COYOTE X DOG HYBRIDIZATION AND RED WOLF INFLUENCE IN THE WILD *CANIS* OF OKLAHOMA

By

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PREFACE

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Interspecies hybridization, particularly among mammals, is considered extremely rare (Mayr 1970, Stebbins 1959). The genus *Canis*, however, appears to be a major exception. Four species of *Canis* occur in North America: the gray or timber wolf (*Canis lupus*); the red wolf (*C. rufus*); the coyote (*C. latrans*); and the domestic dog (*C. familiaris*). Interfertility appears to be universal among the *Canis* species and while ordinarily pre-zygotic isolating mechanisms such as behavior, habitat preference, or geographical separation serve to prevent interbreeding, numerous examples of hybridization have been reported in both wild and captive animals (Gray 1954).

Young and Goldman (1944) cited numerous instances of hybridization between the gray wolf and dogs and concluded that many of the dogs kept by Plains Indians showed signs of recent wolf ancestry. Coyote x dog and coyote x red wolf crosses have been reported over much of the original range of the coyote (Bee and Hall 1951, Gier 1968, McCarley 1962, Young and Goldman 1944, Young and Jackson 1951). In addition, numerous coyote x dog hybrids have been produced in captivity with little or no reduction in fertility among the hybrids (Gier 1968, Hall 1943, Kennelly and Roberts 1969, Mengel 1971, Silver and Silver 1969). Kolenosky (1971) has reported the successful breeding of a female gray wolf to a coyote in captivity and stated that animals appearing to be gray wolf x coyote hybrids occur in the wild in Ontario.

Following habitat disturbances brought about by lumbering and clearing for farming, together with the decline of the larger wolves, the coyote has dramatically expanded its range. Many *Canis* specimens taken from areas recently invaded by coyotes have been extremely difficult to identify and suggest the possibility of large scale hybridization. McCarley (1962) was the first to hypothesize massive hybridization between the coyote and red wolf based on a study of skull morphology of animals taken in eastern Texas and southeastern Oklahoma. McCarley concluded that the red wolf was extinct over most of its former range and had been replaced in eastern Oklahoma and Texas by a hybrid population. These conclusions were affirmed in a later study by Paradiso (1968).

A similar situation exists in the New England states where coyote-like canids first appeared in the 1930's. Since then an increasing number of hard-to-identify canids have been taken (Richens and Hugie 1974, Silver and Silver 1969). Using multivariate analysis on a series of skull measurements, Lawrence and Bossert (1969) concluded that the canids of New England are predominantly coyote with some dog and wolf ancestry. This population has apparently established itself as the predominant group of predators in New England (B. Lawrence personal communication 1975).

Gipson et al. (1974) also used multivariate analysis in a comprehensive study of *Canis* in Arkansas. Red wolves were the dominant canid in Arkansas until about 1940 when habitat modification and heavy trapping caused a sharp decline in the wolf population. The coyote, restricted to the extreme western and northwestern counties during the early 1900's, expanded its range to occupy the entire state and was abundant in most areas by 1960 (Gipson et al. 1974). Skulls from 284 wild canids collected from 1968 to 1971 were examined and identified as follows: coyote, 208; coyote x dog intermediate, 38; dog, eight; red wolf, two; coyote x red wolf intermediate, 27; dog x red wolf intermediate, one. These results showed more than 13 percent of the Arkansas canids to be coyote x dog hybrids with more than one-fourth of the animals being something other than pure coyote (Gipson et al. 1974).

Numerous reports from field personnel of the Division of Wildlife Services (U.S. Fish and Wildlife Service), stockmen, and private trappers indicate a similar situation in Oklahoma (B. Peterson personal communication 1975). Nowak (1973), however, examined 886 *Canis* skulls collected in the south-central and southeastern states and considered only seven (0.8 percent) to show evidence of dog hybridization, none from Oklahoma or Arkansas.

Further disagreement arises over the possibility of non-synchronous breeding seasons in coyotes and coyote x dog hybrids. Coyotes mate in late winter from late January to March with a mid-February peak (Young and Jackson 1951). Gier (1968) and Mengel (1971) each produced coyote x dog hybrids in captivity and reported late fall (October-December) breeding seasons for male and female hybrids which, it was argued, would prevent the introgression of dog genes into the coyote gene pool. Silver and Silver (1969) reported similar findings for hybrids produced from matings of dogs with wild-caught New England canids. However, in another study of captive raised hybrids, Kennelly and Roberts (1969) stated that while female hybrids had fall breeding seasons "...hybrid males are not seasonal, but follow the pattern of the dog and produce sperm throughout the year." Gipson (1972) reported male Arkansas coyotes capable of breeding in November as well as male coyote x dog hybrids which were probably capable of mating in January. Dunbar (1973) found mature spermatozoa present in the testes and epididymides of Oklahoma coyotes in November and considered most adults capable of breeding by December. These results indicate that male coyotes can breed with female hybrids in November and December and male hybrids can breed with female coyotes in January. Furthermore, the hybrids may breed among themselves. Clearly, many questions concerning coyote x dog hybridization remain unanswered.

Debate over the validity of the red wolf as a true species has occurred since the accumulation of evidence indicating massive hybridization between the coyote and red wolf. Pimlott and Joslin (1968) reviewed the taxonomic history of Canis rufus. Lawrence and Bossert (1967) concluded that red wolves "...are no more than sub-specifically distinct from Canis lupus." Paradiso (1968) stated that massive hybridization between the red wolf and coyote in eastern Texas implied only subspecific differentiation between the coyote and red wolf. Mech (1970) considered these differing opinions and hypothesized that the red wolf, which formerly ranged from eastern Texas and Oklahoma to the south Atlantic coast, is no more than a population of coyote x gray wolf hybrids. Based on his study of skull morphology, Nowak (1973) concluded that Canis rufus is sufficiently distinct from coyotes and gray wolves to warrant its status as a valid species. Atkins and Dillon (1971) examined cerebellum morphology within the genus and stated that the red wolf is a distinct species more closely related to C. lupus than to coyotes. Shaw (1975) used ecological and behavioral criteria to conclude that the red wolf is distinct from both coyotes and gray wolves and should retain its specific status.

Oklahoma is possibly the area most crucial to the understanding of *Canis* hybridization. Coyotes and gray wolves occurred together on the prairies of central and western Oklahoma for perhaps thousands of years while red wolves inhabited the forests of eastern Oklahoma. Rural dogs are prevalent in all parts of the state and are often observed in association with coyotes or coyote-like canids (C. Dodd personal communication 1974).

Both McCarley (1962) and Nowak (1973) surmised that massive hybridization between red wolves and coyotes first occurred shortly after 1900 in central Texas and Oklahoma. This hybrid population, termed "hybrid swarm" by Nowak, then began to spread eastward as human activities reduced red wolf populations and perhaps created habitat more suitable to these coyote-like hybrids. Nowak (1973) further stated, however, that by 1930 the wild *Canis* population in central Texas was almost completely extirpated due to extremely heavy livestock and predator control operations. Records also indicate that in a large area centered in northeast Texas wild canids were very rare or absent after 1900 (Nowak 1973). This leaves the Oklahoma population as a probable source of animals to move into eastern Oklahoma, northeast Texas, and western Arkansas.

The sizes reported for Oklahoma coyotes in recent years may be the result of hybridization. Young and Jackson (1951) reported a size range of 8.2 to 13.6 kg for coyotes in general. Seven male coyotes taken during 1971 on the Wichita National Forest (now Wichita Mountains National Wildlife Refuge), southwestern Oklahoma, averaged 13.8 kg (Crabb 1924). A series of 93 coyotes taken in northwestern Oklahoma in 1947 averaged 11.3 kg each, while 96 coyotes taken the same year in northeastern Oklahoma averaged 12.3 kg (Young and Jackson 1951). More recent Oklahoma canids show a wider range than previously reported. B. Peterson (personal communication 1975), state supervisor of the Division of Wildlife Services, U.S. Fish and Wildlife Service, stated that the largest coyotes reported to the Denver Wildlife Research Center in recent years have come from Oklahoma. Male "coyotes" taken by state field personnel averaged about 15.5 kg with some individuals weighing up to 27.2 kg.

Coloration of Oklahoma canids may also indicate hybridization. Young and Jackson (1951) knew of only one black coyote among over one and one-half million taken by federal trappers from 1915 to 1945. However, black or very dark "coyotes" have been reported fairly regularly in recent years by Oklahoma trappers (B. Peterson personal communication 1975). Gipson (1972) examined 23 black canids taken in Arkansas from 1968 to 1971 and identified them as follows: coyotes, 15; coyote x dog intermediates, four; coyote x red wolf intermediates, three; dog, one. Gipson (1972) felt that black pelage reliably indicated past hybridization even on those animals identified as coyotes. In a study in Missouri, Elder and Hayden (1975) reported that five of seven animals identified as red wolves or red wolf x coyote hybrids were either black or had been associated with black animals.

Oklahoma has traditionally been one of the leading states in reports of livestock losses attributed to predators and cattle losses have been particularly severe (U.S. House 1973). Numerous stockmen have expressed the belief that much of the cattle depredation is attributable to feral dogs or coyote x dog hybrids because of their larger size, aggressiveness, and a greater tendency to run in packs. Denny (1974) estimated nation-wide damage to livestock by free-ranging dogs in excess of $5 million annually as well as substantial damage to wildlife populations. Mengel (1971) noted that in all instances captive coyote x dog hybrids were more aggressive than dogs. This suggests an even greater potential for damage by hybrids which would probably be better adapted for a wild existence than dogs.

Similar work conducted in Texas (McCarley 1962, Nowak 1973, Shaw 1975), Louisiana (Nowak 1973, Goertz et al. 1975), Arkansas (Gipson 1972), and Missouri (Elder and Hayden 1975) has illustrated further need for a comprehensive review of Oklahoma *Canis*. This state has a high degree of ecological diversity, varying from sub-humid forests in the southeast to semi-arid high plains in the northwest (Blair and Hubbell 1938) and along with Texas and Missouri is the only state which historically contained extensive ranges of the gray wolf, red wolf, and coyote (Hall and Kelson 1959).

This study had the following objectives:

1. To identify to species or hybrid group specimens of wild *Canis* within populations sampled in Oklahoma during and prior to the study period.
2. To detect temporal changes in the extent and/or distribution of hybridization in the wild *Canis* population in Oklahoma.
3. To determine if the extent of hybridization in any given area of Oklahoma is related to the amount of cattle depredation reported for that area.

CHAPTER II

METHODS AND MATERIALS

A series of 16 skull and tooth measurements was taken of each specimen. These measurements (Appendix A) are those which Lawrence and Bossert (1967) found to have the highest diagnostic value for species identification. However, only 15 measurements were included in the statistical analyses. Measurement number 16 (Appendix A) could not be measured with enough precision in all specimens to justify its inclusion in the analyses. In a similar study, Elder and Hayden (1975) found that dropping this measurement did not significantly affect the results. Measurements and other available information for each specimen were recorded on individual data sheets (Appendix B).

Most of the skulls used in this study came from animals taken in routine predator control operations by personnel of the Division of Wildlife Services of the U.S. Fish and Wildlife Service. Heads from these animals were tagged and saved until picked up and transported to the OSU campus. Tags were provided to field personnel for notation of sex, date, and location of capture. The tags were also printed with categories of size, pelage and eye color, and behavior to provide additional information on each animal (Appendix C). A small number of additional specimens were obtained from private trappers, hunters, and road kills.

Museum skulls from the various state colleges and universities were measured to compare temporal changes in *Canis* hybridization. Where sufficient skulls were available from specific areas, the data were compared to animals from the current population to detect changes in the extent of hybridization. To facilitate comparisons the state was divided into five regions (Figure 1) based primarily on the habitat types described by Duck and Fletcher (1943).

Statistical procedures employed were the following: discriminant function analysis, Mahalanobis distance, and canonical variable analysis. The discriminant function allows consideration of numerous variables simultaneously and uses data from known populations to build a set of criteria with which to distinguish between the known populations. The procedure also calculates the Mahalanobis distance (D^2) value between each target population. This statistic is essentially a measure of the overall statistical distance separating each pair of the known populations. The discriminant function then analyzes the data from each unknown, calculates the D^2 value separating it from each of the targets, and uses a set of assigned prior probabilities to determine the relative position of the unknown. The procedure then prints out the probability of the unknown belonging to each of the targets. The prior probabilities were assumed to be uniform, meaning that the probability of each unknown belonging to any one of the target populations was equal. This, of course, is not the case in the wild *Canis* but was judged to be the most consistent basis for comparison.

