: a progress report Proc Vertebr Pest Conf 16.308-310.

Nunley, G 1986 The extirpation and re-establishment of coyotes in the Edwards Plateau of Texas. Proc. Great Plains Wildl Damage Control Workshop 7 9-27

Shelton, M and J Klindt 1974. Interrelationship of coyote density and certain livestock and game species in Texas Texas Agric. Expt. Stn. Bull MP-1148 12pp

Texas Crop and Livestock Reporting Service. 1994. Texas livestock, dairy, and poultry statistics. 2pp

U S. Department of Agriculture 1995. Sheep and goat numbers in Texas. Natl. Agric Stat. Serv. 2pp

U.S Department of Agriculture 1995. Sheep and lamb death predator loss. Natl Agric. Stat Serv 36pp

Walton, M T and C.A. Feild. 1991. Use of donkeys to guard sheep and goats in Texas. Proc East Wildl Damage Control Conf. 4:87-94

Young, S. P. and H. T Jackson 1951. The clever coyote Univ Nebr Press, Lincoln. 411 pp.

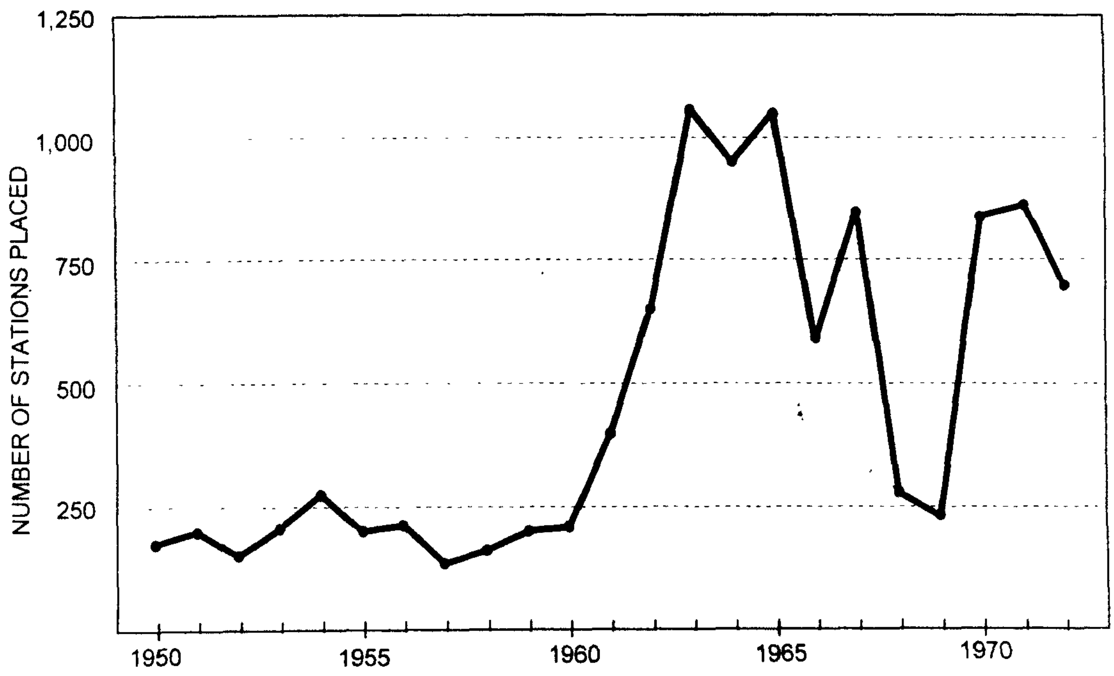


Figure 3. Numbers of 1080 baits placed in Texas (1950-1972)

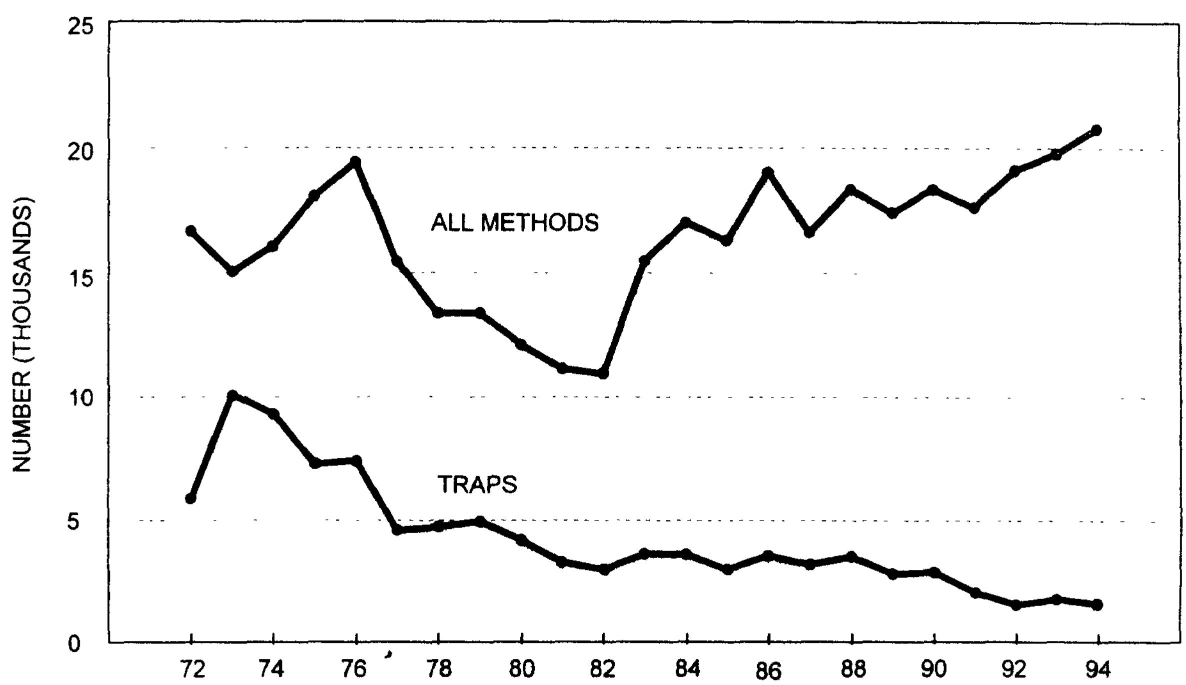


Figure 4. Trends in the number of coyotes taken in foothold traps by TADCS (1972-1994).

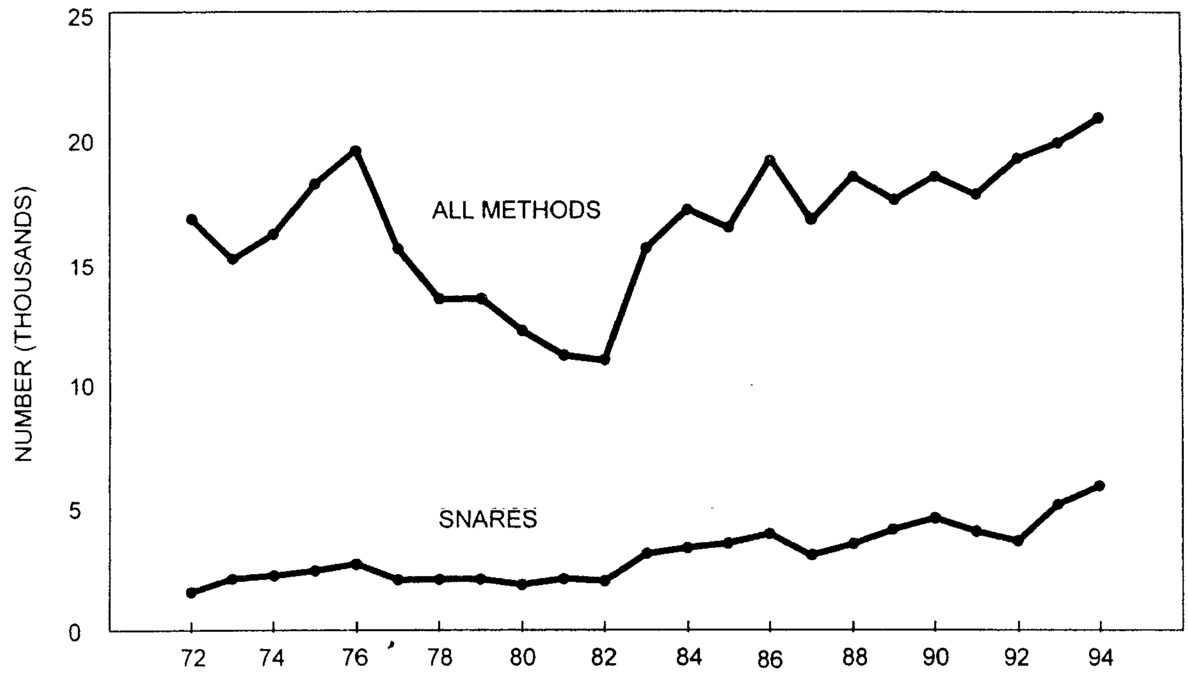


Figure 5 Trends in the number of coyotes taken in snares by TADCS (1972-1994).

