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## Introduction

We appreciate this opportunity to present a brief synopsis of a complex field study recently completed near Laredo, Texas. It provides a preliminary assessment of differences in coyote vulnerability to several management tools At this point, our analyses are incomplete and interpretations are tentative, at best Nonetheless, the data provide some insights and a basis for speculations and questions about coyote behavior, population processes, and the logistics of coyote population reduction.

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## Objectives

The primary objective of the study was to obtain a better understanding of factors influencing coyote reproductive success. Previous information from the vicinity of Laredo (Wimdberg unpubl. data) suggested that yearling female coyotes were seldom reproductively active and that 2-year-old females were less productive than older females. Because substantial numbers of coyotes were suspected to be transients (Le. not having a territory, or "belonging" to a territorial group), the implications of territoriality to reproductive success were also examined.

Because the coyotes were to be "handled" twice and a detailed knowledge of each individual's spatial use patterns obtained, 3 other objectives were incorporated for nominal additional costs

1. Obtain a density estimate for a coyote population in the South Texas brushland:
2. Determine the relative efficacy of 3 placement strategies for delivering small baits to coyotes; and
3. Attempt to assess the efficacy of helicopter gunning under some very stringent environmental conditions.

Because all activities were not applicable to each objective, procedures relevant to each are provided within the sections related to the respective phases of the study.

## Coyote Density Estimates

### Methods

Two study areas, 20- and 24-mil respectively. 15 miles apart were established northwest of Laredo, Texas. Coyotes were captured with steel leg-hold traps equipped with tranquilizer tabs (Baker 1965) to reduce foot damage. Each female coyote was ear-tagged, equipped with a radio-transmitter. relieved of a premolar tooth for age determination. injected intramuscularly with 10 microcuries of 65Zn and released at site of capture. Males were not the focus of the reproductive study but they were treated similarly except radio transmitters were not attached nor were they injected with 10 microcuries of "Zs.. Two weeks after the last coyote was released, 26 0.5-mile scat collection transects were established along roads and trails on each study area. They were walked once in each direction and ail detected scats removed. Subsequently, the transects were re-walked 3 times at 4-day intervals and ail detected scats collected, placed in individual paper bags, labeled, and taken to the laboratory where a multi-channel analyzer was used to assay the scats for the presence of 65Zn The number of "coyote-days" spent on the study areas by isotope-marked animals, as assessed by radio telemetry, was used in mark-recapture equations (Schnabel 1938. Davison 1980) to estimate the number of coyotes on each study area.

### Results

The isotope assays revealed 9.396 and 15.196 of the scats from the 2 areas were marked (Table 1), resulting in estimations of 141 and 86 coyotes respectively on the 2 study areas. These estimates convert to densities of 2.7 and 1.4 coyotes per km= (7.0 and 3.6 coyotes/ mi2 respectively). We have reservations about the accuracy of the larger value because the percentage of scats that were marked was low and the territorial coyotes that were isotopemarked were not dispersed throughout that study site. Both estimates, however, suggest the areas harbored some of the highest spring coyote densities reported thus far.

## Aspects of Territoriality

### Methods

Fixed-station telemetry techniques were used to establish the spatial use patterns of each of the radio-instrumented coyotes. This was accomplished by simultaneously determining azimuths from 2 locations at 15- and 30-minute intervals. A computer was used to synthesize the data and plot the relative distribution of each animal's locations. Each animal was judged territorial or transient on the basis of the number and relative distribution of locations.

### Results '

Overall,- 49% of the 47 instrumented female coyotes appeared to be territorial (Table 2) but, as expected, the proportion of females that were territorial varied significantly with age. Forty percent of the yearlings (animals approaching or just past their first birth date) appeared to be territorial; these females probably still belonged to the social group into which they were born. Twenty-three percent of the 2-year-old females and 67% of older females were classified as territorial.

Table 1. Coyote population estimates for two areas in the South Texas brushland.

| Parameter | Galvan area (20 mi2) | Mines area (24 mi2) |
| --- | --- | --- |
| No. marked females | 19 | 24 |
| No. "marked coyote-days°s | 157 | 141 |
| No. scats collected | 118 | 106 |
| No. 65Zn labelled scats | 11 | 16 |
| ESTIMATED N0. COYOTES | 141 | 86 |

ₜStan of the number of days isotope-marked coyotes spent on the study area during the scat accumulation period, as determined from radio-tracking data.