The canonical analysis provided a visual representation by plotting each of the target animals in relation to its canonical variables in the form of a two dimensional graph. Variables were then calculated for each of the unknowns and used to plot the unknowns relative to the target

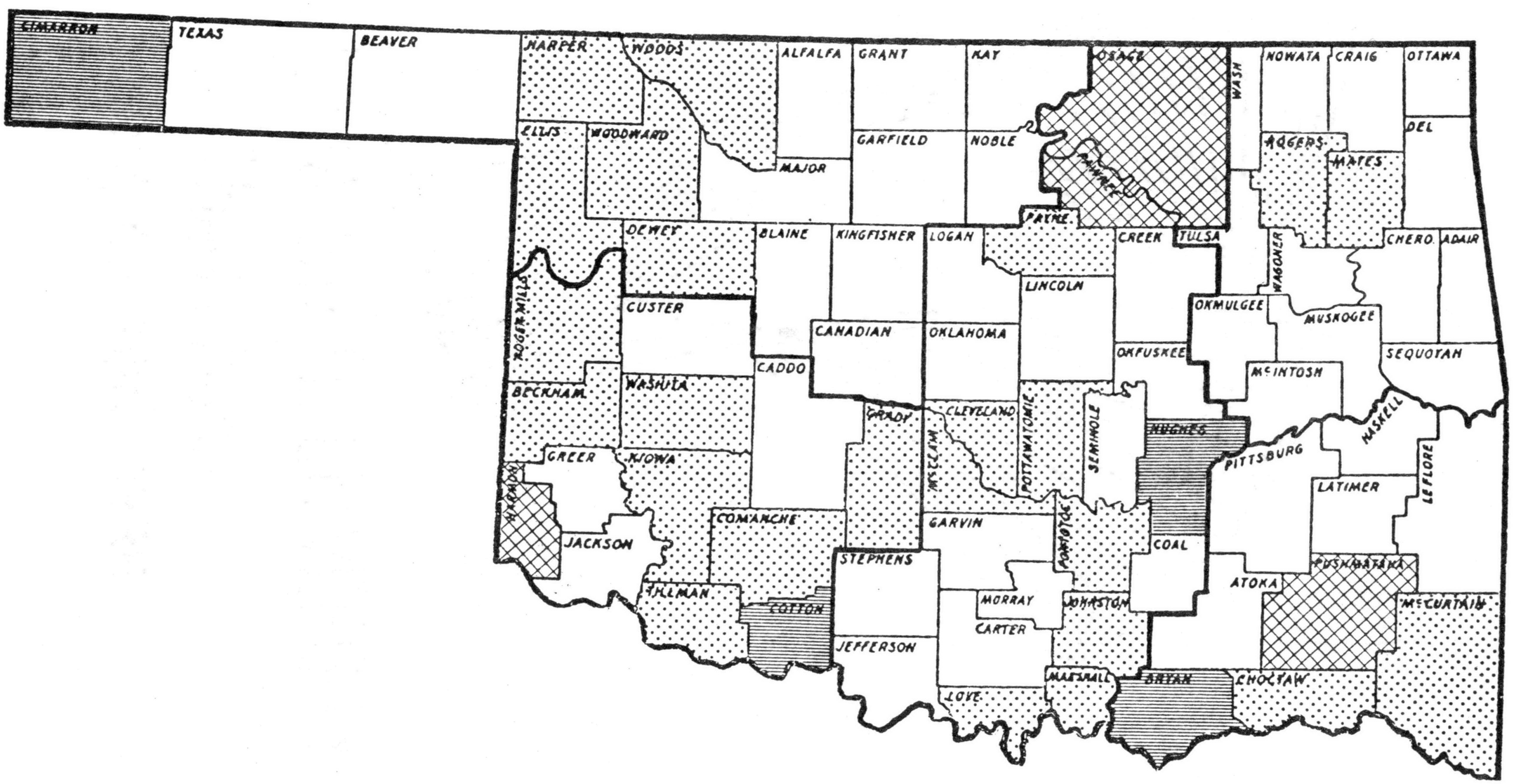

Figure 1. County Map of Oklahoma Showing Regional Boundaries (Heavy Lines) and Distribution by County of Specimens of Wild *Canis* Collected During 1975-76. Dots Indicate One to Five Canids; Cross-Hatching, Six to 10; Shading, More Than 10

animals. The results of this and the discriminant analysis, along with physical characteristics (weight, coloration) available for most of the animals, were used to identify the unknowns. These techniques have been used successfully for similar studies (Lawrence and Bossert 1967, 1969, Gipson 1972, Nowak 1973, and Elder and Hayden 1975). The methods have been described by Rao (1952) and discussed in detail by Lawrence and Bossert (1967, 1969) and Gipson (1972). In addition, Jolicoeur (1959) provided an excellent graphical description of the techniques.

Each unknown was compared to five target populations. These targets were the following: coyotes, 20 males and 20 females; red wolves, 24 males and 20 females; gray wolves, 22 males and 21 females; dogs, 15 males and nine females; and coyote x dog hybrids, five males and seven females. Coyote and red wolf target animals were selected from populations presumed to be free of influence from other Canis species. Coyotes were taken in Kansas and red wolves were collected in Arkansas prior to 1925 (Gier 1968, Gipson 1972). Gray wolves (C.l. monstrabilis and C.l. nubilus) were selected from animals collected over a large geographic area of the Great Plains. Coyote x dog hybrids were from the series reported by Mengel (1971). Stray and road-killed animals collected in Arkansas provided most of the dog target (Gipson 1972).

After each specimen was classified according to the procedures discussed above, regional and temporal comparisons were made using standard analysis of variance and F-tests to detect single character differences (e.g. total length, zygomatic width, etc.) The same comparisons were made using multivariate tests of significance to detect over-all differences which might not be apparent through single character analysis. All statistical procedures were carried out under the 1975 version of the Statistical Analysis System (SAS) on an IBM 360 computer.

Division of Wildlife Services depredation records for fiscal years 1974 and 1975 were examined. The total number of cattle (including calves) reported killed by canid predators was recorded by county and averaged for the two years. Each county average was then divided by the mean number of cattle per county for the same time period to obtain an index to cattle losses. These figures were then multiplied by 1,000 for convenience. Loss indices were also compiled on a regional basis. These indices were then used to compare cattle losses to areas corresponding with those of the various *Canis* populations.

CHAPTER III

RESULTS

Approximately 250 skulls from the current Oklahoma wild *Canis* populations were collected. Of these, 138 were suitable for analysis, the rest being eliminated due to damage, lack of data, or because they were less than 12 months of age. Figure 1 shows the statewide distribution of those useable specimens. In addition, 114 skulls from adult canids collected prior to 1975 were analyzed. These animals were for the most part collected from 1953 to 1970 and provided a limited basis for temporal comparisons.

Specimen Identification

Statistical Analyses

The probabilities of group membership assigned by the discriminant function and the visual relationships of each unknown to the target populations provided by the canonical analysis were examined along with physical characters to assign each unknown to the most appropriate category. Appendix D gives the numbers assigned to all current specimens as well as sex, weight, county in which the animal was captured, and classification.

Sixty-eight (82.9 percent) of 82 adult male unknowns collected after 1974 were classified as coyotes according to the criteria above. Twelve (14.6 percent) appeared to be intermediate between coyotes and dogs and two (2.4 percent) were coyote-red wolf intermediates. None of the animals were considered to be pure red wolves or red wolf-dog hybrids. Figure 2 shows the canonical plots of these animals in relation to the target populations. Of the animals taken prior to 1975, 52 (83.9 percent) of 62 adult males were coyotes. Seven (11.3 percent) were identified as probable coyote x dog hybrids, two (3.2 percent) were intermediate between coyotes and red wolves, and one (1.6 percent) was a feral dog (Figure 3).

From the total sample of 56 current adult females, 44 (78.6 percent) were not significantly different from the coyote target. Six (10.7 percent) of the animals were classified as coyote x dog hybrids and six (10.7 percent) appeared to be intermediate between coyotes and red wolves. None of the specimens were identified as dogs or red wolf-dog intermediates (Figure 4). Similar results were obtained for the museum (pre 1975) skulls. Thirty-nine of 52 (75.0 percent) female adults were coyotes, eight (15.4 percent) were classified as coyote-dog hybrids, and five (9.6 percent) were considered to be coyote x red wolf intermediates (Figure 5).

Pelage Coloration

Pelage color was recorded for 121 of the animals from the current population. Twelve (9.9 percent) of these canids were black or very dark and were identified by the multivariate analysis as follows: eight coyotes, two coyote x dog hybrids, and two coyote x red wolf intermediates. In addition, museum skins of two black canids and the corresponding skulls were examined. One of these animals was a coyote and the other a coyote x dog hybrid. Black animals were reported in two

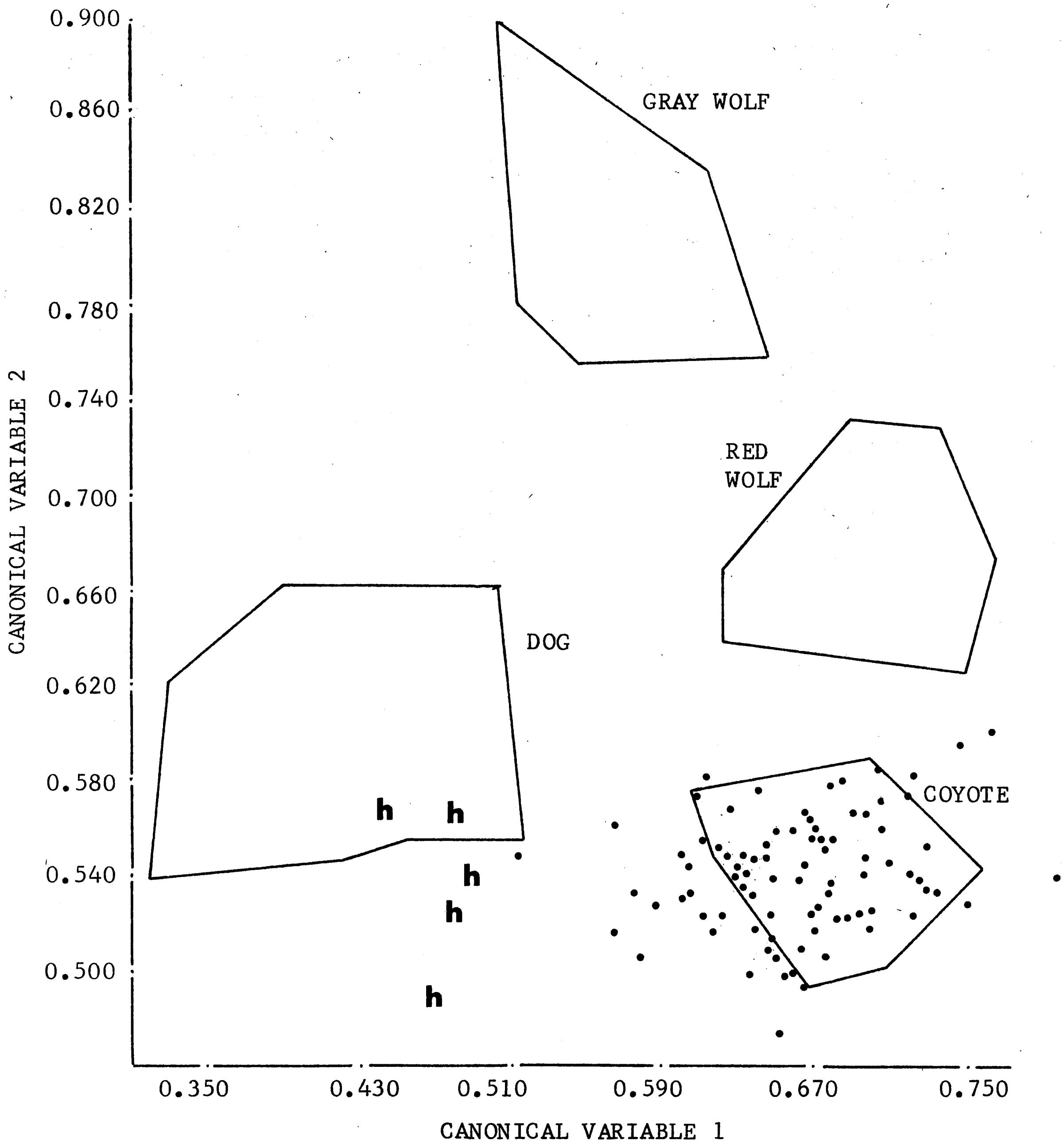

Figure 2. Canonical Plots for Current Males; "h" Denotes Known Coyote x Dog Hybrid