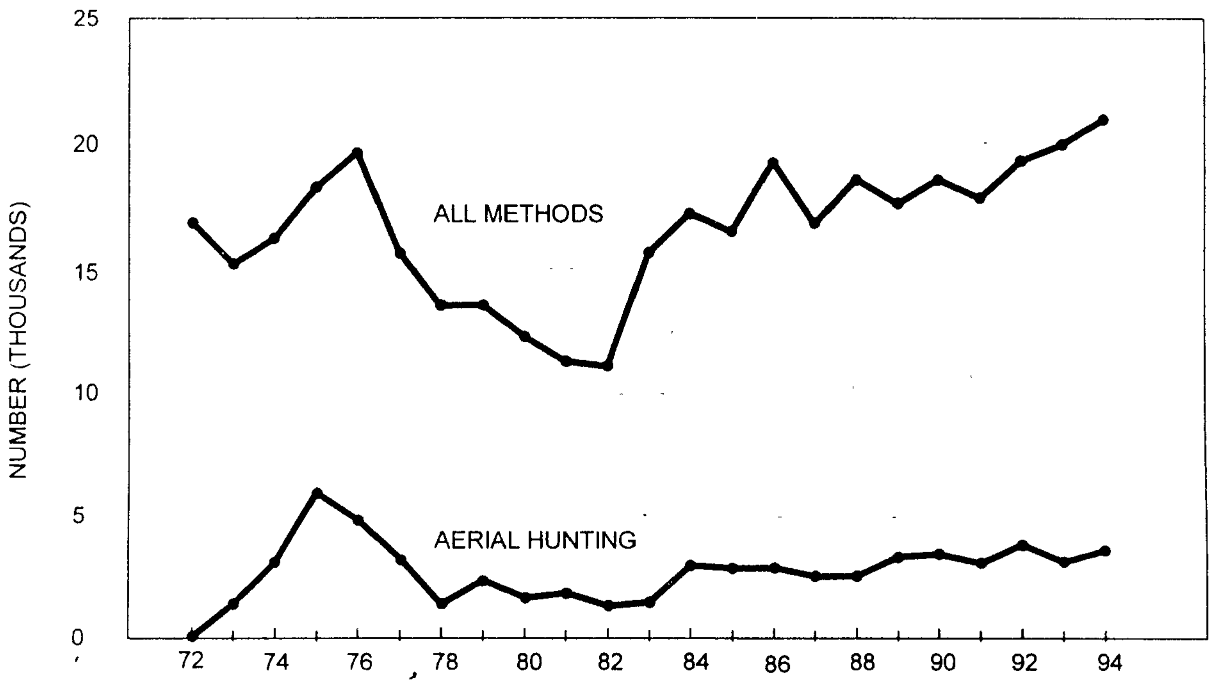


Figure 6 Trends in the number of coyotes taken by aerial hunting by TADCS (1972-1994).

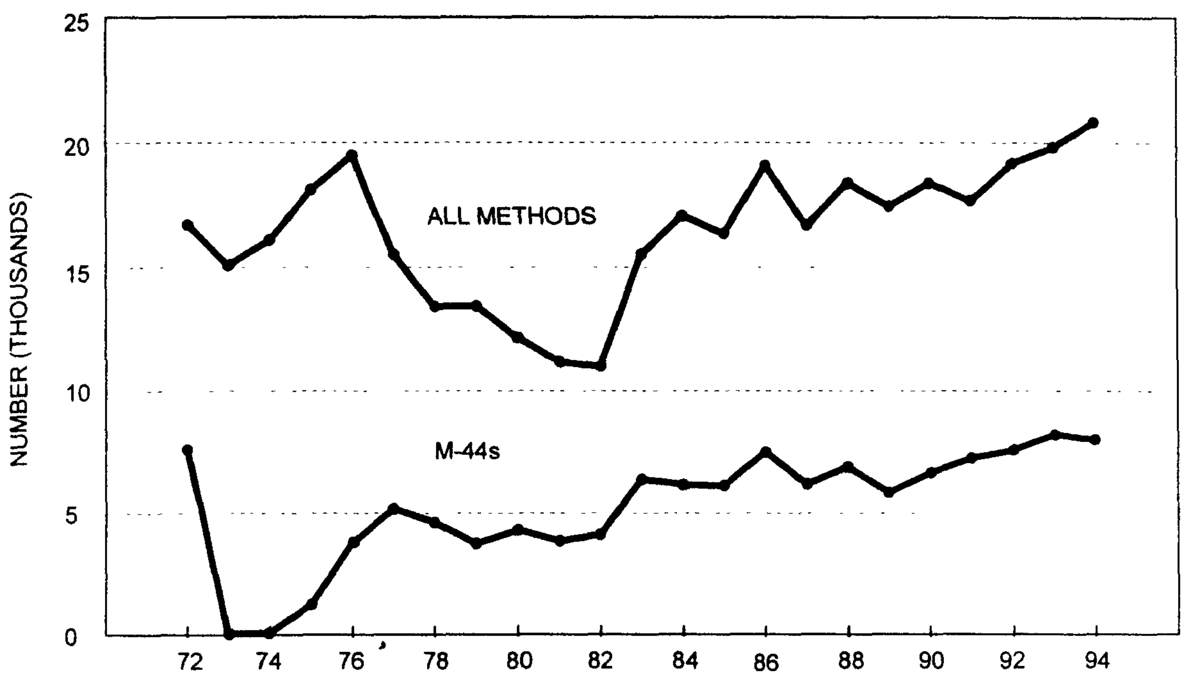


Figure 7. Trends in the number of coyotes taken by M-44s by TADCS (1972-1994).

LETHAL OPTIONS FOR CONTROLLING COYOTES

JOHN W. DORSETT, District Supervisor, Texas Animal Damage Control Service, 33 East Twohig, Room 313, San Angelo, TX 76904

Abstract: Lethal control methods are required to stop coyote depredation or to reduce the coyote population in an area. Various lethal control options are available, including traps, snares, shooting, denning and toxicants. The effectiveness, selectivity, and specificity of each method should be considered before being utilized. Each method requires varying degrees of skill and experience to be made effective. Usually a combination of control methods is most effective in coyote control situations.

When coyotes are causing damage to crops or livestock, or when there is a desire to reduce the coyote population, lethal control methods are required To stop coyote predation it is usually necessary to remove the offending coyote(s) There are various lethal methods available for coyote control No single control method is best, but depending on the circumstances, several methods should be used simultaneously to solve a predation problem. A lethal control method's effectiveness for the situation, selectivity for coyotes, and specificity for taking a particular coyote should be considered when deciding on which method(s) to use. When possible, control efforts should be directed toward coyotes in particular (i e , selective), and towards the offending individual coyote that is causing damage (i.e., specific).

All lethal control methods require a degree of user knowledge, skill and experience to be used effectively Lethal methods that involve the use of restricted use toxicants also require special training and licensing for the user In Texas, the Texas Department of Agriculture has regulatory authority over the use of predacides

Leghold traps

The steel leghold trap is a mechanical capture device that is a versatile tool for coyote control Traps can be set to work in various situations. They can be used as blind sets on trails or at fence crossings, or they can be set using different baits or passion lures depending on the time of year and circumstances

The selectivity of traps to catch the target animal can be increased by use of under-pan-tension devices that minimize the capture of small nontarget wildlife species (e g., rabbits, opossums). Careful selection of trapping sites and appropriate attractants also increase the selectivity of traps. However, in sheep and goat pastures, traps regularly catch livestock.

The successful use of traps for coyote control requires skill and experience in setting traps, appropriate use of attractants, and knowledge of coyote behavior. Traps must be kept clean and in good working condition to be effective for coyote control A No. 3 or No. 4 trap size is recommended for coyotes. Trap effectiveness and selectivity is dependent on the skill and experience of the trapper. Unskilled trappers are likely to catch more nontarget animals

Snares

The neck snare is the most common tool used for coyote control in sheep and goat areas where pastures are fenced with net-wire. Snares are relatively economical and do not require as much skill or training as traps do to be used effectively. The snare is a mechanical device consisting of a flexible wire cable loop and locking device that tightens around the coyote's body as it passes through the loop Snares are effective where coyotes are crawling under a net wire fence, or passing through holes in the fence. Trail sets can be used in some situations

Snares used for coyote control are made of flexible cable, usually 1/16 inch, 5/64 inch, or 3/32 inch in diameter. The length of snares varies, but they are usually between 32 and 48 inches long. The snare should be long enough to attach the end with a swivel to a firm object or drag, with enough of the cable left to make a loop from 8 to 10 inches in diameter.

Snares are not a vary selective tool and will catch nontarget wildlife. Nontarget catches can be minimized somewhat by adjusting loop size and height of loop placement. Livestock are sometimes caught in snares, but snares are less likely to be interfered with by livestock than are steel traps.

M-44 device

The M-44 is a spring-operated device used to deliver a toxicant (sodium cyanide) to control coyotes. A fetid bait is used to attract coyotes to pull the device. When the coyote pulls the baited cyanide capsule holder with its teeth, the spring ejector releases, propelling powdered sodium cyanide into the animal's mouth. The animal becomes unconscious within a few seconds and dies within a short time (Wade 1982)

The M-44 is relatively selective for canids, and selectivity for coyotes can by enhanced by using baits attractive to coyotes However, other species such as foxes, dogs, raccoons and skunks will also pull M-44s Livestock occasionally pull M-44s M-44's are most effective during the cool months of fall and winter and least effective during hot summer months.

Sodium cyanide is a restricted use pesticide. M-44 applicators must be trained and licensed by the Texas Department of Agriculture. Use of the M-44 is limited by 26 use restrictions set by the Environmental Protection Agency. The M-44 is relatively selective, easy to set, environmentally safe, of little risk to humans, and effective for coyote control if properly used and maintained.

Calling and shooting

Hunting coyotes by attracting them within shooting range with predator calls can be effective in some cases. Calling coyotes during daylight, especially in the early morning hours, is best Calling and shooting is a selective tool, but requires some skill. Successful coyote calling cannot be approached in a haphazard way In sheep and goat areas where coyote populations are usually relatively low, considerable effort must be made to locate the area where the coyote is living before a call is attempted. The caller should make a careful entry into the area to be called, wear camouflage, consider wind direction, and be skilled at calling and shooting. Coyotes that have been called in and missed won't normally fall for the ruse a second time.

Various calls are available from open reed mouth calls to electronic calls. Calling sounds may imitate injured prey, howling coyotes or injured pup squeals to call in coyotes. Injured pup squeals or coyote howls used in conjunction with "decoy dogs" are effective techniques to take coyotes during the spring and summer when coyotes are highly territorial and aggressively protect their young and den areas (Rowley 1987)

Calling success improves in areas of high coyote populations. To be successful in areas of low coyote density, it is critical to be in the right place at the right time when you call. In the right situations calling is a good tool to try for taking coyotes.