Table 2. Territorial status of female coyotes captured in South Texas %

| Age | n | Territorial | Transient |
| --- | --- | --- | --- |
| Yearling | 10 | 40 | 60 |
| Two-year-old | 13 | 23 | 77 |
| Mature | 24 | 67 | 33 |
| OVERALL | 47 | 49 | 51 |

For each territorial female, we arbitrarily excluded up to 10 % of the outlying relocations to account for exploratory trips that coyotes occasionally make. The remaining locations were circumscribed with a line to represent the territorial boundaries. The maps of the individual territories were then superimposed on a common coordinate system to create a single map containing all of the territories identified (Fig. 1). It was obvious that most of the habitable area was occupied by a series of contiguous territories. In several cases, it appeared that 2 or 3 females were using the same territory. and presumably belonged to the same social group. Otherwise, there was remarkably little overlap in the identified territories. In the single case where extensive use of a common area by 2 females from apparently different social groups was noted, a fallow farm field was included and may not have been actively defended by either female. Transient coyotes spent most of their time in the interstices or around the periphery of the territories and appeared to avoid interior areas of the territories.

The implications of territoriality to reproductive success was of particular interest to us. The radio-instrumented females were recovered at the end of the study and examined for evidence of recent reproductive activity: presence . of corpora albicantia. or degenerating corpora lutes, from the most recent reproductive season was used as evidence the female had ovulated; enlargements of the uterus or presence of bands of dark pigment in the uterus signified implantation had occurred; and loss of mammary hair and enlarged or scarred nipples served as evidence the female had whelped

None of the 5 yearling females examined at the end of the study showed signs of reproductive activity; none had ovulated (Table 3). None of the 2-year-olds successfully whelped. although 4 in this age group had ovulated (3 transient and 1 territorial female) and 3 showed evidence of implantation sites. All of the mature females classified as territorial ovulated and 9196 had current implantation sites, but only 55% apparently whelped successfully. Among the non-territorial. mature females, 7196 ovulated, less than half of those showed evidence of implantation sites. and none successfully whelped. Trends *evident* in the data suggested a much higher percentage of females initiated reproductive activity than were successful. Territorial females 2-years-old and older performed better in all categories than did their non-territorial counterparts. Although only territorial. mature females whelped. there were ample sexually active replacement animals available, should any territories become vacant.

We were also interested in ramifications of territoriality with regard to vulnerability to capture. Toward this end, we scaled a 0.5-km wide band around each territory (0.25-kilometer inside and outside the identified territory boundaries). This partitioned the study area into 3 components identified as: territorial cores (central area of the territories); territorial edges (a peripheral zone); and interstitial areas (space between adjacent territories). Subsequently, we plotted the respective capture locations of all coyotes and evaluated them with regard to the zones defined above.

About two-thirds of the coyotes captured were caught along territorial edges or in the interstitial areas (Table 4). Of greater significance, only 3 of the 20 female coyotes judged to be territorial were captured within the "core" of their own territories. Forty-four percent of the females were captured within the peripheral zone around the territories. Among males, 2496 were caught in the peripheral zones and 4396 in the interstitial areas.