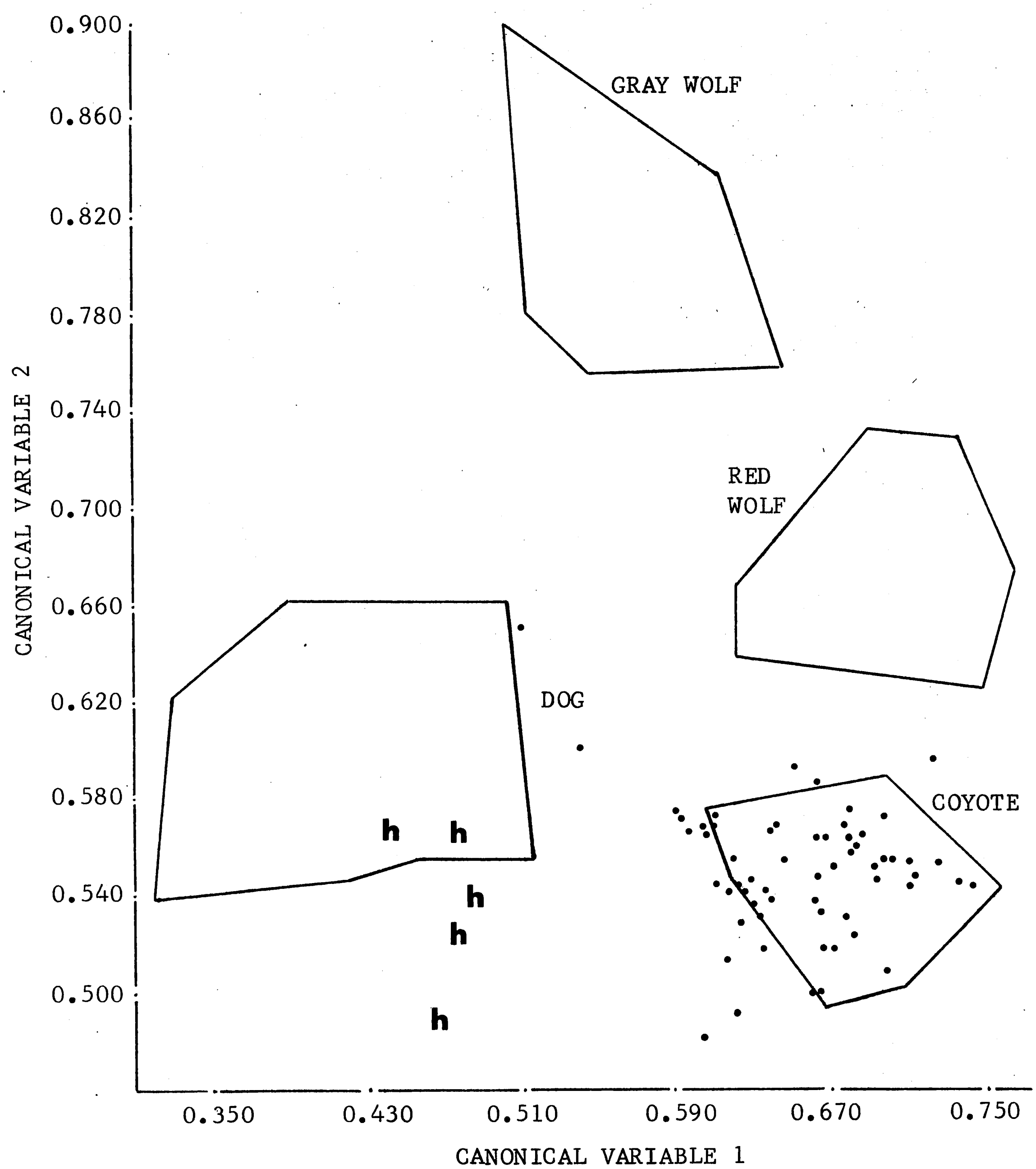

Figure 3. Canonical Plots for Museum Males; "h" Denotes Known Coyote x Dog Hybrid

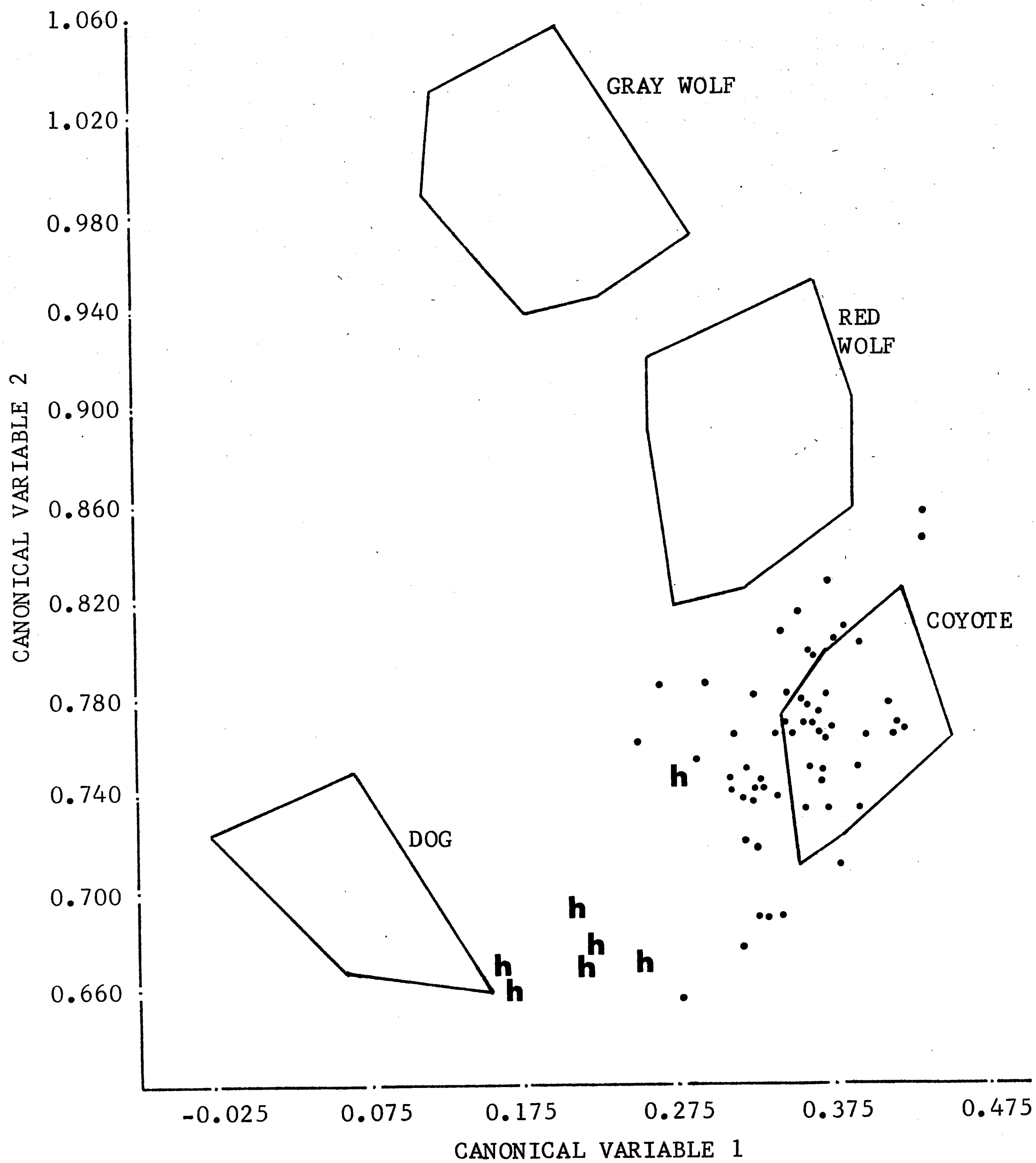

Figure 4. Canonical Plots for Current Females; "h" Denotes Known Coyote x Dog Hybrid

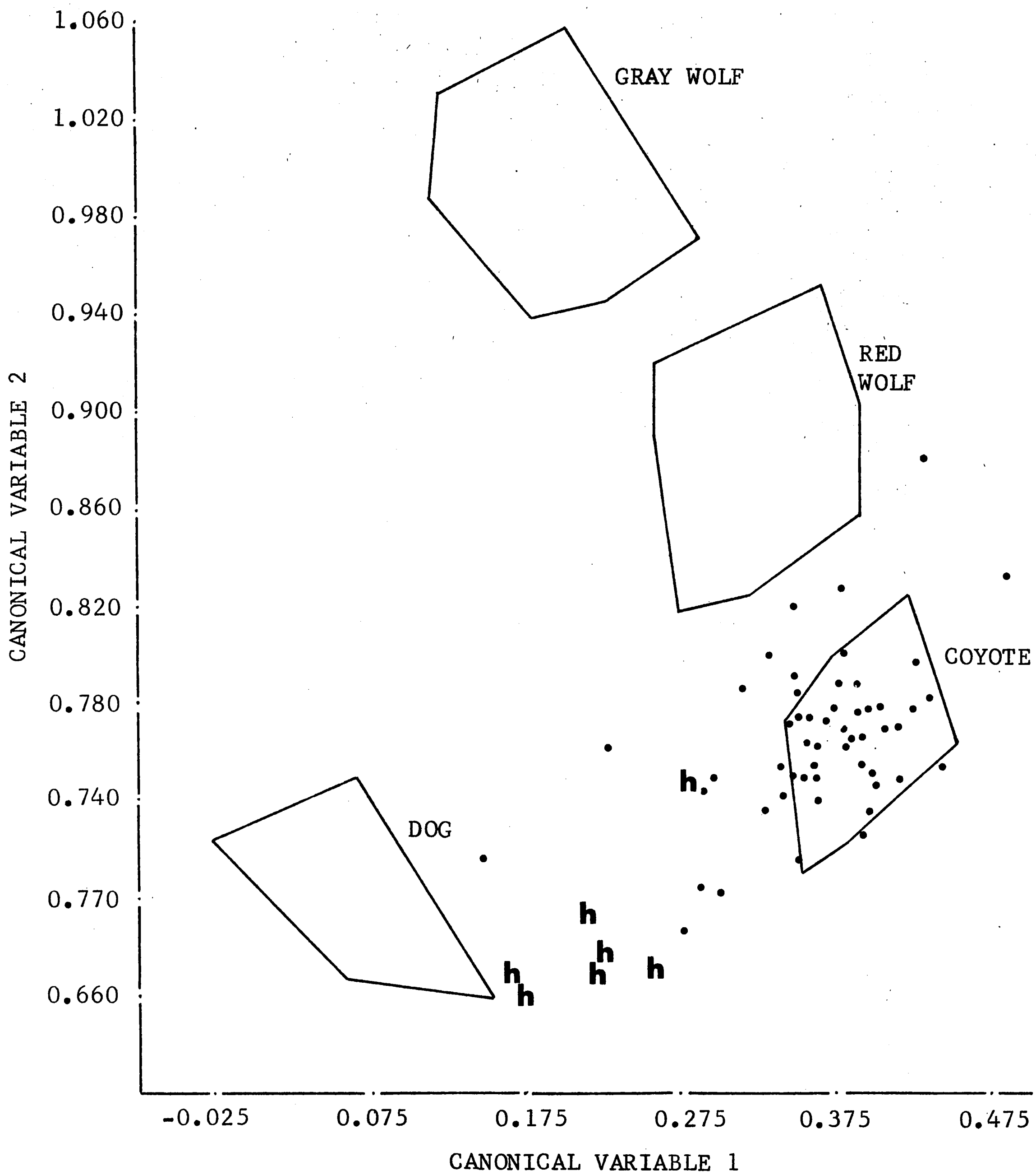

Figure 5. Canonical Plots for Museum Females; "h" Denotes Known Coyote x Dog Hybrid

newspaper articles with accompanying photographs during the study. One report was from "near Russell," Harmon County, extreme southeastern Oklahoma (J. D. Tyler personal communication 1976) and the other from the "southern part of Ottawa County," extreme northeastern Oklahoma. The latter contained a photograph of a black canid with a white pectoral spot and reported that two other similar animals had been taken in the same vicinity, at least one of which had a "bobbed tail" (Clay 1976). This and the fact that several black farm dogs lived in the same area indicates that these animals were almost certainly coyote x dog hybrids. Since Harmon County is outside the known former range of the red wolf it is likely that this animal was also a coydog. Figure 6 shows the distribution of black canids reported in this study along with the former ranges of the red wolf in Oklahoma.