Denning

Denning is the practice of removing coyote pups and/or the parent coyote from the den during whelping season, from April through June. The primary purpose of denning is to reduce or stop predation by adult coyotes that are killing livestock to feed their pups. Normally if the pups are removed, the predation by the parent coyote will stop (Crosby and Wade1978). Denning is a highly selective technique, however, tracking skills and a knowledge of coyote behavior is required for the den hunter to be consistently successful.

Aerial hunting is also a good method for locating coyote dens. A ground crew with radio contact with the aircraft should be used in conjunction with the aerial den hunting. The ground crew can check out possible den sites located by the aircraft. Aircraft are especially useful for den hunting in areas where tracking is difficult such as in rocky terrain. Areas where dens have been found previously should be checked out each season, as often coyotes may den in the same area if not in the same den site.

Hunting with dogs

Sight-hunting dogs such as greyhounds can be used to hunt coyotes in open, flat country with good visibility and limited fencing. Trail hounds can also be used for coyote hunting, and are especially effective if used in conjunction with aerial hunting. The trail hounds can be used to move coyotes out of rough or heavily-vegetated terrain for aerial hunters. Some dogs are also useful in locating coyote dens or as decoy dogs to lure coyotes within shooting range. The selectivity of taking coyotes with hunting dogs depends on how well the dogs are trained.

Aerial hunting

Aircraft, either fixed-wing or helicopter, are often the tool of choice to try to get immediate relief from coyote predation, or to quickly reduce a high coyote population. Aerial hunting is highly selective for coyotes, and can be used to take specific depredating coyotes. In a study conducted on a western Montana sheep ranch where coyote predation was occurring, 6 of 11 coyotes taken by aerial hunting were confirmed as having attacked or fed upon sheep (Connolly and O'Gara 1976).

In areas where coyote populations are low, the success of aerial hunting greatly depends on the ground work that is done before aerial hunting is attempted. The specific area(s) where the coyotes are active should be located before any flying is done. A ground crew with radio communications with the aircraft also enhances the success of aerial hunting operations. The ground crew often elicits vocal responses from coyotes to pinpoint their location for the aircraft. The ground crew can also assist by driving coyotes out of dense cover for the aircraft. Coyotes can become aircraft shy just as they do with other control tools, and the use of a ground crew and the use of an additional aircraft to fly cover for observation enhances success for taking these coyotes.

Fixed-wing aircraft are most useful over flat or gently rolling terrain that is not too brushy. Helicopters, with their ability to maneuver quickly and fly slow, are preferred in areas with more dense vegetation and rough terrain. In either situation, a 12-gauge semi-automatic shotgun loaded with No. 1 to No. 4 buckshot is recommended.

Aerial hunting is regulated by state and federal authorities, and a permit must be obtained from the Texas Parks and Wildlife Department. Aerial hunting, although an effective method of coyote control, is expensive and can be hazardous because of the low altitudes involved.

Livestock Protection Collar

The Livestock Protection Collar (LPC) is a coyote control tool that is applied directly to the target animals, i.e., sheep or goats. The LPC consists of two rubber bladders containing compound 1080 (sodium fluoracetate) solution attached with Velcro straps to the throat of a sheep or goat. A coyote attacking the throat of a collared animal receives a lethal dose of 1080 when it punctures one or both of the collar pouches. The LPC is highly selective for coyotes and is an extremely specific method of removing coyotes that are preying on livestock, especially those that evade other control tools.

The effective use of the LPC does not require extensive experience or skills. However, because compound 1080 is a highly toxic, restricted use pesticide, LPC applicators must be trained, certified, and licensed by TDA. Use of the LPC is limited by 21 use restrictions set by EPA. LPCs are environmentally safe, and pose minimal risk to non-target animals, livestock, and people when used properly. The LPC is registered for use only on sheep and goats for coyote control.

Several factors should be considered before using LPCs. These include availability and effectiveness of other control tools, cost of collars, labor requirements to apply collars and monitor collared livestock, suitable habitat for LPC use, regularity of predation, ability to target livestock, and ability to abide by LPC use restrictions. Targeting of livestock, the process of directing coyote predation to collared livestock, is one of the most important considerations when using the LPC and may require intensive management of livestock. Without proper targeting, optimum results cannot be expected. LPC use restrictions, which limit the number of collars used depending on pasture size, may affect targeting of livestock. Targeting may be difficult or impossible under some conditions. LPCs are usually recommended on ranches with high rates of coyote predation and management conditions that permit effective targeting of coyotes to collared livestock.

Conclusion

When attempting to control coyotes, no one single control method should be relied on for all coyote control situations. Several different control methods should be used simultaneously to solve a predation problem. Each method's effectiveness, selectivity, and specificity for coyote control should be considered before being utilized. Different situations for coyote control may require different combinations of lethal control options.

Literature Cited

Connolly, G. and O'Gara, B W. 1987. Aerial hunting takes sheep-killing coyotes in western Montana Pages 184-188 *in* Proc. 8th Great Plains Wildlife Damage Control Workshop. U.S D.A. Forest Service Gen. Tech. Rept., RM-154.

Crosby, L. and Wade, D. 1978. The coyote den. Wyoming Department of Agriculture Bulletin. 25pp.

Rowley, G.J., and Rowley, D. 1987. Decoying coyotes with dogs. Pages 179-181 *in* Proc. 8th Great Plains Wildlife Damage Control Workshop U.S.D.A. Forest Service Gen Tech. Rept., RM-154

Wade, D. 1982. Impact, incidence and control of predation on livestock in the United States, with particular reference to predation by coyotes Council for Agric. Sci. and Tech Special Pub No. 10: 20pp.

ALTERNATIVE METHODS OF PREDATOR CONTROL

CRYSTAL A WILBANKS, Texas Department of Agriculture, P O. Box 12847, Austin, TX 78711

***Abstract*:** Acceptable solutions to animal damage problems must consider the social and recreational values of wildlife, regulation of population levels, potential hazards of chemical use, human safety and disturbance to biotic communities. The objective should be to reduce harm and economic loss of livestock to an acceptable level. This paper reviews alternative, i.e. nonlethal, predator management methods. Alternative methods include guard animals, fencing, repellents, frightening devices and perhaps someday, immuno-contraception. The intent of animal damage control should be an integrated pest management approach tailored to fit the individual landowner's needs

Texas leads the U.S. in sheep production with 1.7 million head (Texas Agric. Statistics Serv. 1995). Another 1 95 million goats resided in Texas in 1995. This count includes Spanish, angora, Boer and a small number of dairy and cashmere goats. The Texas sheep and goat industry is located primarily in the Edwards Plateau region of the state. Rangelands used primarily for sheep and goat production are fairly rugged limestone hills with moderate to dense brush

Under such conditions, predation losses to coyotes (*Canis latrans*), domestic and feral dogs, bobcats (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*), red fox (*Vulpes vulpes*), feral hogs (*Sus scrofa*), golden eagle (*Aquila chrysaetos*) and other predators were estimated to be 168,000 head in 1994 (Texas Agric Statistics Serv 1995). Coyote predation typically accounts for over 50% of predator losses Value of livestock losses from predators on sheep and lambs in Texas amounted to $1.2 million in 1994 Predation is considered as the primary problem of the sheep and goat industry by many producers

When toxicants were banned for predator control in the 1970s, many producers and researchers began to explore other methods of predator management. Considerable attention was focused on European and Eurasian breeds of livestock guarding dogs. While the use of dogs was gaining popularity, many Texas sheep and goat producers began to use donkeys and mules as guard animals (Walton and Feild 1989) Llamas have also been utilized as an effective means of predator deterrent (Franklin 1993), and other species (e g. ratites) are often promoted for guarding animals.

The goal of predator management should be to protect livestock and minimize losses due to predators, not necessarily maximizing the take of predators. Public opposition to coyote population reductions will likely become even more apparent in the future.

Livestock guarding animals

Dogs. Livestock guarding breeds originated in Europe and Asia, where they have been used for centuries to protect sheep from wolves and bears. American stockmen have used guarding dogs since the mid-1970s. Several breeds of dogs have been used for predator control; no particular breed has emerged as the most effective. The more common breeds include the Great Pyrenees of France, the Akbash and Anatolian Shepherd of Turkey, the Maremma of Italy, the Shar Planinetz of Yugoslavia and the Komondor of Hungary. Most of the breeds range from 75 to over 100 pounds and stand 25 inches or taller at the shoulder. However, smaller mongrel dogs have also been used successfully, especially when accompanied by herders (Black and Green 1985, Coppinger et al 1985).

Several research projects have been conducted to determine the effectiveness of the various breeds under field conditions. Dogs can be used effectively in farm flock pastures, on open range and in feedlots

Guard dogs have become a more widely recognized form of predator control and therefore have increased in abundance and availability. In selecting a dog for guarding purposes, one should consider all characteristics of that particular breed. Such traits include behavior, rate of maturity, aggressiveness and self-confidence, along with gender-specific traits and the number of dogs needed for the area to be protected.

Buyers should also consider the bloodline of the guard dog and purchase or lease a dog based on a history of proven results. There are many guard dog breeders; the Texas Department of Agriculture maintains a current listing of breeders within Texas.

Guard dogs should be reared with a flock of sheep in order to secure a close bond between the dog(s) and the livestock. This act is called socialization and can be accomplished in various ways, depending on the dog and your situation. Dogs generally mature rather slowly, thus increasing the need to form a bond between the dog and the sheep before the dog is introduced to a specific flock of sheep. Guard dogs may be purchased as grown, mature adults ready to work, or as young puppies with little experience. In either case, there must be some interaction with the dog and sheep before the guard dog is asked to earn his keep.