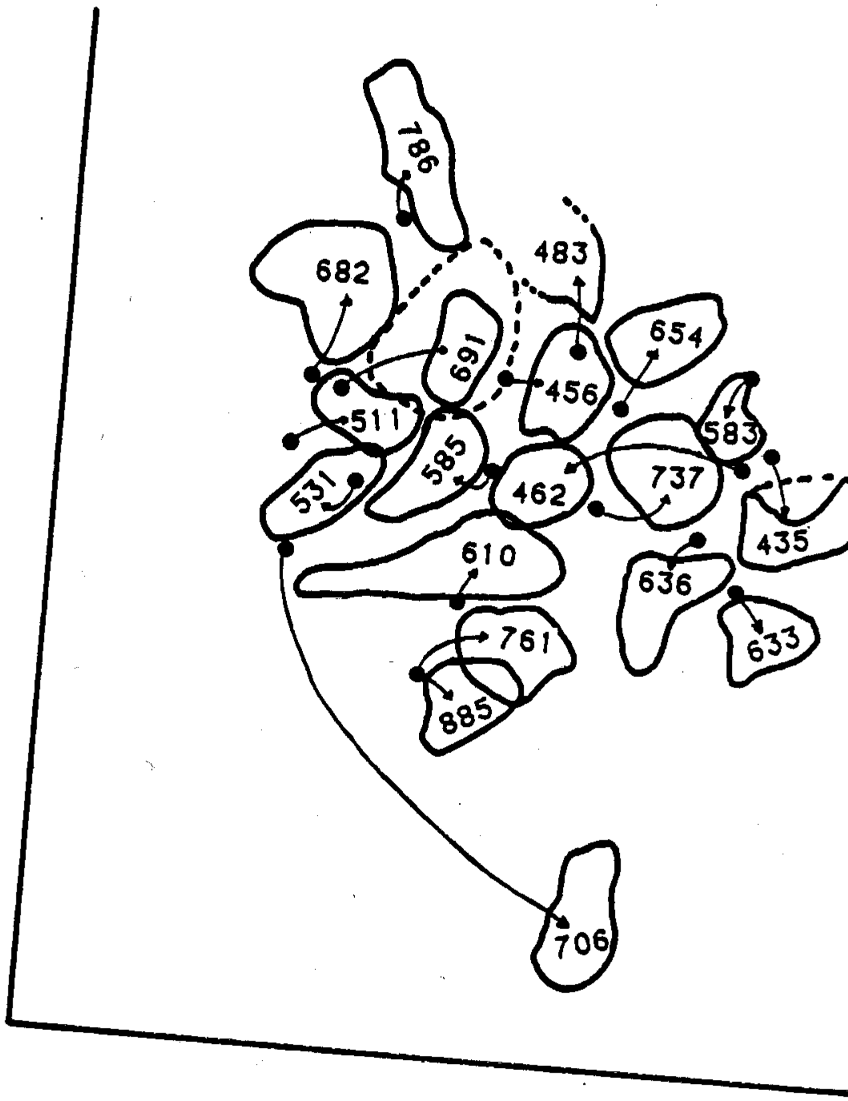


**Figure 1. Relative locations of territories and points of capture (dots) of 91 female coyotes near Laredo, Texas.**

**Table 3. Female coyote reproductive performance** (%).

| Event | Territorial | Transient | Total | |
|---|---|---|---|---|
| Yearlings: | | | | |
| (Sample size) | (2 ) | (3 ) | (5 ) | |
| Ovulate | 0 | 0 | 0 | |
| Implant | 0 | 0 | 0 | - |
| Whelp | 0 | 0 | 0 | |
| Two-year.•olds: | | | | |
| (Sample size) | (1) | (9) | (10) | |
| Ovulate | 100 | 33 | 40 | |
| Implant | 100 | 22 | 30 | - |
| Whelp | 0 | 0 | 0 | |
| Mature Females: | | | | |
| (Sample size) | (11) | (7) | (18) | |
| Ovulate | 100 | 71 | 89 | |
| Implant | 91 | 29 | 67 | |
| Whelp | 55 | 0 | 33 | |
| All females: | | | | |
| (Sample size) | (14) | (19) | (33) | |
| Ovulate | 86 | 42 | 61 | |
| Implant | 79 | 21 | 45 | |
| Whelp | 43 | 0 | 18 | |

**Table 4. Relative distribution of coyote capture locations (90), allocation of study area (%) with regard to territorial core, edge, and interstitial space, and a comparison.**

| Category | Sample size | Territorial Cores | Territorial Edges | Interstitial Areas |
|---|---|---|---|---|
| Coyotes: | | | | |
| Terr. females | (20) \ | 25; | 45 | 30 |
| Traps. females | (16) | 50 | 44 | 6 |
| All females | (36) | 36 | 44 | 19 |
| All males | (37) | 32 | 24 | 43 |
| All coyotes | (73) | 34 | 34 | 32 |
| study Area" | | 57 | 32 | 11 |
| Ratio (X all captures : X area) | | 0.60 | 1.06 | 2.91 |

* of the 5 coyotes involved were caught within core areas of territories other than their own.

** 5% of the study area was not assigned to any of the categories because a suspected territory was neither definitively identified nor defined.