Weights of Oklahoma Canis

The weights of 69 current adult males ranged from 9.1 to 20.9 kg and averaged 14.9 ± 2.3 kg. The smallest canid was a coyote x dog hybrid taken in Woodward County. The largest was a black animal statistically indistinguishable from the coyote target. Weights of eight male coyote x dog hybrids varied from 9.1 to 16.3 kg with an average of 12.4 kg, 2.5 kg less than the average for all current males. The only current male coyote-red wolf intermediate of known weight was a 14.5 kg animal from Cotton County. Eighteen museum males averaged 15.2 kg with a range of 10.9 to 31.8 kg. The largest animal is interesting in that it was statistically classified a dog even though superficially the animal was identical to a coyote except for its size (D. Snay personal communication 1976). Deleting this outsized individual results in an

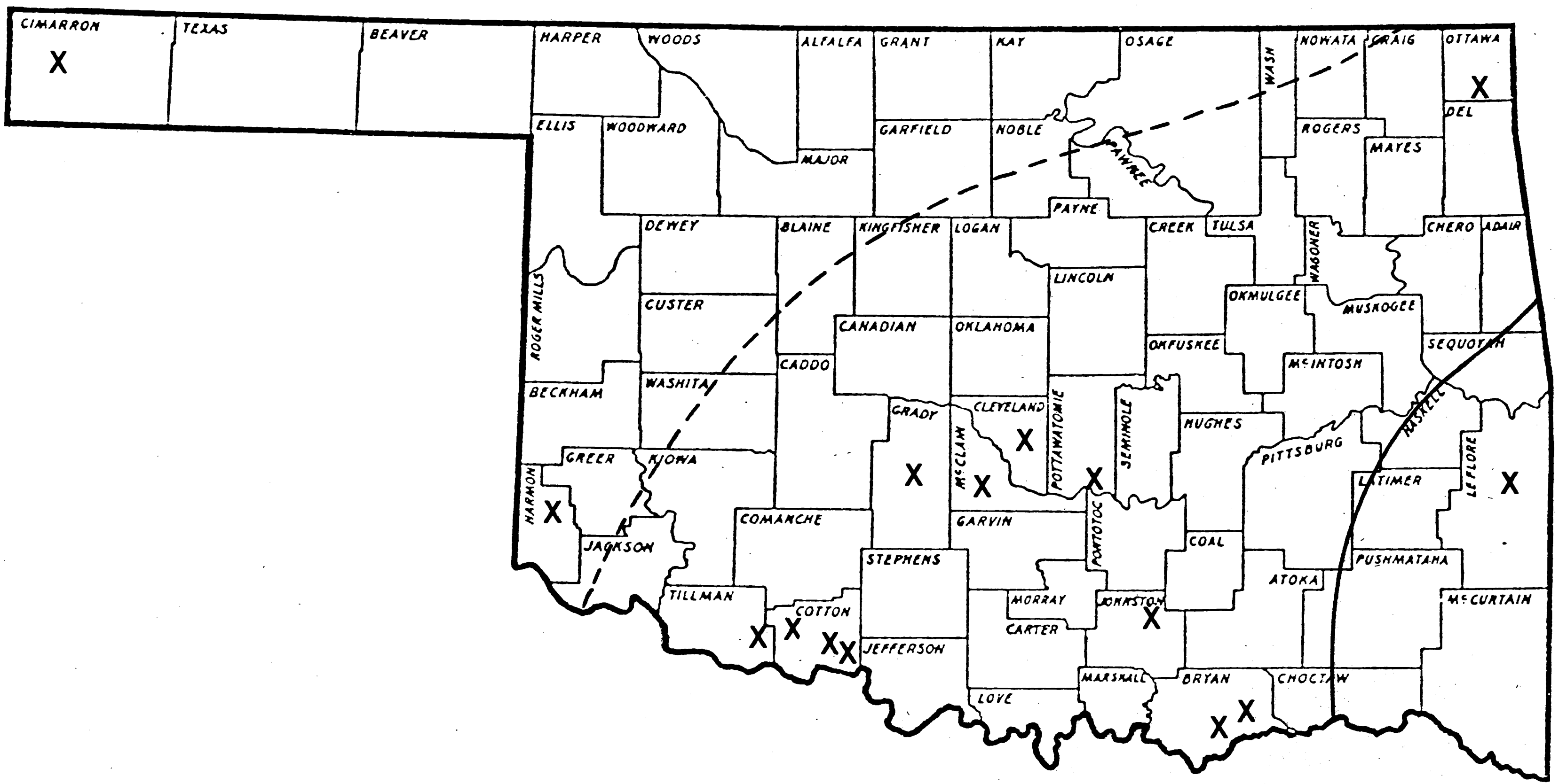

Figure 6. County Map of Oklahoma Showing Distribution of Black Canids (x) Examined or Reported. Dashed Line Is Western Extreme of Range of Red Wolf; Solid Line Is Presumed Boundary Between Subspecies Canis rufus rufus and C.r. gregoryi (Hall and Kelson 1959)

average weight of 14.2 kg. Two coyote x dog hybrids from this series weighed 11.3 and 12.7 kg.

Weights of 51 current females averaged 12.0 ± 2.3 kg and ranged from 8.2 to 18.1 kg. The 8.2 kg female was a coyote x dog hybrid from Woodward County, the same area from which the smallest male, also a coy-dog, was taken. The 18.1 kg female was a coyote-red wolf hybrid taken in Osage County. Six coyote x dog hybrids from this series averaged 10.3 kg while the same number of coyote-red wolf intermediates had a mean weight of 16.0 kg. Twenty-two museum females of known weight averaged 12.3 kg, the largest of which was a 16.3 kg coyote x red wolf hybrid from Hughes County.

Data on eye color and trap behavior was often lacking and when present was found to be too inconsistent between the individual trappers completing the data tags. For example, one individual might consider the normal eye color of coyotes to be brown and record all normal specimens as having brown eyes while another might consider the same color yellow or yellow-brown. Trap behavior, while somewhat less subjective, was often inapplicable or not recorded. For these reasons, these data were not useable in specimen identification and are not reported.

Regional Comparisons

Regional comparisons were accomplished by obtaining the D^2 values separating the pooled regional samples from each other and the dog, coyote, and red wolf targets (Table I). Since only two animals were obtained from the northeast region (Figure 1), this area was by necessity omitted from all comparisons. The results show the central region population to be the one which most nearly approaches the coyote target,

TABLE I

MAHALANOBIS DISTANCE (D^2) VALUES SEPARATING THE *CANIS* POPULATIONS OF EACH OKLAHOMA REGION FROM EACH OTHER AND THREE OF THE TARGET POPULATIONS

	Coyote Target	Red Wolf Target	Dog Target	Northwest	Southwest	Central
Red Wolf Target	30.93					
Dog Target	65.91	66.43				
North-West	5.43	31.21	62.34			
South-West	5.49	29.73	61.96	3.30		
Central	5.03	24.92	55.97	2.50	2.16	
South-East	9.39	25.50	57.65	4.75	3.79	2.42

followed by the northwest and southwest regions which are about equally separated from the Kansas coyotes. The statistical distance separating the southeastern Oklahoma canids from the coyote target is almost twice that of the other three populations.

Comparison of distances separating Oklahoma _Canis_ and the red wolf target show the central and southeast populations to be the most closely related followed by the southwest and northwest samples, respectively. It should be noted that these are multidimensional distances so no contradiction is involved with the central region being nearest both the coyote and red wolf targets. In addition, the central region sample is primarily composed of two separate groups; a fairly large sample from the extreme north-central counties which show only very limited red wolf influence and thus closely approaches the coyote target, and a sizeable sample from the south-central counties which exhibit a much larger amount of red wolf influence. Better comparisons would probably have been obtained had the central region been divided into northern and southern sections.

Considering the magnitude of the distances involved, all Oklahoma subpopulations are roughly equally removed from the dog target. Each is also somewhat closer to the dog target than is the coyote target, indicating a small and relatively constant amount of dog influence in the wild Oklahoma _Canis_ population.

Since all regions included samples from relatively widely separated areas, comparisons were also made of animals from single counties or adjacent groups of counties. Greatest length of skull and weight were used to determine overall differences in size (Table II). Samples from the southeastern and south-central counties tend to be larger, as would

TABLE II

AVERAGES AND RANGES OF VARIATION FOR SKULL LENGTH AND WEIGHT OF CURRENT CANIDS FROM SELECTED AREAS OF OKLAHOMA

County(ies)		Skull Length (mm) Male	Skull Length (mm) Female	Weight (kg) Male	Weight (kg) Female
Payne, Pawnee, Osage	$\bar{x} \pm s$	194.7 ± 6.0 (8)[1]	190.4 ± 7.9 (9)	12.2 ± 1.3 (6)	12.0 ± 2.8 (9)
	Range	188.5 - 207.0	177.5 - 203.5	10.4 - 13.6	8.6 - 18.1
Cimarron	$\bar{x} \pm s$	195.8 ± 4.8 (6)	184.3 ± 4.1 (7)	14.0 ± 0.9(4)	11.2 ± 1.4 (7)
	Range	188.0 - 201.5	177.5 - 189.0	12.7 - 14.5	9.5 - 12.7
Harper, Woods, Ellis, Woodward, Dewey	$\bar{x} \pm s$	197.3 ± 6.7 (6)	188.9 ± 9.9 (4)	13.7 ± 3.9 (6)	11.5 ± 2.7 (4)
	Range	189.0 - 205.0	179.0 - 201.0	9.1 - 20.0	8.2 - 13.6
Grady, McClain, Cleveland	$\bar{x} \pm s$	198.5 ± 5.7 (3)	190.3 ± 5.8 (4)	14.5 ± 0.0 (3)	11.9 ± (4)
	Range	192.0 - 202.5	183.0 - 196.0	14.5 - 14.5	10.9 - 13.2

[1] Sample Size in Parentheses

TABLE II (Continued)

County(ies)		Skull Length (mm) Male	Skull Length (mm) Female	Weight (kg) Male	Weight (kg) Female
Roger Mills, Beckham, Washita, Harmon, Kiowa	$\bar{x} \pm s$	199.2 ± 5.6 (11)	184.3 ± 6.6 (4)	14.7 ± 2.2 (11)	11.7 ± 1.0 (4)
	Range	190.0 - 209.0	177.0 - 192.5	11.3 - 18.6	10.4 - 12.7
Hughes, Pontotoc	$\bar{x} \pm s$	200.6 ± 9.3 (14)	192.9 ± 7.6 (8)	15.7 ± 2.5 (7)	14.9 ± 1.6 (5)
	Range	179.0 - 212.5	185.0 - 204.0	10.9 - 19.1	14.1 - 17.7
Bryan, Choctaw, Pushmataha, McCurtain	$\bar{x} \pm s$	201.4 ± 7.6 (17)	185.0 ± 14.1 (13)	15.9 ± 2.0 (13)	11.5 ± 2.9(13)
	Range	186.5 - 215.5	161.5 - 212.5	11.3 - 18.1	8.2 - 17.2
Tillman, Cotton	$\bar{x} \pm s$	203.5 ± 6.0 (11)	192.8 ± 1.5 (3)	15.4 ± 0.9 (11)	11.9 ± 2.2 (3)
	Range	188.0 - 210.0	191.5 - 194.5	14.1 - 16.8	10.4 - 14.5
Love, Marshall	$\bar{x} \pm s$	203.7 ± 0.6 (3)	194.8 ± 3.9 (2)	14.7 ± 0.7 (3)	12.5 ± 0.3 (2)
	Range	203.0 - 204.0	192.0 - 197.5	14.1 - 15.4	12.2 - 12.7

be expected, than those from other areas. The largest animals on the average appear to occur in counties adjacent to the Red River. Smallest canids were taken in the north-central and northwestern sections of Oklahoma.

Temporal Comparisons

Sufficient museum skulls, with which to make meaningful temporal comparisons, were present from only three areas of the state. These were the Payne, Pawnee, Osage counties area; the Cleveland, McClain, Grady counties area; and the south-east region. Since sex was not known for many of the older skulls from the southeast, it was necessary to pool the sexes for this area while sexes were tested separately for the other two areas. In each case significance tests were run comparing the means of each of the 15 measurements from the older with the more recent skulls. In addition, two separate multivariate tests were used to test the null hypothesis of no difference between the museum and current samples (Table III). In all cases the probabilities associated with each of the multivariate tests was exactly equal.

A series of nine males and 11 females taken from Payne, Pawnee, and Osage counties between 1953 and 1960 was compared to 12 males and 12 females from the same area collected during 1975 to 1976. For both sexes there was no significant difference between the older and current animals. There was also no difference detected for either sex between a series of 32 males and 27 females collected during 1969 and 1970 from Cleveland, McClain, and Grady counties and seven males and six females taken during the winter of 1975-76 although the females closely approached the 0.05 significance level.