Ideally, puppies should be placed with a flock of sheep in an enclosed environment so the pup is not allowed to leave his flock. Pen the newly-weaned pup with 6 or more sheep for 8 to 16 weeks (until the pup reaches 5 months of age) near water, bedding ground or other points, where the sheep gather (Lorenz and Coppinger 1986) After this time, evaluate the dog's capabilities to determine when it is best suited to be left alone with sheep.

Some ranchers choose to leave the dog with the sheep during the day and pen them at night This allows the puppy to become accustomed to being alone with the sheep for extended periods of time in an open environment. A pup is usually ready to guard livestock at about 8 months of age A good indicator that you can leave your dog alone is that it stays with the sheep rather than following you as you leave the pasture (Lorenz 1986).

The cost of a livestock guarding dog varies among breeds and breeders, and depending on the level of maturity and training. Common costs associated with guardian dogs include feeding, veterinary care and maintenance. Costs associated with acquisition of the dog as well as the dog's longevity need to be figured in the overall cost to your operation. The average life span of a dog is 10-12 years. However, untimely deaths take their toll during the early years, primarily because of accidents

Effective use of dogs depends on their training, care and feeding. Factors to consider in the use of guard dogs include: severity of predation losses, pasture size, livestock habits (i.e., herding tendency, acceptance of dog), expense, the time involved in training the dog, compatibility with other predator control methods in practice, and also the predator control methods used by adjacent ranches

Donkeys and mules. Though livestock guarding dogs have received much attention in recent years, other animals (e g., donkeys) are also being used to deter predators. Donkeys and mules have been used with some success to reduce predation on sheep and goats from coyotes and dogs (Walton and Feild 1989). The effective use of guard donkeys capitalizes on the equines' herding instincts and natural dislike of, and aggressiveness towards, canines. Loud braying may also be helpful in discouraging some predators

Under proper conditions, guard donkeys can provide a high degree of around the clock protection against dogs and coyotes. They may also offer some protection against foxes and bobcats. However, larger predators such as mountain lions, gray wolves and black and grizzly bears (*Ursus* spp.) may prey on donkeys. Because individual differences in guarding abilities exist among donkeys, management practices may need to be tailored to capitalize on particular qualities of a donkey

Donkeys are compatible with most traditional methods of predator control and can be used in an integrated predator management program. Because they can forage with sheep or goats, are inexpensive to maintain, and they have an expected useful life of 10-15 years as guard animals.

Donkeys are easy to obtain and can be purchased from breeders or from auction barns. Most often, jennies are suitable for guard animals and cost

$75 to $150 (1995 prices) Jacks cost half as much as jennies, but should be neutered before use as a guard animal due to an intact jack's aggressive behavior to all animals. Proven guard donkeys may be more expensive. After initial acquisition of breeding stock, some guard donkey users produce their own stock. This practice allows selection for donkeys with good guarding tendencies.

Care and maintenance of donkeys is minimal. Annual health care such as worming and vaccination against common equine diseases is recommended Supplemental feeding during periods of poor range conditions may also be required. Donkeys should not be allowed access to feed containing ionophore feed additives (e.g. rumensin), urea or other products intended only for ruminants. Other veterinary care, e g , floating of teeth or hoof trimming may be needed periodically Average maintenance costs averaged less than $70 in 1989 (Walton and Feild 1989)

Guard donkeys require no special training However, bonding with the livestock to be protected is necessary in some instances to ensure that the donkey will stay with the flock. Halter-breaking and teaching a donkey to load in a trailer will increase ease of handling. Donkeys can be used with relative safety in conjunction with snares, traps, M-44 devices and Livestock Protection Collars.

Guard donkeys should be selected from medium- to large-sized stock Do not use extremely small or miniature donkeys Always select a donkey that can be sold or culled if it fails to perform properly (which may preclude animals from such programs as the Bureau of Land Management's Adopt-a-Burro program)

Donkeys ideally should be raised with the animals they will guard If possible, place the donkey with the sheep at birth or at time of weaning Jennies with newborn foals may be overly protective or too aggressive to sheep Further, guard donkeys should be monitored during lambing or kidding times as some donkeys may be aggressive or overly possessive of the newborn lambs/kids. The donkey(s) may be temporarily removed in these instances Guard donkeys should also be raised away from dogs, and the use of herding dogs around donkeys should be avoided

When placing a donkey into a pasture, isolate it from other equines Donkeys tend to socialize with other equines and will stray away from the flock if given the opportunity to mix with other equines. Donkeys tend to be most effective when used in small (less than 600 acres) open pastures with not more than 200 head of sheep or goats (Walton and Feild 1989). Large pastures, rough terrain , dense brush, too large a herd and sheep or goats that become scattered all lessen the effectiveness of guard donkeys.

Llamas. Llamas (*Llama glama*), like donkeys, have a natural dislike for canines. This instinct allows llamas to work well as guard animals The use of llamas as guard animals is not as extensive as either guard dogs or donkeys at this time. However, llamas are becoming more common, less expensive and therefore being utilized as guard animals more frequently (Franklin 1993). Research on guard llamas has been underway at Iowa State University since 1981 with positive results.

Llamas are generally more expensive than guard dogs and considerably more expensive than donkeys. Most guard llamas are gelded males costing $700 to $800; intact males are about $100 cheaper (Franklin 1993). The average lifespan of a llama is 10-15 years. Llamas fit easily into a sheep herd, readily foraging on whatever the sheep are eating. They do not require special feed, except in times of drought or adverse conditions. Other veterinarian practices such as vaccinations and regular deworming are recommended. Guarding effectiveness of llamas may be adversely affected by hot weather, but proper shearing may help with this problem

Introduction of llamas to sheep has been accomplished at various ages. Llama breeders traditionally wean offspring at 6-8 months of age and castrate males at 6-24 months of age. In the study conducted at Iowa State University (Franklin 1993), nearly all llamas had no prior experience with sheep before being introduced to the herd they were to protect Average age of llamas used was 2 years but ranged from a few months to over 12 years. Most introductions of llamas to sheep required only a few days before bonding between species occurred. Many producers reported that guard llamas show intense interest and attachment to young lambs (Franklin 1993).

Repellents and frightening devices

Several devices or chemicals have been promoted as having utility for deterring predation. However, the use of devices to frighten and/or repel predators is almost always short-term, if any response is noted at all (Lehner 1987, Shelton and Thompson 1975). Experiences to date suggest they offer no real solution to predator problems.

Various repellents including capsaicin, cinnamaldehyde, undecenovannillylamie, coal-tar derivatives and other chemicals have been evaluated as either pour-ons or in collars that are attached to the target sheep (see summary in Lehner 1987). M. Shelton (Texas Agric. Exp. Sta., San Angelo, pers commun.) reported that short-term relief from predation is sometimes observed after treating goats with insecticides used to control lice

Predators tend to become accustomed to these devices/chemicals, therefore most authors suggest a diversity or combination of methods be used Linhart (1983) and Lehner (1987) summarized research studies involving gustatory and olfactory repellents and concluded that such repellents offer little potential for resolving coyote damage problems

Propane cannons, horns, sirens and radios are sometimes used in attempting to repel coyotes from lambing grounds These devices may also adversely affect the livestock to be protected. They may also result in disturbance to neighbors and non-target species. While sonic repellents usually have only short-term effects, they are generally compatible with other forms of predator management. The "Electronic Guard" emits periodic sirens and strobe lights and has been used successfully to curb predation losses on sheep bedding grounds (Linhart et al. 1984).

Aversive conditioning

Considerable research was undertaken during the 1970s and 1980s to evaluate the concept of aversive conditioning (Lehner 1987, Olsen and Lehner 1978). Aversive conditioning involves dosing a prey item with an emetic compound (e.g., lithium chloride) to produce an induced nausea in the coyote. Ideally, the coyote associates the illness with the novel food, and learns to avoid that food (prey). Although results in field trials varied, aversive conditioning is generally not considered as a viable damage control tool

Lithium chloride is a chemical that has been used in research studies conducted in the United States and Canada It is an emetic, and when consumed results in the animal experiencing short-term, severe gastrointestinal discomfort, usually accompanied by vomiting. Taste aversion has variable success in deterring predators from particular species of livestock. In order to be successful, predator must make the association between the illness produced and the taste of the species.

Baits injected with lithium chloride solution may be prepared and placed in strategic locations to encourage uptake by predators. Baits should be made out of hides and ground mutton from cull ewes or losses. Carcasses may also be injected with the solution Proponents of this technique maintain that coyotes with a conditioned taste aversion will avoid sheep and lambs and also will not teach offspring to use sheep as a food source These claims are speculative and have not been documented by other researchers.

Livestock husbandry and management practices

Several livestock management practices have proven to be effective in deterring predators. These methods should be practiced in conjunction with other forms of predator control.

Total confinement offers the highest degree of protection, but has it's drawbacks These include increased cost of feed, disease control, quality of wool and mohair production, increased labor costs, etc. Thus, total confinement is impractical for range operations Shed birthing of lambs and kids provides protection at the most vulnerable age This method requires increased capital investment and costs associated with labor and disease control, but these costs may be offset by an increase in lamb and kid crops

Predators often respond to the most abundant and available food source, therefore, alternating lambing and kidding seasons to prevent a build-up of predators dependent on this food source may result in a decrease in predation. Coyotes typically whelp in the early summer (April-May) and food demands of the parents are highest during early-summer (Till and Knowlton 1983). Fall-lambing may avoid the period of greatest demand for food by these predators

Penning of sheep at night may be another option. Predation by coyotes, foxes and bobcats most often occurs primarily between dusk and dawn; therefore, night penning provides protection during the period of greatest vulnerability This method does involve increased labor as a result of movement of livestock and maintenance of facilities.

Removal and proper disposal of dead livestock and other sources of carrion may be helpful in reducing incidence of predation by reducing the attraction of predators to areas used by livestock. It also reduces the artificial food supply available to predators, with predators becoming less likely to develop a taste for livestock.