### Gunning from **Rotary-Winged Aircraft**

**Results**

An Animal Damage Control (ADC) aerial gunning team recovered the coyotes during early June. A total of 45 coyotes were shot Routine ADC hunting procedures were used initially for 10.5 hoots within the 44 mil of the 2 study areas and 6 coyotes were shot and recovered. None of the 20 radio-instrumented females known to be present was seen. Subsequently, 33 radio-collared coyotes were located with the assistance of radio directionfinding equipment and shot, along with 6 other coyotes accompanying them. Although the gunning crew did not comment about poor visibility at the time, a combination of dense brush in midsummer foliage sad the adverse effect of hot weather on coyote activity patterns may have contributed to the low capture rate.

Among the 12 coyotes without radio collars that were shot, 9 were 1 or 2 years of age. Only 16 of the 33 coyotes trapped and ***marked on*** **the** areas 4 months earlier and known to still be on the area were in these age groups. The 2 samples were not statistically different, but perhaps testing for age bias between trapping and aerial gunning with larger samples is warranted.

### Relative Efficacy of Small Bait Placement Strategies

Methods

Baits incorporating 1 of 3 physiologic marking agents were distributed on each of the study areas to compare the relative efficacy of 3 placement strategies in delivering baits to coyotes In mid-March, equal numbers of bite-site baits (5 gm each) were used in each distribution pattern. A small quantity of FAS attractant (Roughton 1982) was applied near each bait On each area, 100 baits were distributed (1) is a systematic pattern within 20 meters of livestock water impoundments; (2) in a standard pattern within 15 meters of goat carcasses used as draw stations; and (3) along ranch roads and trails at 0.3-mile intervals throughout the area. Baits used in the vicinity of water impoundments contained 100 mg. of tetracycline: those at draw stations contained 10 mg, of iophenoxic acid and those distributed along roads had 100 mg. of mirex. The latter two compounds produce "marks" detectable in blood serum samples more thaw 16 weeks after ingestion (Larson et al. 1981, Beer et al. 1985, Knowlton et al. In press) and tetracycline causes fluorescent bone labeling that can be detected for that period also (Linhart and Kennelly 1967). Baits were checked every 2 days for 10 to 14 days to determine the number removed and to replace missing once Subsequently, when coyotes were recovered from the study areas, samples of blood serum, and a scapula and mandible were removed, preserved, and taken to the laboratory sad examined for the presence of each of the "marks."

Results

Among the 45 coyotes shot at the end of the study, nearly 50% had ingested at least 1 of the marked baits (Table 5). Less than 1096 of the coyotes had taken baits placed near water while about twice that number ate baits placed near the draw stations. A third of the coyotes had eaten baits placed alongside roads sad trails. The relative distribution of marked animals was reasonably consistent across categories related to territorial status of the animals involved (Table 5). It is curious, however, that among animals for which territorial status was unknown. 7596 had consumed baits.

Table 5. Percent coyotes "marked" by baits.

| Baiting Technique | Territorial Status Tarr. | Traps. | Unknown | Total |
|---|---|---|---|---|
| (Sample size) | (1u) | t19) | t12) | (u5) |
| Near hater | 14 | 11 | 0 | 9 |
| At draw stations | 29 | 5 | 42 | 22 |
| Along roadsides | 36 | 21 | 50 | 33 |
| OVERALL* | 50 | 32 | 75 | 49 |

coyotes double-marked as a result of eating baits from 2 or more placement strategies are counted only once.

As yet, the data have not beat corrected for differential bait exposure nor have adjustments been incorporated with respect to animals that were known to be off the study area during the baiting period. The latter should not be important for comparison of relative bait-take by coyotes among the 3 placement schemes.

## Discussion

Until we have more thoroughly analyzed and assessed the data presented here, we are reluctant to delve into protracted interpretations. In the interest of generating ideas and discussion, some aspects are worth mentioning

The coyote density estimates provided here probably represent the best documented attempts at estimating. coyote populations is the brushlands of South Texas. Even the lower estimate of 1.4 coyotes per km= is spring is higher than other published estimates. Andeit (1985) suggested spring coyote densities of 0.8 and 0.9/km= on the Welder Wildlife Refuge on the Texas coastal plain and Knowlton (1972) speculated that fall densities is areas of South Texas might approach 1.5-23 coyotes/km=. Normal attrition might reasonably be expected to reduce the latter to spring densities of about 0.75-L2/km . Estimates from other areas of North America are invariably lower. The South Texas brushiands consistently harbor some of the highest coyote densities known.