TABLE III

SINGLE CHARACTER AND MULTIVARIATE PROBABILITIES OF A SIGNIFICANT DIFFERENCE AT THE 0.05 LEVEL* BETWEEN MUSEUM AND CURRENT SAMPLES

	Cleveland, McClain, Grady		Payne, Pawnee, Osage		Southeast
	M	F	M	F	Pooled
Measurement	Probability > F		Probability > F		Probability > F
1	0.4498	0.0300*	0.5319	0.8259	0.1429
2	0.5394	0.9751	0.4008	0.7568	0.5938
3	0.0384*	0.0374*	0.8505	0.7712	0.8172
4	0.6826	0.0582	0.1154	0.9923	0.4968
5	0.3374	0.6908	0.3620	0.5584	0.8016
6	0.3125	0.0087*	0.3787	0.5771	0.2721
7	0.2260	0.0007*	0.2040	0.5943	0.1202
8	0.2967	0.4746	0.3416	0.8567	0.1054
9	0.0603	0.8797	0.9114	0.4593	0.0103*
10	0.4711	0.3167	0.4377	0.2456	0.0393*
11	0.4155	0.2166	0.4794	0.8620	0.7877
12	0.0422*	0.6188	0.7367	0.1523	0.0334*
13	0.3265	0.0604	0.6008	0.6636	0.8092
14	0.2584	0.4518	0.2829	0.2911	0.2468
15	0.3443	0.1615	0.3962	0.5680	0.0652
Multivariate Tests	0.2799	0.0534	0.1328	0.6340	0.0143*

Different results were obtained for the southeast sub-population. A pooled series of 16 animals taken mostly from 1960 to 1970 was significantly different from 38 skulls collected during 1975 and 1976 with almost all of the measurements showing a distinct decrease in size.

Cattle Depredation

Table IV gives cattle loss indices for those counties for which one was calculated. Only about half of the Oklahoma counties contribute to cooperative predator control and they receive priority in response to depredation complaints or prophylactic control. Therefore, virtually all canids comprising the sample and most loss reports were from paying counties. For these reasons, only paying counties were included in the depredation comparisons. Since specimens from the northern part of the central region were on the average much smaller than those from the southern part, the central region was divided into north and south sections for these comparisons. All central region counties south of and including Cleveland, Pottawatomie, Seminole, and Hughes counties (Figure 1) were considered the south-central section. The remaining central counties comprised the north-central section.

Hughes County in the south-central region had easily the highest loss index for the reported counties. This county also had among the largest coyotes and the greatest amount of red wolf influence in the state (Table II) (Figure 7). Four of the top ten counties in cattle losses came from the south-central region which also had the highest average depredation rate of the five regions (Tables IV, V).

The northwest and north-central regions showed the lowest depredation rates and also had the smallest coyotes in terms of skull length

TABLE IV

CATTLE LOSS INDICES FOR ALL OKLAHOMA COUNTIES CONTRIBUTING TO THE COOPERATIVE PREDATOR CONTROL PROGRAM AND REPORTING CATTLE LOSSES (AVERAGE LOSS/AVERAGE CATTLE PER COUNTY) X 1,000

County	Loss Index	County	Loss Index
Hughes	.4782	Pottawatomie	.1486
Oklahoma	.4145	Greer	.1480
McClain	.3545	LeFlore	.1462
Stephens	.3214	Harper	.1455
Beckham	.2501	Dewey	.1369
Grady	.2419	Pushmataha	.1239
Pontotoc	.2416	Osage	.1111
Bryan	.2395	Woods	.0741
Creek	.2309	Grant	.0623
Pawnee	.2171	Seminole	.0585
Noble	.2145	Logan	.0523
Garvin	.2121	Lincoln	.0498
Roger Mills	.1853	Custer	.0353
Okfuskee	.1790	Cleveland	.0288
Caddo	.1587	Payne	.0274
Woodward	.1586	Garfield	.0215
Love	.1545		

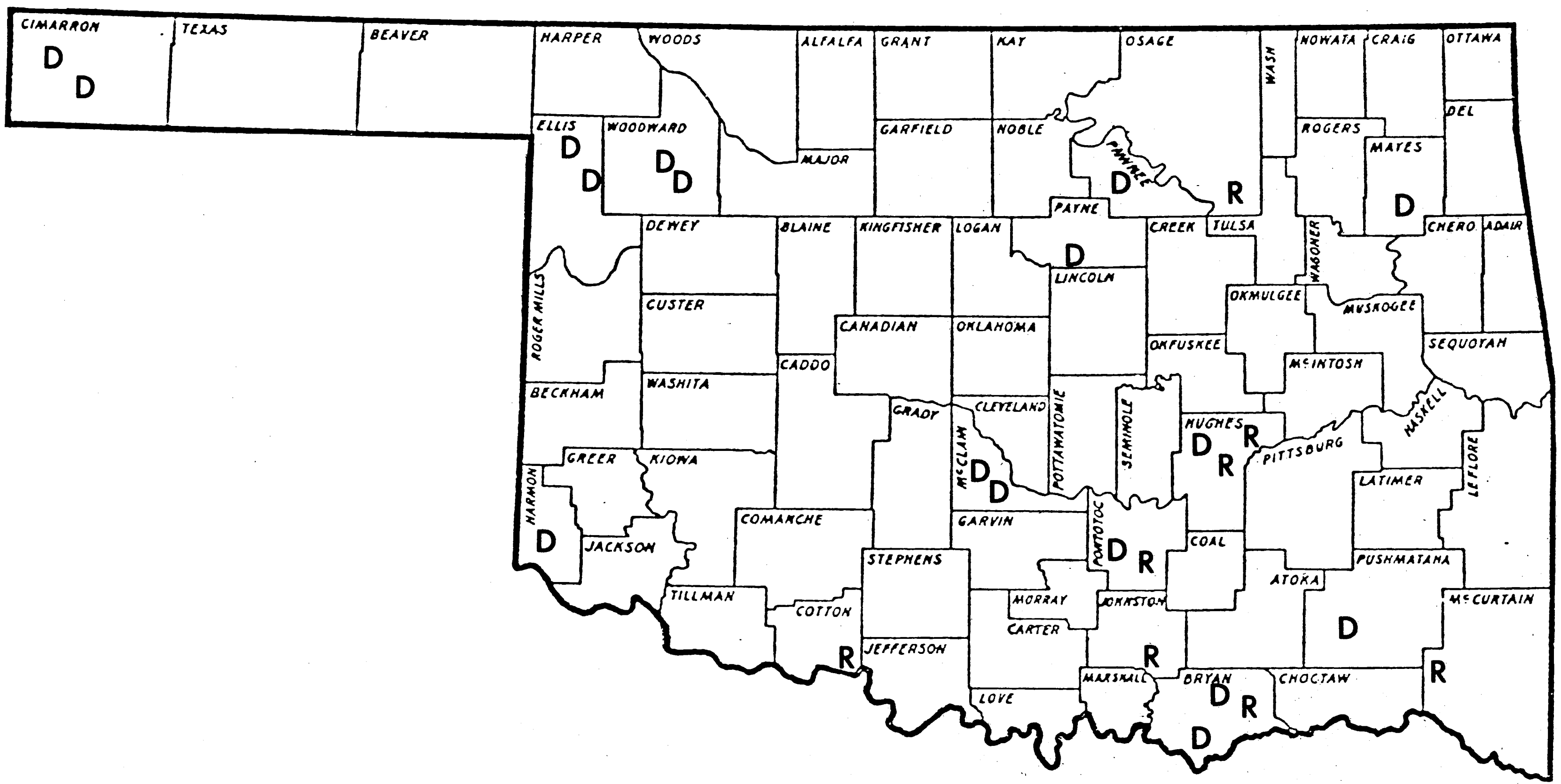

Figure 7. Distribution of Coyote-Dog Intermediates (D) and Coyote-Red Wolf Intermediates (R) Collected from the Current Oklahoma Population

TABLE V

AVERAGE CATTLE LOSS INDEX FOR EACH REGION AND THE NUMBER OF COYOTE X DOG AND COYOTE X RED WOLF HYBRIDS IDENTIFIED FROM EACH

Region	Counties Reporting Losses	Coyote x Dog	Coyote x Red Wolf	Average Loss Index
Northwest	7	6	0	.1162
North-Central	8	2	1	.1603
Southwest	6	1	1	.1699
Southeast	3	3	2	.1699
South-Central	9	4	4	.2219

and weight. The southwest and southeast regional average loss rate was exactly equal, but the latter sample was based on depredation reports from only three counties. Apparently, red wolf influence in the south-central and southeastern counties, resulting in larger animals, correlates well with increased cattle losses.

Coyote-dog intermediates were collected from all regions of the state and appear to occur randomly (Figure 7). Although numerous reports from trappers and stockmen indicate dogs and coyote x dog hybrids at times cause severe losses to cattle and other domestic animals, the scattered distribution and lack of significant local concentrations make an analysis of the effects of these animals on cattle depredation impossible.

CHAPTER IV

DISCUSSION

Questions concerning the extent and distribution of hybridization among the wild *Canis*, particularly in the south-central United States, has prompted a number of investigations. Studies by McCarley (1962), Gipson (1972), Nowak (1973) and others give evidence that the coyote has expanded throughout much of the former range of the red wolf with subsequent coyote populations being modified by the introgression of red wolf genes. Opinions concerning coyote x dog hybridization have varied, both as to its occurrence and the ability of coyotes to absorb genetic material of dogs into their own gene pool (Lawrence and Bossert 1969, Mengel 1971, Gipson 1972, Nowak 1973).

Current Status of Oklahoma *Canis*

Data presented in this thesis indicate Oklahoma *Canis* to be essentially coyote-like in character. More than 80 percent of 252 canids examined during this study were statistically indistinguishable from coyotes (Figures 2, 3, 4, 5). Animals exhibiting red wolf influence (but not necessarily enough to classify as intermediates) occur sporadically in the eastern half of the state, but appear to be of significance only in south-central and southeastern Oklahoma (Figure 7). Coyote x dog hybrids were identified from specific areas approximately in proportion to the sample size from that area and appear to occur randomly throughout the areas sampled (Figure 7).

Size of Oklahoma specimens (as reflected by weight and skull length) tends to increase in west-east and north-south gradients. The smallest animals occurred in the northwestern and north-central counties while the largest canids most often were taken from areas adjacent to the Red River and southeast. Adult males from the south-central and southeastern counties averaged approximately 6 to 7 mm more in skull length and 1.8 kg more in weight than their northwestern and north-central counterparts. Slightly smaller differences were noted for females (Table II). The more pronounced north-south cline is probably attributable mostly to red wolf influence in the south and southeast while the west-east gradient is partially accounted for by subspecific variation between *Canis latrans latrans* in the western third of the state and *C.l. frustror* in the east (Hall and Kelson 1959).

Black coloration in Oklahoma canids occurred throughout the state but is much more prevalent in the southern half (Figure 6). As well as being a fairly common color phase in coyote x dog hybrids and coyote-red wolf intermediates, it appears that genes for black pelage have now become an integral part of the coyote gene pool, probably through introgression of the red wolf.

Red Wolf Influence on Oklahoma *Canis*

The degree to which past coyote x red wolf hybridization has modified the current Oklahoma *Canis* population is considerably less than that recently reported in adjacent states (Paradiso and Nowak 1971, Gipson 1972). The percentage of Oklahoma canids exhibiting red wolf characteristics is well below that reported for Arkansas. Gipson (1972) found that 34 of 272 (12.5 percent) Arkansas canids showed wolf ancestry compared to only 5.8 percent of the current Oklahoma sample. Three of the Arkansas canids were indistinguishable from true red wolves while none of the skulls examined in this study could be so classified. Only one animal, a black 17.2 kg female from Bryan County, was considered to be possibly a recent hybrid and since no other specimens from a rather large sample for this county showed similar characteristics, it is probable that this animal represented a random recombination of genes from remote red wolf ancestry.

The Oklahoma population also appears to be farther removed from significant influx of red wolf genes than animals recently reported from east Texas and Louisiana. Paradiso (1968) reported averages of approximately 209 mm for greatest length and 105 mm for zygomatic width for skulls of adult males collected after 1960 in east Texas. Goertz et al. (1975) reported a similar size range for recent Louisiana canids. Skulls from adult males taken in south-central and southeastern Oklahoma during this study averaged only 201.8 mm and 102.4 mm, respectively. Maximum and minimum measurements of the Texas and Louisiana canids were also considerably greater than those of the Oklahoma animals (Figures 8, 9).