Selective use of pastures is a technique relatively easy to implement, given alternate grazing lands are available. Some pastures, due to vegetative and physiographic features or proximity to preferred habitat, lend themselves to higher predation rates. Changes in seasonal use or class of livestock used in such pastures may provide some relief.

Fencing

The use of conventional and electric fencing has increased as a predator management method because of restrictions on alternate methods Various types of fencing exists that may be utilized as predator deterrents (Shelton and Gates 1987, Linhart et al. 1981). Fencing is most successful if it is implemented before a pattern of movement has been established by a predator. If coyotes have been feeding on animals within a given pasture, the construction of a fence will probably not deter them, as they recognize these animals as a food source.

Cost effectiveness of fences is related to the type and density of predators, along with acreage involved and land productivity. Other factors that contribute to the cost effectiveness of fences are construction and maintenance cost, stocking density, terrain and soil type Fencing to ward off predators has been proven to be most useful and cost effective on small, level, open pastures with a minimum of brush (Shelton 1984, .

There are many types of fencing used to manage predators; however, the most common types are net wire and electric fencing. A fence should be at least 5.5 feet tall to discourage predators from attempting to jump the fence. An overhang on the outside of the fence prevents climbing. Digging under the fence can be prevented by a buried barb wire or mesh apron The mesh size of the fence should be a maximum of 4 inches by 6 inches, but preferably smaller to ensure that coyotes won't attempt to crawl through the fence.

Netwire may be fatal to livestock and deer after feeding through the wire or attempting to jump over and becoming entangled This option is also very expensive. By using information on stocking rate, fencing costs, size and shape of area fenced and estimated life of the fence, producers can calculate relatively easily the annual per-head costs to determine if this approach is feasible (Shelton 1984)

Electric fencing may be suitable as temporary or permanent fencing This type of fencing will provide a physical barrier as well as, a psychological barrier to predators. This type of fencing is less expensive than net-wire fencing but it requires a higher degree of maintenance.

Modifying existing net-wire fences by adding one or more electric wires have proven effective at deterring coyotes (Shelton 1984, Rollins 1991). This may include adding a trip wire to the bottom, middle or top of the fence. When adding a wire to the bottom of the fence, it is necessary to place it in the proper position. Placing the wire too high or too far away form the fence may prove to be ineffective. Generally, the electrified trip wire should be located about 8-10 inches outside the fence and about 6 inches off the ground. Brush in fencelines may be a chronic problem with placing and servicing such trip wires. Adding an electrified wire to the top of a fence will give added height to the fence and discourage climbing by predators

It should be noted that fencing is not a cure-all for predator problems; however, with proper use fencing can be very effective in a predator management program

Conclusion

Predator management continues to be a problem that livestock producers must address. With ever-increasing pressure against the use of lethal methods of control, producers increasing have adopted alternative, non-lethal control methods. The use of guard animals, including donkeys, dogs and llamas has provided some relief from predation. Other forms of control and/or deterrents are the repellents and frightening devices, along with proper use of fencing. An alternative that is currently under product registration review is the use of lithium chloride as a taste aversion product.

At any rate, an effective predator management program must incorporate the use of several methods of control into an integrated pest management philosophy. This approach should combine the ranchers' concerns over predator- related livestock losses with the equally valid need to protect wildlife, the environment and the public.

Literature Cited

Black, H. L and J. S. Green. 1985. Navajo use of mixed-breed dogs for management of predators. J. Range Manage. 38:11-15.

Coppinger, R , C. K. Smith, and L. Miller. 1985 Observations on why mongrels may make effective livestock protecting dogs. J. Range Manage 38:560-561.

Franklin, W L. 1993 Guard llamas Iowa State Univ. Ext. Pub. PM-1527 12pp

Lehner, P. N. 1987 Repellents and conditioned avoidance Pages 56-61 *in* J. S. Green (Ed.) Protecting livestock from coyotes. USDA Agric Res Serv Publ 105pp

Linhart, S B 1983 Managing coyote damage problems with nonlethal techniques: recent advances in research. Proc. East. Wildl Damage Control Conf 1:105-118

_____. 1984. Strobe light and siren devices for protecting fenced-pasture and range sheep from coyote predation. Proc. Vertebr Pest Control Conf. 11:154-156.

_____., J. D Roberts, and G. J. Dasch. 1981. Electric fencing reduces coyote predation on pastured sheep. J Range Manage. 35:276-281.

Lorenz, J. R., and L. Coppinger. 1986. Raising and training a livestock-guarding dog. Oregon St. Univ. Ext. Serv. Circular 1238. 8pp.

Olsen, A., and P. N. Lehner. 1978. Conditioned avoidance of prey in coyotes. J. Wildl. Manage. 42:676-679.

Rollins, D. 1991. Coping with coyotes. Tex. Agric. Ext. Serv. Bull 1664. 8pp.

Shelton, M. 1984. The use of conventional and electric fencing to reduce coyote predation on sheep and goats. Tex. Agric. Expt. Sta. MP-1556. 12pp.

_____, and P Thompson 1975. Use of chemical repellents to reduce coyote predation on sheep and goats. Unpubl. Rept. PR-3396. 8pp.

_____., and N. L. Gates Antipredator fencing. Pages 30-37 *in* J. S. Green (Ed.) Protecting livestock from coyotes. USDA Agric. Res. Serv. Publ. 105pp.

Till, J. A , and F. F. Knowlton. Efficacy of denning in alleviating coyote predation on domestic sheep. J. Wildl. Manage. 47:1018-1025.

Texas Agricultural Statistics Service. 1995.

U S Department of Agriculture. 1990. Livestock guarding dogs: protecting sheep from predators. Animal and Plant Health Inspection Service. Animal Damage Control. Agric. Info. Bull. No. 588. 31pp.

U S Department of Agriculture. 1992 A producer's guide to preventing predation of livestock. Animal and Plant Health Inspection Service. Agric. Info. Bull. No. 650. 14pp.

Walton, M.T., and C.A. Field. 1989. Use of donkeys to guard sheep and goats in Texas. Proc. Eastern Wildl. Damage Control Conf. 4:87-94.

THE LIVESTOCK PROTECTION COLLAR FOR REMOVING DEPREDATING COYOTES: A SEARCH FOR PERFECT JUSTICE?

DALE ROLLINS, Associate Professor and Extension Wildlife Specialist, Texas Agricultural Extension Service, 7887 N Hwy. 87, San Angelo, TX 76901

Abstract. Lethal control techniques for controlling coyotes (*Canis latrans*) are often maligned as a means for resolving coyote depredations on domestic livestock. With the exception of theh Livestock Protection Collar (LPC), lethal control methods (e.g., foot-hold traps and neck snares) lack the ability to specifically remove those coyotes actually preying upon livestock. The LPC capitalizes on attack behavior of coyotes to remove offending individuals. Although currently registered for use in 5 states, LPCs have been used routinely only in Texas. Success with LPCs involves an understanding of coyote behavior and proper targeting of collared livestock. LPCs have been used in Texas to successfully remove problem coyotes that have learned to evade other forms of control, and this may be their niche in an arsenal of lethal and nonlethal control alternatives. Herein, I review the development and testing of LPCs and current use in Texas.

Arguments surrounding coyotes often involve the control methods available for resolving damage incidents. Over the last 20 years, public concerns over the use of toxicants and other forms of lethal control have increased greatly. Proponents of lethal techniques such as foothold traps or neck snares criticize these methods as nonselective, i e , as likely to take nontarget animals as coyotes.

The ideal control method is one that would combine effectiveness, safety, selectivity, cost-effectiveness, social acceptability and ease of use (Sterner and Shumake 1978). Given the range of habitats and damage situations that characterize coyotes, these criteria will likely never be achieved However, the Livestock Protection Collar (LPC) may come as close as any technique currently available.

History of LPC

The LPC was invented by Roy McBride in the early 1970s and is currently registered for use with the U S. Enivornmental Protection Agency under McBride's company (Rancher's Supply, Inc , Alpine, TX) EPA registration was preceded by intensive research by the Denver Wildlife Research Center to assess the efficacy of LPCs as a predator management tool (Burns et al 1984, Connolly 1985).

McBride's orginal prototype of the LPC stemmed from his observations that most coyotes attack sheep and goats at the throat, just behind the mandible In its current form ("small size"), the LPC consists of of 2 rubber bladders each of which contains 15 ml of a 1% solution of sodium fluoroacetate (Compound 1080). A "large size" version contains 30 ml in each bladder of a 0.5% solution of 1080 Only the small version is registered currently for use in the U.S., but registration is being sought for the larger version as well. A pink (Rhodomine B) [early versions] or yellow (Tartrazine) dye is contained in the solution as a contamination indicator. The LPC is held in place with Velcro straps for attachment beneath the throat and just behind the jaw of a lamb or kid goat (USDA-APHIS 1990) (Fig. 1)

The LPC capitalizes on the killing behavior of coyotes attacking sheep and goats Coyotes typically attack sheep-sized animals by biting them under the neck and crushing the trachea, causing suffocation (Connolly et al. 1976). Coyotes that exhibit such attack behavior ruptured one or both bladders of the LPC in at least 75% of their attacks on sheep under pen-monitored trials (Connolly 1985) In doing so, the attacking coyote receives a lethal oral dose of 1080 Dosed coyotes die from 2 to 7 hours later (average about 4 hours)

Figure 1 Diagram of Livestock Protection Collars in use on sheep (left) and goat (from TDA 1994)

As of 1989, LPCs were registered for use by state-certified applicators in Texas, Montana, Wyoming, South Dakota and New Mexico. Of these, most of the field use has been conducted in Texas (Walton 1990). Training materials for certification to use LP Collars are available that address user certifcation, application and hazard information (Wade 1985, TAEX 1990, TDA 1994). Use of LPCs is restricted in extreme south Texas due to the possible presence of 2 species of end-angered felines.