The logical integration of information provided by Witham (1977), Czmenzind (1978). Bowen (1982). Aadelt (1985), and others with that provided here suggests that coyotes are territorial, with social groups of 2-7 defending any given territory. Such territories occupy most of the habitable environment. Transient coyotes spend most of their time in the interstices between, and around the periphery of, established territories. It appears that about half of the yearling and 2-year-old coyotes belong to a social group and the other half are transients, presumably seeking vacant territories or social groups willing to tolerate their presence. A majority of older coyotes apparently belong to territorial social groups. It appears chat is a relatively stable environment, territories have an integrity of their own and a longevity that exceeds that of the individuals actively utilizing and defending them.

Belonging to a territorial social group has important implications insofar as reproductive success is concerned. Only about 4096 of the transient females identified in this study ovulated and none whelped. On the other hand, 8696 of the territorial females ovulated and half of them apparently whelped. In this study, the proportion of territorial females that whelped was lower than we had anticipated from preceding estimates (Windberg 1985). Potential factors involved in this low rate include: (1) reduced success among subordinate females within social groups; and (2) the study coincided with a decline in abundance of rodents and lagomorphs during a prolonged drought f Windberg 1985). Although social dominance and territorial status apparently are not requisites for initiating the. reproductive process, they may be strong arbiters in determining which animals whelp. Observations here suggest that part of the reproductive strategy of coyotes is for most females to initiate reproductive activity even though the probability of success may be uncertain. If circumstances become more favorable (ie. a territory becomes available), recruitment continues without substantial disruption. "Release" of such suppressed reproductive potential may partially contribute to the resilience of coyotes to population reduction efforts.

Our study strongly suggests that coyotes are more vulnerable to being trapped in some pare of the environment than others. Territorial core areas comprised 5790 of the study area but only accounted for 3496 of the coyote captures. On the other hand, 3296 of the coyotes were caught in interstitial areas which comprised only 1196 of the area.

If "capture efficacy" is defined ax percent captures, percent of area the relative capture efficacy within core, edge, and interstitial areas was 0.60, 1.06 and 2.91 respectively; nearly a 5-fold difference between core and interstitial areas. At this point we have not adequately assessed the relative distribution of the trapping effort (Le. trapnights) within the respective areas which could appreciably influence interpretations.

There have bees few attempts to determine the efficacy of capturing/removing coyotes by any technique. On 1 of our areas, we estimated 86 coyotes present on 24 square miles. During 3 weeks of non-removal trapping in February, 49 coyotes were captured. We suspect that lees than half the resident coyotes were captured because less than 1596 of the scats collected were marked with isotopes and about 50'b of the animals were transients who sport only half of their time on the study area proper.

Routine aerial gunning from a helicopter was relatively ineffective is reducing the number of coyotes under the conditions dictated by this study. Using the lower density estimate 3.6/mi= obtained via isotope marking, 158 coyotes would have bees on the 2 study areas in March. Normal attrition at that time of year (Wiadberg et al. 1985) presumably would have reduced that number to about 140 by June. If such projections are realistic. 10.5 hours of helicopter gunning is June resulted in removal of less than 596 of the coyote population. The dense brush is full foliage and the hot temperatures may have contributed substantially to the low hunting success.

The combined effect of all 3 small bait placement strategies resulted is 5096 of the coyotes ingesting bait. efficacy of any single placement strategy was appreciably less. The proportion of coyotes that were orally marked in this study, combining all bait distribution strategies, was greater than reported in previous studies of this kind (Liahart et al. 1968. Tigaer et al. 1981). In general, a grater percentage of territorial coyotes took baits, especially those placed in the vicinity of draw stations, than did coyotes classified as transient. Also, the placement strategy in which baits were most widely dispersed within the area resulted in delivery of baits to more coyotes

None of the techniques or procedures tested here conformed to those "typically" used within the Animal Damage Control Program. The aerial gunning was done with shrub foliage present and with high ambient temperatures, which probably decreased coyote activity and response to aircraft: trapping was not conducted by experts cad trap densities (>2 per square mile) were unusually high, cad although small toxic baits are not currently used within the ADC Program, the 2-week exposure period reported here was longer than normally used on an operational basis in the past. Seemingly much productive effort could be profitably directed toward documenting the relative efficacy of various depredation management techniques and the circumstances in which each is most effective. As we become more knowledgable about each of the management tools at our disposal, it may become practical to direct activities toward specific segments of coyote populations.

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