It is interesting to note that the largest Oklahoma coyotes (in terms of length of skull) were collected in Tillman, Cotton, Love and Marshall counties. These counties lie in a line along the Red River just to the north of an area of Texas from which large numbers of coyote-red wolf intermediates were collected in the 1930's and 1940's. These Oklahoma canids, though large, show few other red wolf characteristics and may have resulted from an influx of Texas hybrids across the Red River during that period. The current Oklahoma canids collected in

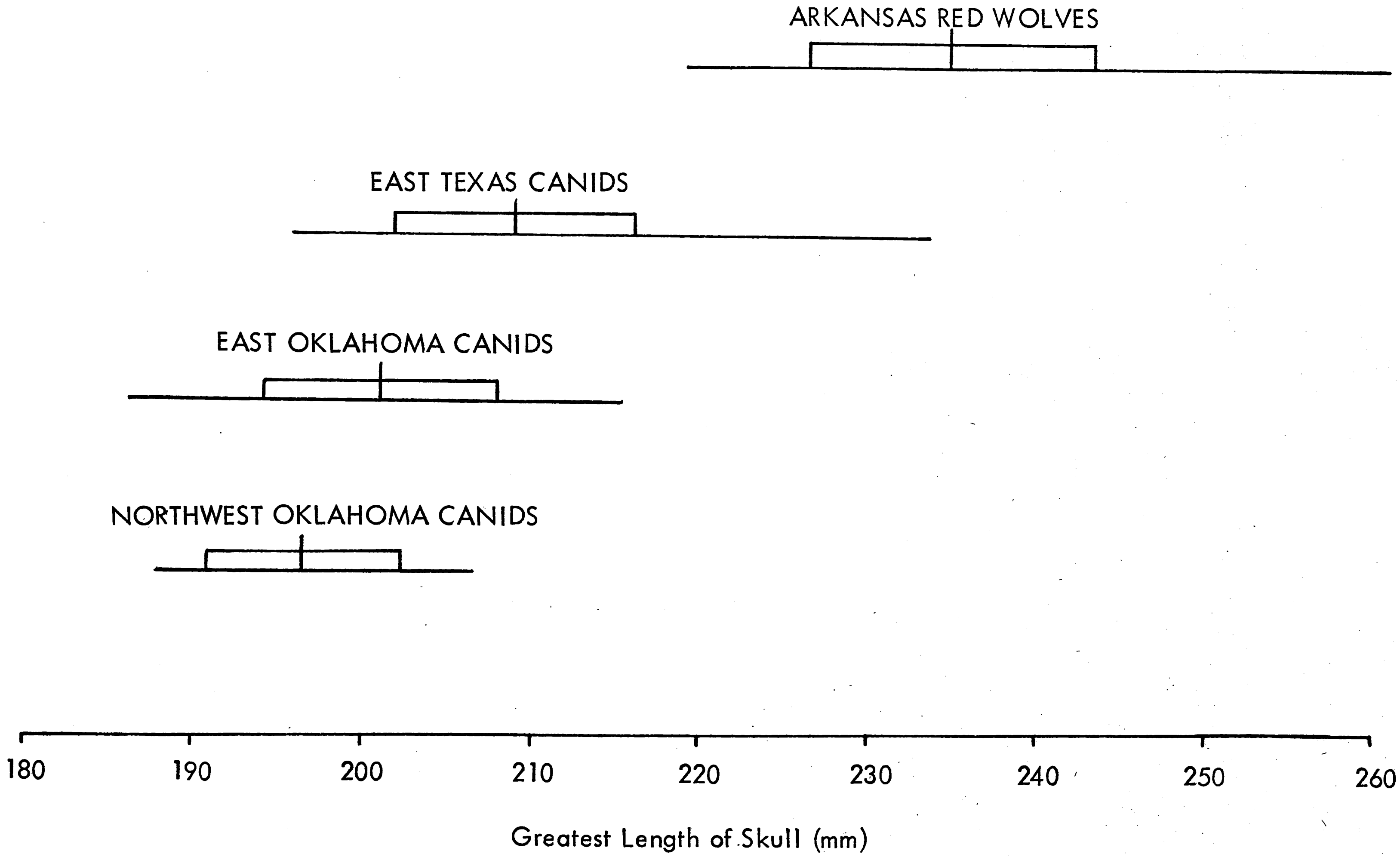

Figure 8. Greatest Length of Skull of Oklahoma Canids Compared to East Texas Canids and Arkansas Red Wolves. Measurements Are of Adult Males Only. Narrow Horizontal Line Denotes Range, Rectangle Is One Standard Deviation on Either Side of the Mean, Vertical Line Is Mean

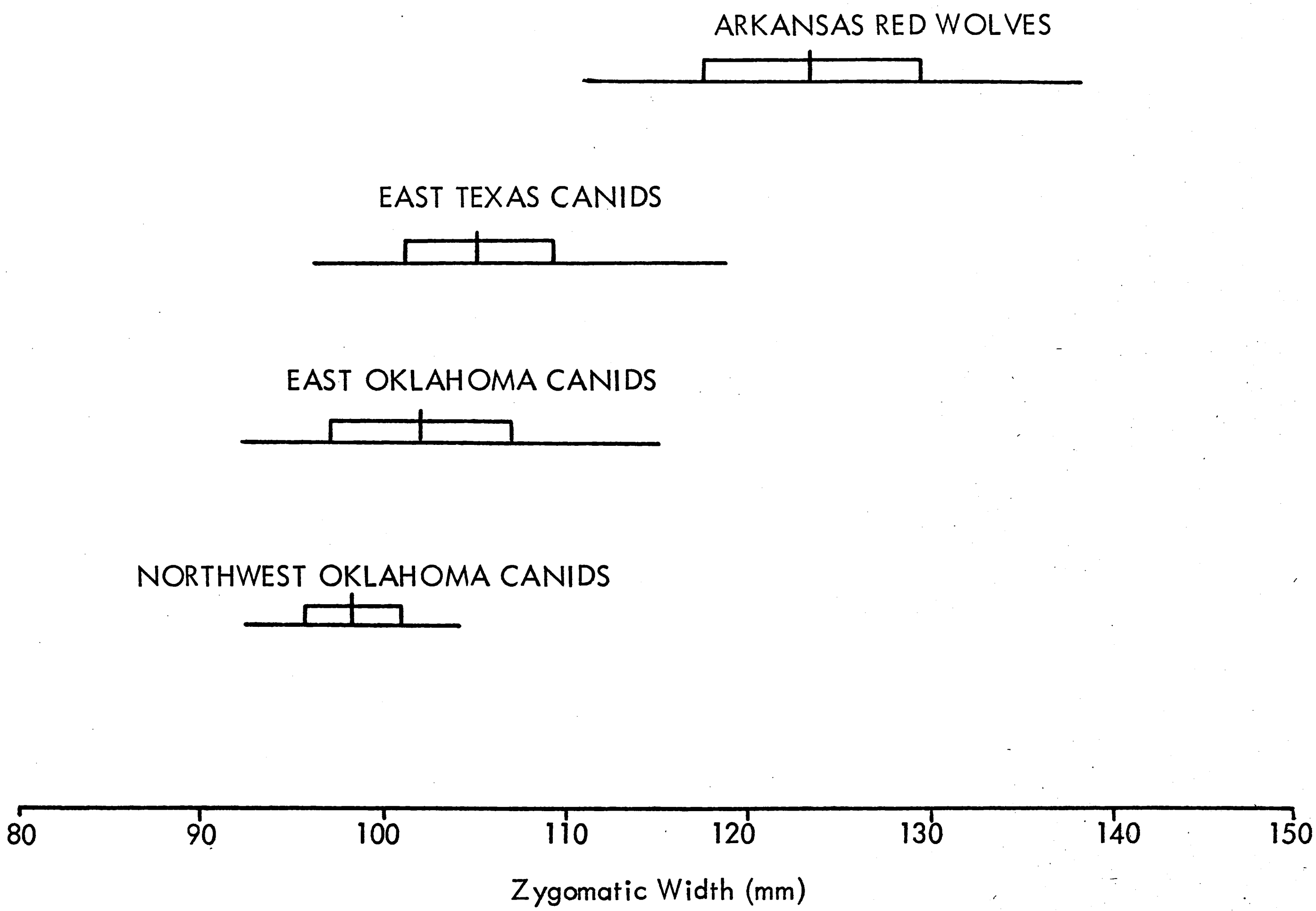

Figure 9. Zygomatic Width of Oklahoma Canids Compared to East Texas Canids and Arkansas Red Wolves. Measurements Are of Adult Males Only. Narrow Horizontal Line Denotes Range, Rectangle Is One Standard Deviation on Either Side of the Mean, Vertical Line Is Mean

Bryan, Choctaw, McCurtain, and Pushmataha counties show a relatively high amount of red wolf influence but are significantly different from a sample collected from the same area in the 1960's. Paradiso and Nowak (1971) reported the "hybrid swarm" had reached the northeast Texas counties during the years 1963-69. It seems probable that much of the red wolf influence existing in current Oklahoma canids originated from initial hybridization in Texas rather than Oklahoma. The Red River would probably not present a significant barrier to dispersal or prevent contact between the Texas and Oklahoma Canis populations.

A discrepancy was noted in the number of males and females exhibiting significant red wolf influence. Females outnumbered males in this category by a combined total of 11 to four for all animals examined. This amounts to 10.2 percent of the females versus only 2.8 percent of the males. Since there is no reason to suspect actual differences in the natality or mortality rates of male and female hybrids, this discrepancy may be attributable to the target populations and/or the statistical procedures used to classify the specimens. An examination of Gipson's (1972) data for Arkansas canids shows a much wider margin between male and female red wolf intermediates in favor of the males. Not including three males identified as red wolves, 29 of 155 Arkansas males (18.7 percent) were identified as red wolf intermediates compared to only five of 117 (4.3 percent) for females. This suggests the statistical procedures as the probable cause and may have resulted from the failure of all necessary prior assumptions concerning the targets and unknowns (listed by Gipson 1972) to be valid.

Temporal comparisons indicate genetically consistent Canis populations except in southeastern Oklahoma. Statistical comparisons of two samples separated by from five to 23 years indicates no significant changes have occurred in the overall effects of wolf or dog influence. Examination of the total samples of current and museum specimens also give evidence of stability within the composition of the Canis populations. Of the current sample, 13.0 percent of the animals were identified as coyote x dog hybrids and 5.8 percent as having significant red wolf influence. This compares to 13.2 percent and 6.1 percent of the museum sample, respectively. Although samples separated by a greater period of time would have been more desirable, the results seem to show the coyote population with a constant rate of dog hybridization and essentially stable amount of red wolf influence except in the southeast region which apparently is shifting toward more coyote-like canids.

Coyote x Dog Hybridization in Oklahoma

The amount of coyote x dog hybridization found in Oklahoma corresponds closely with that reported for Arkansas canids. Thirty-seven of 272 animals (13.6 percent) examined by Gipson (1972) were identified as intermediates between domestic dogs and wild Canis. Gipson (1972) felt that numerous poultry dumps present throughout Arkansas contributed greatly to coyote x dog hybridization by providing an easily available food source for feral dogs which might be less able to survive on wild prey and by increasing contact between the species while utilizing the common food source.

Other than an occasional discarded pig or other domestic livestock carcass, no similar situation exists in Oklahoma. Apparently only a relatively high rural dog population is necessary for significant hybridization to occur. Reports from trappers and ranchers indicate that dogs need not be completely feral to mate with coyotes. Several reports of pet dogs running with coyotes were received with one account of a witnessed mating occurring between a male coyote and female dog within a hundred yards of a farmhouse (J. Lilley personal communication 1976). It seems evident that coyote x dog hybridization is a well-established, widespread phenomenon in Oklahoma requiring only sufficient contact between the two species. Hybridization may be more likely to occur in areas where coyotes are heavily persecuted by trappers and organized hunters but there is no conclusive evidence to support this hypothesis.

Opinions vary concerning the capability of coyote populations to absorb dog genes into their gene pools. Specifically, the controversy hinges on whether F_1 hybrids can backcross with coyotes rather than just breeding among themselves or with dogs. Lawrence and Bossert (1969) concluded that New England canids were predominantly coyote but maintained genes of both dogs and gray wolves in the gene pool. On the other hand, Mengel (1971) found that the shift of coyote x dog hybrids to a fall breeding season effectively prevented hybrids from mating with winter breeding coyotes. Gipson (1972) felt that enough overlap existed in coyote and hybrid breeding seasons to allow the introgression of dog genes by the wild _Canis_ population. Skulls identified as coyote x dog hybrids in this study ranged from dog-like to obvious intermediates to animals hardly separable from coyotes. This degree of variation would not be expected if all specimens were from F_1 hybrids because most known first generation offspring show little variation and are usually intermediate between the parental species (Gier 1968, Kennelly and Roberts 1969, Silver and Silver 1969, Mengel 1971).