Although users and agencies have been slow to adopt the LPC and use it widely, LPCs have gained immediate and widespread use in several foreign countries in Central and South America and Africa (R. McBride, Rancher's Supply, Inc., pers. commun.).

Advantages of LPCs

The LPC is the most selective control method available for removing those coyotes that are actually attacking sheep and goats This latter ability illustrates the LPC's specificity, a characteristic unaddressed by other techniques but important in determining public acceptance of control alternatives (Cain et al 1972, USFWS 1978).

The notion that a coyote population contains both "killer" and "nonkiller" coyotes (relative to livestock) has been espoused and has at least some empirical support (Connolly et al. 1976, USFWS 1978). Eight of 11 captive-reared coyotes killed sheep (Connolly et al. 1976), and 18 of 19 pen-reared coyotes killed sheep in another study (USFWS 1978:74). However 16 of 54 wild-caught coyotes did not kill sheep when confined in a 2 5 acre observation area, even after being deprived of food for several days. However, these authors caution about extrapolating results of pen trials to field situations. A consensus seems to be that, while all coyotes do not kill sheep, most coyotes that are exposed to sheep, especially lambs, will probably learn to kill sheep eventually (USFWS 1978)

The niche that LPCs currently occupy in Texas' predator control scheme has been primarily one as a measure of "last resort". LPCs have been used successfully by users and the Texas Animal Damage Control Service (TADCS) to remove problem coyotes that have learned to avoid more traditional control methods (e g , traps) (Walton 1989, Dorsett 1995a, b) Additional field studies need to be conducted to address the LPC's effectiveness as the primary corrective control.

Use in Texas, 1988-94

EPA granted a conditional registration to Rancher's Supply, Inc for use of small LPCs in December 1987, and certification of applicators began in April 1988 (Walton 1990) A total of 51 licensed LPC applicators obtained LPCs, and 40 applicators used LPCs during this period. Use by TADCS employees began on a pilot basis in 1990 (Dorsett 1991) LPC use by TADCS personnel increased from 12 projects in FY90 to 44 in FY94 Success rates (i e., coyotes were taken by LPC use) have averaged just under 50% over the 4 years of use by TADCS (Dorsett 1995). This success rate should be viewed in the context that the coyotes removed had already evaded other ongoing control efforts, including M-44 devices, traps, snares and aerial gunning. Dorsett (1995) acknowledged that the LPC has become a very useful tool to TADCS for removing problem coyotes.

One of the disadvantages of using LPCs is the expense of purchasing enough LPCs to collar a sufficiently large target flock (e.g., 100 head). Collars cost $20 each and could present a sizeable investment for the individual rancher. A collaborative effort of the TDA, Rancher's Supply, Inc. and the Texas Agricultural Extension Service (TAEX) allowed for the formation of "county collar pools" (TDA 1991) Restrictions concerning collar pools are found in TDA's (1994) certification training handbook Although the agreement allowed a maximum of 15 participating counties, only 6 counties actually formed collar pools (TDA 1991), and these have been used infrequently Most of the LPC use in Texas currently is under the auspices of TADCS personnel

Using LPCs effectively

McBride (in TAEX 1991) lists the following reasons when citing failures in LPC use:

(a) using collars where killing frequency is erratic and infrequent;

(b) users try to manipulate coyote behavior by placing collared animals in pastures where attacks had not been occurring, or by using collared animals unlike those being attacked;

(c) using insufficient collars to ensure that a coyote will prey upon a collared individual; and

(d) improperly targeting the coyote's attack to the collared animals.

A 14-minute instructional video "*Using Livestock Protection Collars*" is available from TAEX (write to author at address listed on this paper) and provides management tips for increasing success with LPCs.

LPCs are most effective in areas with a high frequency of attacks and where other control measures have failed. Success will be highest when proper "targeting" methods are used to focus coyote attacks on collared livestock (Wade 1985). A "target flock" consisting of a small number (e.g., 20) of collared lambs or kid goats are accompanied by 100 or more adult animals. McBride (pers. commun.) recommends target flocks consisting of 100 or more collared lambs/goats with several hundred adult animals, in a ratio of about 1 collared young per 10 adult animals If given a preference, coyotes will almost always attack the younger animals (Guthery 1977). Other uncollared livestock on the site should be moved to a safe area or penned until offending coyote(s) are removed or predation ceases.

Conclusions

The invention, testing, registration and subsequent field use of LPCs has been a drawn out, political process. Users certified by TDA complain that record-keeping requirements and use restrictions are cumbersome, and user acceptance of LPCs in Texas has been slow to date. However, these political constraints should not overshadow that the LPC has proven to be a selective, effective and indeed specific tool for removing coyotes that actually kill sheep and goats.

The LPC is the only control alternative currently available for delivering "perfect justice" to coyotes guilty of killing livestock, i.e., its specificity rarely affects non-offending animals (coyote or nontarget). The fact that it involves a relatively slow-acting and highly politicized toxicant (Compound 1080) hinders its acceptance among animal welfare groups However, such groups generally oppose the use of all lethal control alternatives, regardless of their selectivity, specificity or perceived humaneness.

Literature Cited

Burns, R. J., G. Connolly, D. L. Meeker, I. Okuno, and P. J Savarie. 1984. Efficacy and hazards of Compound 1080 in toxic collars. Unpubl. Rept for EPA File 6704IL, U. S. Fish Wildl Serv , U S.D I , Denver, CO.

Cain, S. A , J A. Kadlec, D. L Allen, R. A. Cooley, M. G. Hornocker, A. S. Leopold, and F. H Wagner. 1972. Predator control - 1971 · report to the Council on Environ. Qual. and the Dept. of Int. by the Adv. Comm. on Predator Control. Inst. for Environ. Qual , Univ Mich., Ann Arbor. 207pp.

Connolly, G. 1985 Technical bulletin for the Livestock Protection Collar EPA Registr. No. 56228-22 U S D.I , U.S Fish Wildl. Serv., Denver Wildl Res. Ctr., Denver, CO.

_____., R M Timm, W. E. Howard, and W. M. Longhurst. 1976. Sheep killing behavior of captive coyotes. J. Wildl. Manage. 40:400-407.

Dorsett, J 1995. Report of Livestock Protection Collar Use 1990-94 to Texas Department of Agriculture. Texas Animal Damage Control Serv., San Angelo, TX.

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

Sterner, R T., and S. A. Shumake. 1978. Coyote damage-control research: a review and analysis. Pages 297-325 in M Bekoff (Ed.) Coyotes· biology, behavior, and management. Academic Press, San Diego, CA. 384pp.

Texas Agricultural Extension Service. 1990. Using livestock protection collars. Video available from Texas A&M Res. & Ext. Ctr., San Angelo. 14 min.

Texas Department of Agriculture. 1991. Livestock Protection Collar Use - 1990. Ann. Rept., Austin, TX. 19pp.

_____. 1994. M-44 sodium cyanide and Compound 1080 Livestock Protection Collar Certification Manual. Austin, TX. 174pp

U.S D.A. Animal Plant Health Inspection Service. 1990 Appendix "J" Sodium Fluoroacetate Livestock Protection Collar. Draft Environmental Impact Statement on Animal Damage Control Program. Hyattsville, MD.

U S Fish and Wildlife Service. 1978. Predator damage in the west: a study of coyote management alternatives. U. S D. I. , Washington, DC. 168pp.

Wade, D. A. 1985 Applicator manual for Compound 1080 in Livestock Protection Collars. Texas Agric Ext. Serv. Bull. B-1509 Texas A&M Univ., College Station. 50pp.

Walton, M. T. 1990. Rancher use of Livestock Protection Collars in Texas. Proc. 14th Vetebr Pest Control Conf., Sacramento, CA. 7pp

IMMUNOCONTRACEPTION AS A TOOL FOR CONTROLLING REPRODUCTION IN COYOTES

LOWELL A MILLER, U. S. Department of Agriculture, National Wildlife Research Center, 1716 Heath Parkway, Fort Collins, CO 80524

Abstract: The development of immunocontraception as a tool for population management of coyotes (*Canis latrans*) and reduction of coyote predation may provide an environmentally safer alternative to pesticides. Because they are proteins, immunocontraceptive vaccines do not persist in the environment or bioaccumulate in the food chain. The National Wildlife Research Center (NWRC) will examine the effects (immunological, hormonal and behavioral) of treating penned coyotes with 2 immunocontraceptive vaccines: porcine zona pellucida (PZP) and gonadotropin releasing hormone (GnRH). Initial studies will be conducted using traditional subcutaneous injections; however, the goal is to develop an orally-deliverable immunocontraceptive vaccine as an alternative tool for coyote population management

Livestock predation by coyotes is a chronic conern of many sheep and goat ranchers. A 1990 survey estimated that, of the nearly 6 million lambs born in the 16 western states, 549,000 lambs died from all causes (Connolly 1992). Nearly 60% of the losses were a result of predators. Coyotes were the main culprit, accounting for 70% of the predator-caused mortalities The economic impact on producers and consumers in 1990 was approximately $11 4 million Despite intensive historical control efforts in livestock production areas, and despite sport hunting and trapping for fur, coyotes continue to thrive and expand their range, occurring widely across North and Central America

Scientists at the National Wildlife Research Center and its predecessor laboratories have conducted research for over 50 years on the problem of livestock predation by coyotes, and on developing methods to minimize predation losses Available techniques include husbandry practices, shooting, trapping, frightening devices, livestock guarding dogs and toxicants (Fall 1990). None of these control methods is completely practical or effective in all of the diverse situations in which coyote predation on livestock occurs. Also, as the costs of labor-intensive skills and approaches continue to increase, new techniques are needed. Further, coyotes are viewed increasingly by the public as a desirable wildlife species Accordingly, effective nonlethal methods are being sought for resolution of predation problems.