Evidence presented by Gipson (1972) and Dunbar (1973) indicates that at least some male coyotes are capable of breeding in December. Kennelly and Roberts (1969) reported male hybrids produced viable sperm throughout the year. Since several of the Oklahoma hybrids tended toward the coyote target, it seems probable that at least some coyote x hybrid mating occurs. It is recognized that several generations of breeding among hybrids could also account in part for the observed variation. However, offspring from this cross would be expected to produce individuals completely bridging the range of variation between coyotes and dogs. Since most of the hybrids examined in this study tend to clump toward the coyote target (Figures 2, 3, 4, 5), it is doubtful that breeding among hybrids alone can completely explain the observed distribution.

Mengel (1971) observed that male hybrids show no inclination to participate in the rearing of the young and that litters produced by hybrid females would be born in the middle of winter. He suggested this was evidence that F_2 hybrids would be less likely to survive and contribute to the Canis gene pool. While essentially true, it is doubtful that these conditions would effectively prevent the survival of a significant portion of hybrid offspring in Oklahoma.

Male coyotes capable of and breeding with female hybrids in December would in all probability assist the female in raising the litter. Oklahoma winters are normally comparatively mild with little significant snow cover or extreme temperatures and except in years of extremely low rodent populations would probably not seriously affect the survival of the young. It is also common knowledge among trappers that a single coyote, after losing its mate, can and often does successfully rear the young. One of the most serious obstacles to survival of young canids, den hunting by professional predator control agents, occurs only during the normal coyote denning season and could conceivably provide an advantage to young born earlier in the year.

Effects of Hybridization on Cattle Depredation

Numerous problems were encountered in an attempt to determine the effects of past and current Canis hybridization on cattle depredation in Oklahoma. As explained earlier, counties providing financial support to the cooperative predator control program receive priority over those counties which do not. Since virtually all canids comprising the current sample were taken during routine predator control activities, and if it can be assumed that paying counties participate because of heavier losses, the sample was immediately biased toward high loss counties. In addition, much variation was noted in the individual depredation reports turned in by trappers. It was obvious that some of the field men made serious attempts to determine the cause of the stock losses while others simply reported what the rancher told them had occurred. It was necessary to make the assumption that the variation was relatively constant within and between the various regions of the state in order to calculate average loss indices for the counties and regions.

Despite the drawbacks mentioned above, it does appear that a relationship exists between the average size of the coyotes from a particular area and the losses reported from that area. The northwestern and north-central counties are by far the largest cattle producers in the state (Anonymous 1974, 1975), yet have the smallest coyotes (Table II) and lowest loss rate (Table V). Conversely, the south-central region has comparatively few cattle (Anonymous 1974, 1975), but contains some of the largest canids (Table II) and has the highest loss index (Table V). Several red wolves were reported by Young and Goldman (1944) to be notorious cattle killers and there may be a relationship between red wolf influence and cattle depredation. However, it must be noted that this apparent correlation does not necessarily prove causation. Variables such as land use priorities and animal husbandry practices could affect the vulnerability of cattle to predation. For example, large scale beef cattle operations more prevalent in the west might provide better protection during calving than small acreage farmers to whom cattle production may be secondary. In the southeast, cattle are often allowed to range freely over Weyerhaeuser Company timber lands with virtually no supervision. These conditions could make these animals highly vulnerable to predators during the critical calving period.

It is commonly believed that wild dogs and coyote x dog hybrids are somewhat more apt to cause cattle losses than normal coyotes. However, the randomness with which hybrids occur and the apparent lack of localized concentrations indicates that while they may contribute somewhat to statewide losses, they do not have significant regional effects. The northwest region, which had the greatest number (Table V) and highest percentage of coyote x dog hybrids, had the lowest average loss index. On the basis of the evidence obtained in this study, there appears to be no positive correlation between the occurrence of coyote x dog hybrids and cattle depredations.

Decline of the Red Wolf in Oklahoma

The red wolf formerly ranged throughout the eastern two-thirds of Oklahoma (Figure 6). Primarily a woodland animal, the red wolf inhabited the dense forests of the east and south and the more broken woodlands of central Oklahoma prior to 1900 (Hall and Kelson 1959). At that time the coyote was for the most part confined to the prairies of western Oklahoma. However, a broad region of central Oklahoma is characterized by broken Postoak-Blackjack forest interspersed with numerous small areas of Tallgrass prairie (Duck and Fletcher 1943). This region, termed the "Cross Timbers," provided a large area of sympatry between the coyote and red wolf. Although very limited hybridization may have occurred in this region of overlap prior to 1900, the bulk of early specimens indicates that the two species maintained themselves as distinct entities throughout at least the first decade of this century. A series of skulls taken in 1905 from Tillman, Comanche, Creek and Tulsa counties are all easily distinguishable as either coyotes or wolves with no indication of extensive interbreeding. In addition, a large number of specimens taken in eastern and southeastern counties prior to 1930 are all typical red wolves (Paradiso and Nowak 1971). The coyote was apparently restricted in eastern Oklahoma to a few of the northeastern counties. Essentially the same situation existed throughout central Texas before 1900 (Nowak 1973). Extensive settlement by the white man in the late 1800's and the establishment of the federal predator control program about 1915 drastically altered these stable conditions.

Habitat destruction, particularly agricultural activities, is by far the major cause of interspecies hybridization with the rarity of one of the parental species another primary factor (Mayr 1970, Anderson and Stebbins 1954, Stebbins 1959, Remington 1968). Clearing of forests for farming and grazing destroyed much red wolf habitat and created conditions more favorable to the coyote. At about the same time the U. S.

Biological Survey had initiated a highly effective predator control program with the wolf being the principal target (Young and Goldman 1944). This combination of circumstances resulted in the initial massive hybridization between red wolves and coyotes in the Edward Plateau region of central Texas from approximately 1910-20 (Paradiso and Nowak 1971).

Central Oklahoma was not densely settled until after the land rush of 1889 so extensive habitat alteration probably did not occur until the early 1900's. Records also indicate that although a cooperative federal predator control program was initiated shortly after 1915, the program was abandoned in Oklahoma until the state again entered into an agreement with the Biological Survey beginning August 1, 1928 (Oklahoma Game and Fish Commission Biennial Report 1928). Though few Oklahoma specimens are available from the 1920's it appears that only limited hybridization had occurred prior to 1930 (Nowak 1973).

The first significant numbers of questionable Oklahoma canids began to appear in the early 1930's. In 1932, four years after the resumption of organized predator control, animals apparently intermediate between coyotes and red wolves were taken in Cleveland, Cherokee, Atoka, and LeFlore counties of central and eastern Oklahoma. At the same time, a large series of intermediate canids were obtained from counties in north-central Texas, immediately adjacent to the Red River and south-central Oklahoma, and from extreme northwestern Arkansas (Paradiso and Nowak 1971).

The Biennial Report of the Oklahoma Game and Fish Commission (1934:42) described the predator control work in Oklahoma as follows:

> Predator control in Oklahoma the last two years has been limited to the southeastern portion of the state . . . The area occupied by wolves in Oklahoma has been worked systematically and their numbers have been reduced to a point where the job has been that of cleaning up. Wolves are widely scattered throughout the range formerly occupied by them. These animals are most difficult to trap, not only because of their inherent wariness, but because of the wide range which they cover.

It appears that by the mid-1930's the red wolf was drastically reduced in its Oklahoma range with the few remaining individuals widely scattered and forced to range over large areas to avoid human conflict and probably also in search of mates.

As noted earlier, the eastern limit of coyote distribution was the eastern edge of the cross-timbers region of central and northeastern Oklahoma prior to 1910. As habitat alteration progressed due to man's agricultural activities, the adaptive coyote began expanding eastward and hybridization probably occurred as they encountered widely scattered wolves who were unable to find mates of their own species. It is also probable that the "hybrid swarm" reported by Paradiso and Nowak (1971) in north-central Texas had moved to a certain extent into the south-central counties of Oklahoma by the mid-1930's. Therefore, it was probably a population of predominantly hybrid character which accounted for the large numbers of "wolves" reported taken during the period 1936-46 (Oklahoma Game and Fish Commission Biennial Report 1936, 1938, 1940, 1942, 1944, 1946). This statement is supported by the fact that the great majority of these "wolves" were taken in the south-central counties (within the range of possible coyote expansion) rather than the southeast. Also, in virtually all instances after 1934, both coyotes and wolves were never reported taken from the same county. Since it is unlikely that in all areas previously occupied by both red wolves and coyotes only wolves would be taken, it appears that the canid populations in these areas were probably coyotes modified by the recent mixture of red wolf genes.

By 1940 the red wolf was probably extinct in Oklahoma for all practical purposes. McCarley (1962) reported two animals, a male and female collected in 1936 from near Battiest, McCurtain County, as probable red wolves. These animals may well have been among the last red wolves in Oklahoma. Although many wolves were reported taken from southeastern Oklahoma during the period 1940-50, these animals were probably coyote-red wolf intermediates. McCarley (1962) also reported on a series of 10 skulls collected since 1949 in extreme southeastern Oklahoma and concluded they were intermediate between coyotes and red wolves.

Museum skulls examined in this study, and those reported by Paradiso (1968), reveal that since approximately 1960 most animals collected in southeastern Oklahoma are clearly referable to Canis latrans with only an occasional canid showing significant red wolf influence. This suggests a gradual dilution of red wolf genes in the coyote population after the major influx of the 1930's.

The decline of the red wolf in Oklahoma may be summarized as follows: the coyotes and red wolves were sympatric throughout central and northeastern Oklahoma with no evidence of extensive hybridization prior to 1920. Habitat modification, primarily forest clearing, and other human activities, probably started a gradual decline of the red wolf and eastward expansion of the coyote through the 1920's. A small amount of hybridization probably occurred during this period. The resumption of federal-state cooperative predator control in 1928, along with control by private landowners, may have greatly accelerated the decline of red wolf numbers in eastern Oklahoma until only scattered individuals remained by the mid-1930's. Continued expansion of the coyote and possibly the influx of hybrids from north-central Texas absorbed the remaining red wolves and resulted in the establishment of a predominantly hybrid population by 1945. By this time the red wolf was probably extinct in Oklahoma. Due to the rapid disappearance of the red wolf in eastern Oklahoma, the amount of hybridization probably never approached the proportions reported for central Texas (Paradiso and Nowak 1971). The last detectable amount of coyote x red wolf hybridization probably occurred in the extreme southeastern counties in the early 1940's. Since then the amount of red wolf influence has gradually decreased until, at the present time, most eastern Oklahoma canids are typical coyotes with only occasional individuals exhibiting red wolf characteristics.

CHAPTER V

SUMMARY AND CONCLUSIONS

Skulls from a total of 138 adult specimens of wild Canis taken during the winter of 1975-76 were analyzed. An additional 114 canid skulls housed in various state museums were also examined and subjected to statistical analysis. Weight and pelage color were obtained from most of the current animals and a portion of the museum specimens. Measurements from each skull were compared to five target populations (coyotes, dogs, coyote x dog hybrids, red wolves, gray wolves) to determine the species or hybrid group of each specimen.

Sixty-eight (82.9 percent) of 82 male unknowns were identified as coyotes. Twelve (14.6 percent) were coyote x dog hybrids and two (2.4 percent) were identified as coyote-red wolf intermediates. Of the 62 male museum specimens 52 (83.9 percent) were coyotes, seven (11.3 percent) were identified as coyote x dog hybrids, and two (3.2 percent) were probable coyote-red wolf intermediates. One museum specimen was identified as a feral dog. Forty-four of 56 (78.6 percent) current females were coyotes, six (10.7 percent) were coyote x dog hybrids, and six (10.7 percent) were intermediate between coyotes and red wolves. The 52 museum females included 39 (75.0 percent) coyotes, eight (15.4 percent) coyote x dog hybrids, and five (9.6 percent) coyote-red wolf intermediates. Coyote x dog hybrids are randomly distributed throughout the Oklahoma regions sampled. Coyote-red wolf intermediates appear to be of significance only in the south-central and southeastern regions.

Pelage color was recorded for 121 of the animals from the current population. Twelve (9.9 percent) of these were black or very dark and were identified as follows: eight coyotes, two coyote x dog hybrids, and two coyote-red wolf intermediates. Black animals occur throughout the state but are more prevalent in the southern half. Black color in coyotes is probably due to the introgression of red wolf genes through hybridization.