Immunocontraception has been suggested as 1 nonlethal technique with application for reducing coyote numbers in areas where they are causing depredation losses, or for managing the predatory behavior of territorial pairs (Knowlton 1989). However, private industry has had little economic incentive to develop new materials for this use because of the small quantities of materials that would be used in predation control This situation with immunocontraception vaccines parallels that for toxicants and other coyote predation control products (Linhart et al 1992).

Basics of immunocontraception

The neonatal vertebrate immune system develops a recognition of "self" proteins, carbohydrates, and hormones. This self recognition is essential, since the production of antibodies against pathogenic bacteria and viruses is necessary for survival. However, the formation of antibodies against "self" can be an abnormal destructive process, e.g., diseases like multiple sclerosis and arthritis.

The entire immune system is in constant surveillance to determine "self" vs "foreign" proteins. For example, in the digestive tract, particles and organisms are examined and either tolerated or attacked by antibodies The respiratory and intestinal mucosal surfaces contain various white blood cells (lymphocytes and macrophages) that are responsible for generating specific immune responses. In the small intestine, groups of lymphoid cells known as Peyer's patches (PP) sample bits of food proteins and microorganisms as they pass through to determine if an immune response will be directed against the incoming organism or food particle.

Anti-fertility vaccines are directed against "self" reproductive antigens (hormones or proteins) to which the recipient normally is immunologically tolerant. These antigens are made "non-self" or "foreign" by coupling them to a protein that is recognized as foreign to the animal. As the animal' immune system examines the conjugated self-foreign protein, antibodies are produced to its own reproductive proteins and hormones This induced immune response against "self" is the key to immunocontraception The infertility lasts as long as there are sufficient antibodies to interfere with the biological activity of the targeted hormone or reproductive protein, usually 1-2 years.

Reproductive hormones and proteins involved in immunocontraception

Immunocontraceptive vaccines can control reproduction at various stages They can interrupt the reproductive activity of both sexes by (a) interfering with the biological activity of hormones, (b) blocking sperm penetration of an ovulated egg, or (c) preventing implantation and development of a fertilized egg

Gonadotropin releasing hormone (GnRH) is produced in the brain by the hypothalamus and controls release of the pituitary reproductive hormones follicle stimulating hormone (FSH) and luteinizing hormone (LH). These hormones in turn control the hormonal functions of the gonads (ovaries and testes) Antibodies to the hypothalamic hormone will reduce the circulating level of biologically-active GnRH, thereby reducing the release of subsequent reproductive hormones. The reduction or absence of these hormones leads to atrophy of the gonads, resulting in infertility in both sexes. Both avian and mammalian forms of GnRH have been identified.

The zona pellucida (ZP) is an acellular glycoprotein surrounding the egg or oocyte. It is located on the outer surface of the egg between the oocyte and the granulosa cells. Antibodies to this glycoprotein layer result in infertility by 1 or both of these actions: (a) blocking sperm from binding to the ZP layer, and (b) interfering with oocyte maturation. For a sperm to fertilize the egg, it must first bind to a receptor on the ZP. An enzyme in the sperm breaks down the ZP and allows the sperm passage into the ovum. Antibodies to the ZP also prevent fertilization by interfering with oocyte-granulosa cell communication, resulting in the death of the developing oocyte (Dunbar and Schwoebel 1988).

Since protein in the sperms' head normally bind to the ZP receptor on the oocyte, antibodies to these sperm proteins can be produced, by vaccination in the female that are available to bind to sperm in the oviduct. This prevents sperm from binding to the ZP receptor Sperm protein immunocontraception is being investigated for contraception of the red fox and the rabbit in Australia (Morell 1993, Tyndale-Biscoe 1991) A ZP protein has not been identified in avian species, nor has the cross-reactivity of PZP been tested in avian species.

Chorionic gonadotropin (CG) hormone, which is produced by the implanting embryo in some species, induces the corpus luteum to continue production of progesterone which is required for the maintenance of pregnancy. Antibodies to CG reduce blood levels of this hormone and thereby prevent implantation of the fertilized egg.

The riboflavin requirement of the developing embryo is satisfied by active transport of this water-soluble vitamin across the placenta. This transport is provided by a gestational-specific carrier protein called riboflavin carrier protein (RCP). RCP plays a pivotal role in embryo development in avian and mammalian species. Antibodies formed against RCP interfere with placental transfer of riboflavin, thereby preventing development of the early embryo. This technology probably would result in the least change in social behavior of the target species of any of the proposed vaccines (Natraj et al. 1987, 1988).

Reproduction can be blocked at many sites in the reproductive process; the above examples are the sites where most investigative work has been done. Behavioral and social changes in target animals resulting from specific vaccines may dictate the vaccine of choice in each situation (Jones 1982, Griffin 1992).

Methods of administering vaccines

Subcutaneous or intramuscular (I M.) injection are the traditional forms of vaccine delivery. In order to accomplish I M injections in free-roaming animals, the vaccine must be delivered by a dart or a "bio-bullet" (Kirkpatrick et al. 1990, Turner and Kirkpatrick 1991, Garrot et al. 1992, Turner et al. 1991, 1992). While these methods may be effective in certain confined locations, they are impractical when dealing with mobile wildlife populations in large open areas

Except for the oral polio vaccine introduced by Dr. Sabin in the 1950s, oral vaccination has received little attention for humans because it requires larger quantities of vaccine and is less predictable than subcutaneous or I M. routes In mammals, oral immunization takes place in the pharyngeal immune follicles (e.g., the tonsils) and in the small intestine. There are thousands of immune follicles throughout the small intestine, with a higher concentration in the distal portion in most species Vaccines, being protein in nature, are digested rapidly in the stomach when given orally, hence, immunization must occur either in the pharyngeal area or the vaccine needs a protective capsule to survive passage through the stomach then be released in the small intestine (McGhee et al. 1992)

The safest way to deliver the antigen orally is to protect it until it is taken up by the PP and delivered to macrophages A combination of 2 approaches could lead to effective antigen uptake and potentiation of mucosal immune response. (a) enteric coating of the antigen resulting in delivery vehicles that prevent degradation in the stomach but allow absorption in the intestine, and (b) designing the vaccine to have enhanced attraction to the immune follicles in the small intestine

Recent understanding of the mechanisms by which pathogenic viruses and bacteria colonize and infect the intestinal tract has provided new insights for developing successful and safe attenuated live or killed, oral vaccines. For example, a bacteria must survive the stomach's acid and proteolytic enzymes to successfully infect the small intestine. After surviving intact through the stomach, it must have adhesive properties which allow it to adhere to and colonize the intestinal wall, resulting in an infection. Bacteria without adhesive properties will be carried out of the gut with the waste material.

Liposomes are spherical, artificial biological membranes made up of phospholipids and cholesterol that can be used to protect oral vaccines from digestive tract degradation. Since the liposome membrane contains lipids, which are stable in the gastrointestinal tract, an antigen placed inside during liposome synthesis is protected from gastrointestinal degradation. Cholesterol in the membrane adds stability and makes it attractive to macrophages in the PP where the liposome is taken up rapidly because of the membrane's lipophilic nature. This characteristic of the membrane causes the liposome to simulate a microbial cell when presented to the immune system The liposome acts as an antigen microcarrier capable of targeting the antigen directly to the PP.

However, before a liposome can be taken up by the macrophages, it must bind to the mucosal surface of the intestine; otherwise it will be swept out with the waste material. This mucosal adhesive property increases the mucosal uptake efficiency, thus requiring a smaller oral vaccine dose The most commonly used liposome adhesive is a nontoxic form of the bacterial lectin, cholera toxin (CT), a member of a family of enterotoxins produced by several strains of enteropathogenic bacteria (Holmgren et al. 1992). Lectins have multiple binding sites and can bind to receptors on the liposome as well as to intestinal receptors.

Recent advancements in molecular biology and immunology have provided us with new tools such as "live vectors" as delivery vehicles. The most prominent use of this technology in wildlife management is the use of the live vaccinia virus to deliver rabies vaccine orally to raccoons *(Procyon lotor)* and foxes (*Vulpes vulpes*). The attenuated vaccinia virus, a member of the pox viruses, was used as a vaccine against smallpox in humans for over 20 years. Using recombinant genetic engineering, the gene responsible for encoding of the rabies virus glycoprotein was inserted into the vaccinia virus by scientists at the Wistar Institute This recombinant pox virus, when given orally, was able to vaccinate the target animal against rabies. The tonsil lymphoid tissue is thought to initiate the immune response in these target animals (USDA-APHIS 1991).

Live viral vectors potentially can be used to deliver a contraceptive vaccine. This delivery system is currently being tested in Australia (Tyndale-Biscoe 1991).

Potential of immunocontraception in coyote management

Immunocontraception as a technology is available today, but only for use in a laboratory setting and pen studies. Immunocontraceptive vaccines are being produced in limited quantities and animals injected with these vaccines become infertile for 1-3 years.

The development of a practical, cost-effective immunocontraceptive vaccine for coyotes is a multi-year, multi-task project. The first task the NWRC will undertake will be to determine the immune, hormonal and behavioral responses to non-species-specific PZP and GnRH immunocontraceptive vaccines. Using serum from known immuno-sterilized and fertile coyotes from the above study, a new mimotope assay will be used to determine portions of the PZP active in sterilizing the coyote. This new test may hold promise for finding a PZP peptide specific to coyotes These species-specific peptides could then be used to develop a species-specific ZP vaccine GnRH will continue to be studied where species specificity is not critical

Some important behavioral questions related to the effects of contraception on pair formation, pair bond maintenance, breeding behavior and territorial defense need to be addressed. The answers may dictate in part the choice of vaccines to be developed for immunocontraception in coyotes

Practical use of immunocontraception for controlling free-ranging coyote populations will have to involve oral delivery of the vaccine The technology for developing oral vaccines is in its infancy However, because of a worldwide need for oral vaccines against cholera and the HIV virus, rapid progress is being made in this area. Oral immunization using liposome or bacterial vectors will be the goal of the NWRC Vaccines encapsulated in liposomes will provide protection from the gastrointestinal environment and can induce a 500-fold greater oral immune response as compared to free antigens We plan to develop liposomes with a cholera-toxin-B subunit on their surface to mimic the adhesive properties of intestinal pathogens and ensure optimal host immune response.

Finally, prior to field use, U. S Food and Drug Administration approval of the safety and efficacy of this new vaccine will be needed Extensive laboratory, field and product testing will be required before this or other materials are available for use in management programs.

Literature Cited

Connolly, G. 1992. Sheep and goat losses to predators in the United States. Proc East. Wildl. Damage Control Conf. 5:75-82.

Dunbar, B. S. and E Schwoebel. 1988. Fertility studies for the benefit of animals and human beings. Development of improved sterilization and contraceptive methods J Am Vet. Med Assoc. 193.1165-1170.

Fall, M. W. 1990. Control of coyote predation on livestock -- progress in research and development Proc Vertebr Pest Conf. 14:386-392.

Garrott, R A , D. B Siniff, J. R. Tester, T C. Eagle, and E D Plotka 1992. A comparison of contraceptive technologies for feral horse management. Wildl. Soc. Bull. 20:318-326

Griffin, P D. 1992. Options for immuno-contraception and issues to be addressed in the development of birth control vaccines. Scand. J. Immunol 36:111-117.

Holmgren, J., C Czerkinsky, N Lycke, and A. Svennerholm. 1992 Mucosal immunity: Implication of vaccine development. Immunobiol 184:157-179.

Jones, W R. 1982 Immunological fertility regulation Blackwell Scientific Publications. London. 273pp.

Kirkpatrick, J. F., I. K. M. Liu, and J. W. Turner. 1990. Remotely-delivered immunocontraception in feral horses. Wildl. Soc. Bull. 18:326-330.

Knowlton, F. F. 1989. Predator biology and livestock depredation management. Pages 504-509 in Proc. Western Sect., Am. Soc. Anim. Sci.

Linhart, S B , G J Dasch, R. R. Johnson, J. D. Roberts, and C. J Packham. 1992 Electronic frightening devices for reducing coyote predation on domestic sheep: Efficacy under range conditions and operational use. Proc. Vertebr. Pest Conf 15:386-392

McGhee, J R , J Mestecky, M T. Dertzbaugh, J. H. Eldridge, M. Hirasawa, and H Kiyono 1992. The mucosal immune system: From fundamental concepts to vaccine development. Vaccine 10:75-88

Morell, V 1993 Australian pest control by virus causes concern Science 261:683-684.

Natraj, U., R. Asok Kumar, and P. Kadam. 1987. Termination of pregnancy in mice with antiserum to chicken riboflavin-carrier protein. Biol of Repro 36:677-685

_____., S. George, and M. S. Kadam. 1988. Characterization of antibodies to chicken riboflavin carrier protein. Biochem. J. 254:287-292.

Turner, J. W. and J. F. Kirkpatrick. 1991. New developments in feral horse contraception and their potential application to wildlife. Wildl Soc. Bull. 19:350-359.

_____., I. Liu, and J. F. Kirkpatrick. 1992. Remotely delivered immunocontraception in captive white-tailed deer. J. Wildl. Manage. 56:154-157.

Tyndale-Biscoe, C. H. 1991. Fertility control in wildlife. Reprod. Fertil. Dev. 3:339-343.

USDA-APHIS. 1991. Proposed field trial of live experimental vaccinia vector recombinant rabies vaccine for raccoons. Unpubl. Environ mental assessment and finding of no significant impact. Pages 1-81.

PHOTOGRAPHING COYOTES

WYMAN P. MEINZER, JR. P. O. Box !95, Benjamin, TX 79505

Abstract: Wildlife photography has become an increasingly popular hobby over the last 10 years. Coyotes (*Canis latrans*) are among the more difficult animals to photograph under natural field conditions (i.e., in the "wild"). For studying and photographing coyotes behaving routinely, I recommend the use of a "draw station" (i.e., cow carcass) and a blind that will allow relatively close inspection of coyote interactions.

Photography has been an effective medium of communication for over a century. Perhaps the earliest and most poignant example are the works of photographers during the Civil War Dedicated in their intent to preserve the images of this brutal struggle, these men braved the hardships of the bloody campaigns to offer the 20th century and beyond a glimpse into this sad saga in American history Since that time, the camera has brought to public's attention the progression of world events through the illustrated pages of books and periodicals.

Until early in the 20th century, serious photography was restricted to those professionals whose dedication and means allowed them to overcome the difficulties of the medium. Heavy cameras and lenses, slow film and complex chemicals effectively isolated almost all of the general public from engaging in the expression of photography

With the introduction of compact small format cameras and a variety of film types, photography finally became an almost essential element in all facets of society by the late 20th century As an educational tool, or simply documenting the progression of family life, the camera has evolved as a key element in the mainstream of education, business, and the private sector

During the past 2 decades, the visual sophistication and demands of the North American, if not world readership, has increased progressively. Photography has become essential in illustrating the written word for both popular and scientific publications. As a result, publishers of almost all periodicals are requiring superior quality and depth to the photo coverage to serve the interests of the ever more demanding reader. Consequently, the need to constantly improve our communication skills through photography is of importance, especially for those of us involved in field of publishing and education.

When documenting the natural history of the coyote photographically, it is essential to show the animal in as natural a state of existence as possible. Almost all published photos to date are of coyotes in controlled conditions or in public access areas where the creatures have largely lost their fear of humans. Accurate documentation of the coyote's ways is often altered dramatically when studied under such artificial conditions. Photographic techniques do exist which could minimize altered behavioral patterns when applied to field studies. Although time consuming and somewhat complex, these techniques have proven to be effective in documenting the natural lifestyle of wild coyotes in the Rolling Plains of Texas.

Three methods of field photography on the wild coyote which have proven effective are calling, still hunting, and natural blinds on draw stations.

Calling is perhaps the most popular method of viewing coyotes Used by hunters dating back to perhaps to the pre-19th century, calling is a favorite method familiar to most hunters It involves the use of a simple hand-held or electronic call that imitates the distress cries of a natural prey species. The coyote, as well as a variety of other creatures, responds to the sound and approaches to within a very short distance of the caller. When well concealed, photographers can often get dynamic close-ups of animals in this manner. The negative side of calling is that most of the photos are basically 1-dimensional in that very little action and interaction between other coyotes is possible.

Still hunting with a camera is a good method in which to attain photos of coyotes unaware of human presence. Although an excellent way to find coyotes behaving in a natural manner, the still approach is time consuming, as it is extremely difficult to approach coyotes to within a close distance.

The use of natural blinds on "draw stations" has proven to be the best method for me in attaining photos showing various types of coyote behavior without expending excessive time and energy covering large tracts of land. Site selection for the blind depends upon prevailing winds, light angles, and coyote abundance. Available terrain and vegetation around the photo site should be conducive to clear viewing of coyote interaction.

Draw stations can be baited with the carcass of any domestic animal of heavy weight. I preferments beef or horse weighing in excess of 300 pounds. Even then, the baits should be staked down to minimize the chances of several coyotes dragging the carcass away from the site

Photographing wild coyotes requires long telephoto lenses that allow photographs under low light conditions. Cost is sometimes prohibitive, but with high quality editorial demands at an all time high, low speed lenses will usually not meet the demanding requirements encountered under normal field conditions.

THE COYOTE

by Baxter Black[1]

Take him for what he's worth, nothing more, nothing less.

I think I can speak for the coyote
With more understanding than most.
Especially those who defend him
And live on the New Jersey coast

They raise up a pitiful cry
And claim he's a mistreated critter.
Who'll soon be extinct if the ranchers out west
Don't put down their rifles and quit'er.

But like all of God's creatures around us
There's always two sides to the tale.
I think if the coyote were human
That most of 'em would be in jail.

Cause there's no doubt he preys on the weaklings
Or the youngsters too little to run
He slits the throats of cute little lambs
And drags little calves from their mom.

So if you must describe him in terms
Such as wily, and clever and keen
You must also include homocidal,
Sadistic, demented and mean

But I will choose to do neither
And somehow I wish you would too.
For the coyote he has no conscience
He's just doin' the best he can do.

You can like and dislike the coyote,
Many ranchers I know do both
When he trespasses he'll get shot at
But his song in the night brings a toast

A toast to our neighbor the coyote
Who'll outlive the earth and the sky.
And be here long after we've parted
Like the cockroach, the rat and the fly.

The Ole Coyote

by Kent Rollins[1]

Some call him a song dog,
Some call him an ol' wolf
Let me tell you fellers,
He shore is tuff

He's been around
For an awful long time,
Before your kinfolk,
And even some of mine.

Now don't get me wrong,
I ain't takin' sides,
Cause I've even took
Some of their mangy hides

The ol' timers made a livin'
Trappin' this ornery cuss,
With the market the way it is now,
Trappers say it ain't worth the fuss

To city folk he's a pretty sight,
They enjoy his yodel on a moonlit night
To the farmer and rancher,
He's like a stick in their eye,
There's no love lost between 'em
They wish they all would die

Now the old sheep farmer
He's tried to get the best of this critter.
But the ole coyote and Mother Nature,
Respond by increasin' the litter.

Now all this ain't just by chance,
This ole wolf can adapt to any circumstance.
He can live in the desert where there's lots of heat,
Or he can survive on the big city's street
He's been here since Columbus first came,
He's made tracks from Texas to Maine

Now remember I ain't choosin' sides,
I've lost many a calf to his cunning hide
If it should come to a nuclear war,
And these ol' plains are barren to grown no more.

Then he comes a crawlin' out of his hole,
This ol' coyote nobody wants to know.
He's a survivor and always will be,
Dad fetch his hide, the cow-yodee!