The weights of 69 adult males ranged from 9.1 to 20.9 kg and averaged 14.9 kg. Fifty-one females averaged 2.9 kg less and ranged from 8.2 to 18.1 kg. Largest animals were collected in the south-central and southeastern counties while the smallest came from the north-central and northwestern counties.

Regional comparisons showed canids from the central region to be most closely related to the coyote target despite a relatively large amount of red wolf influence in the southern counties of this region. Canids from the southeast region are most distinct from the Kansas coyotes. Comparison to the red wolf target revealed that specimens from the central and southeast regions most nearly approach the Arkansas red wolves. All Oklahoma regions are very nearly equally removed from the dog target.

No significant difference was found for males or females between a series of skulls taken from Payne, Pawnee, and Osage counties between 1953 and 1960 and skulls from the same area in 1975-76. Similar results were obtained by comparing animals from Cleveland, McClain, and Grady counties taken in 1969-70 and those from the current sample. A significant difference was obtained when a pooled sample from the southeast region in the 1960's was compared to the current animals from this region. This was interpreted to indicate declining red wolf influence in this area.

Cattle depredation appears to be positively related to larger size of canids in the southern and southeastern counties. This relationship may be coincidental and caused by livestock husbandry techniques. Coyote x dog hybridization apparently has no significant effect on cattle losses, but the absence of localized concentration of hybrids and probable bias in sampling and depredation reports made more effective comparisons impossible.

The decline of the red wolf in Oklahoma probably began due to habitat alteration after extensive settlement occurred. Resumption of federal-state cooperative predator control in 1928 possibly accelerated the decline. Hybridization probably occurred primarily in the early 1930's as the expanding coyote population encountered the widely scattered wolves. Although coyote x red wolf interbreeding apparently was widespread, wolf numbers were probably so reduced that hybridization never approached the proportions reported for Texas and Arkansas. Later influxes of red wolf genes may have occurred when coyote-red wolf intermediates from Texas crossed the Red River into some southern Oklahoma counties.

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APPENDIX A

DESCRIPTIVE LIST OF MEASUREMENTS

1. Total length - greatest distance from tip of sagittal crest to alveoli of I^1.

2. Length from toothrow to bulla - minimum distance from alveolus of M^2 to depression in front of bulla at base of styloid process.

3. Zygomatic width - greatest distance across zygomata.

4. Braincase width - maximum width of braincase at parietotemporal sutures.

5. Crown width across upper cheek teeth - greatest breadth between outer sides of most widely separated upper teeth (P^4 or M^1).

6. Height from maxillary toothrow to orbit - minimum distance from outer alveolar margin of M^1 to most ventral point of orbit.

7. Crown length of upper cheek teeth - maximum distance from anterior edge of upper canine to posterior edge of M^2.

8. Crown length of P^4 - maximum anterposterior length of P^4 crown measured on outer side.

9. Crown width of P^4 - minimum crown width of P^4 taken between roots.

10. Width of canine - maximum anteroposterior width of upper canine at base of enamel.

11. Crown width of M^2 - maximum transverse diameter of M^2 crown.

12. Width across incisors - maximum distance between outermost edges of upper incisors.

13. Height of jugal - minimum height of jugal at right angles to axis of bone.

14. Palatal width of P^1 - minimum width between inner margins of alveoli of first upper premolars.

15. Crown length of P_4 - maximum anteroposterior length of P_4 crown measured on outer side.

16. Length of posterior cusps of P_4 - anteroposterior length of P_4 cusps measured along line parallel to base from back of tooth to point below notch posterior to main cusp.

APPENDIX B

INDIVIDUAL DATA SHEET

Ron C. Freeman
School of Biological Sciences
Oklahoma State University
Stillwater, Oklahoma 74074
Phone: (405) 377-3753 or 372-6211, Ext. 7053

Museum Number____________
Specimen Number____________
County____________
Date Captured____________

GENERAL INFORMATION

Species____________ Trapper____________ Sex________

Pelage Color____________ Eye Color____________ Weight________

Behavior at Trap________________________ Age________

Remarks____

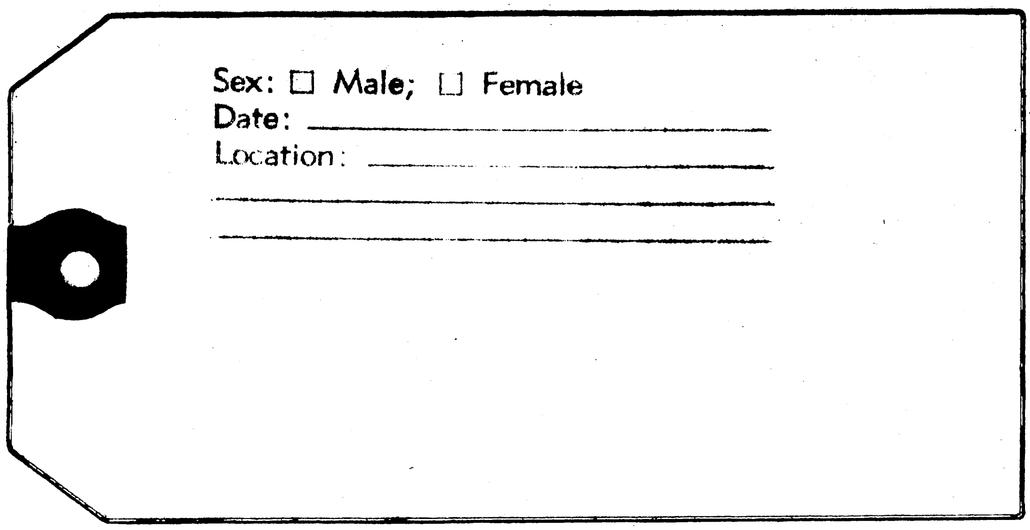
____

SKULL MEASUREMENTS

1. Tot. length____________
2. M^2-bulla____________
3. Zyg. width____________
4. Braincase width____________
5. Width across Molars____________
6. Orbit to alv.____________
7. Crown length. C-M^2____________
8. Length P^4 Crown____________
9. Min. width P^4____________
10. Max. width C____________
11. Crown width M^2____________
12. Width across Incisors____________
13. Min. Hgt. Jugal____________
14. Width between P^1 alv.____________
15. Crown length P_4____________
16. Length post. cusps P_4____________

APPENDIX C

DATA TAGS FOR FIELD USE



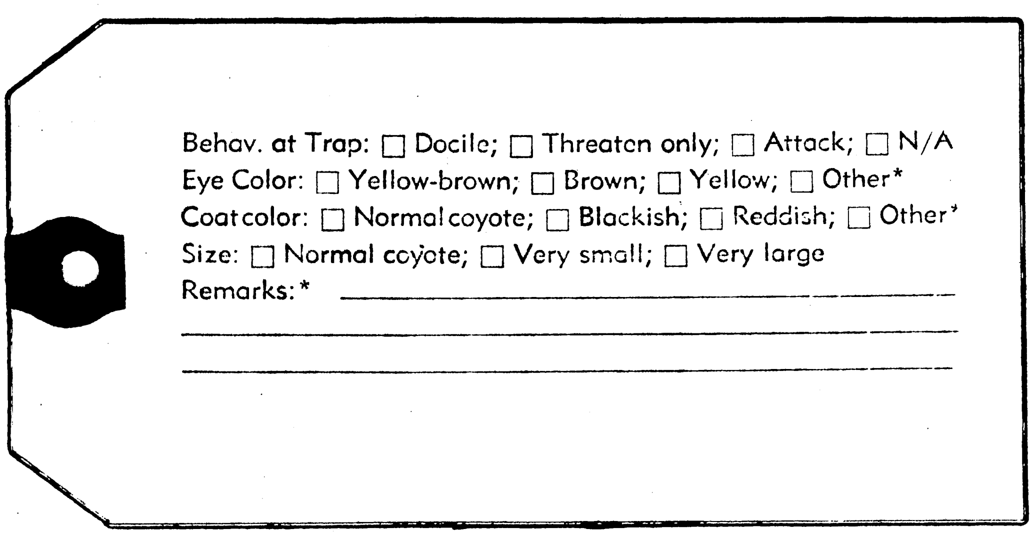
Sex: ☐ Male; ☐ Female

Date: ____________________

Location: ____________________

____

____



Behav. at Trap: ☐ Docile; ☐ Threaten only; ☐ Attack; ☐ N/A

Eye Color: ☐ Yellow-brown; ☐ Brown; ☐ Yellow; ☐ Other*

Coat color: ☐ Normal coyote; ☐ Blackish; ☐ Reddish; ☐ Other*

Size: ☐ Normal coyote; ☐ Very small; ☐ Very large

Remarks:* ____________________

____

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APPENDIX D

LIST OF CURRENT ADULT SPECIMENS

OF OKLAHOMA *CANIS*

Specimen Number	Sex	Weight (kg)	County	Classification
001	M	18.1	Choctaw	Coyote
003	M	15.0	Choctaw	Coyote
029	M	17.2	Pushmataha	Coyote
030	F	10.9	Pushmataha	Coyote
031	F	9.5	Pushmataha	Coyote x Dog
034	M	17.2	Pushmataha	Coyote
035	F	10.0	Pushmataha	Coyote
036	M	15.9	Pushmataha	Coyote
051	M	14.5	Mayes	Coyote x Dog
052	M	16.3	Rogers	Coyote
076	M	13.6	Osage	Coyote
080	M	13.6	Osage	Coyote
081	F	8.6	Osage	Coyote
086	F	11.3	Osage	Coyote
088	F	18.1	Osage	Coyote x Red Wolf
090	F	12.2	Osage	Coyote
100	M	12.7	Osage	Coyote
101	F	10.4	Pawnee	Coyote
103	F	10.0	Pawnee	Coyote
104	F	12.7	Pawnee	Coyote
105	F	10.9	Pawnee	Coyote
106	F	13.6	Pawnee	Coyote
108	M	11.8	Pawnee	Coyote
109	M	10.4	Pawnee	Coyote x Dog
139	F	14.1	Pontotoc	Coyote
140	F	19.1	Pontotoc	Coyote
141	F	17.1	Pontotoc	Coyote x Red Wolf
143	F	15.4	Pontotoc	Coyote
146	M	20.9	Pottawatomie	Coyote
147	M	16.3	Pontotoc	Coyote x Dog
150	F	14.1	Johnston	Coyote x Red Wolf
151	F	11.3	Grady	Coyote
152	M	14.5	Grady	Coyote
154	F	10.9	Grady	Coyote
158	F	13.2	McClain	Coyote x Dog
159	M	14.5	McClain	Coyote x Dog
163	F	12.2	McClain	Coyote

Specimen Number	Sex	Weight (kg)	County	Classification
168	M	14.5	Cleveland	Coyote
176	M	11.3	Harmon	Coyote
179	M	11.8	Harmon	Coyote
180	M	15.4	Harmon	Coyote
182	F	11.3	Harmon	Coyote
183	M	13.6	Beckham	Coyote
184	F	10.4	Harmon	Coyote x Dog
185	F	12.7	Roger Mills	Coyote
186	M	15.0	Harmon	Coyote
188	M	17.2	Harmon	Coyote
191	M	15.9	Beckham	Coyote
193	M	14.5	Beckham	Coyote
195	M	15.0	Roger Mills	Coyote
197	M	13.2	Kiowa	Coyote
198	M	18.6	Washita	Coyote
199	F	12.2	Washita	Coyote
227	M	14.5	Cotton	Coyote
231	M	15.0	Tillman	Coyote
233	M	15.4	Cotton	Coyote
234	M	15.4	Cotton	Coyote
236	M	16.3	Cotton	Coyote
237	M	16.8	Cotton	Coyote
238	F	10.9	Cotton	Coyote
240	M	14.5	Cotton	Coyote x Red Wolf
241	M	14.1	Cotton	Coyote
242	F	10.4	Cotton	Coyote
245	M	16.3	Cotton	Coyote
246	M	15.4	Tillman	Coyote
247	M	15.9	Tillman	Coyote
248	F	14.5	Cotton	Coyote
251	M	-	Cotton	Coyote
252	M	-	Cotton	Coyote x Dog
254	F	12.7	Cotton	Coyote
255	F	12.2	Cotton	Coyote
257	M	12.7	Cotton	Coyote
258	M	14.5	Cotton	Coyote
259	M	14.5	Cotton	Coyote
260	F	10.9	Cimarron	Coyote x Dog
261	F	9.5	Cimarron	Coyote
264	F	12.7	Cimarron	Coyote
265	F	10.4	Harper	Coyote
266	F	9.5	Cimarron	Coyote
268	F	10.9	Cimarron	Coyote
269	M	14.1	Cimarron	Coyote
273	M	20.0	Woods	Coyote
279	M	11.3	Ellis	Coyote x Dog
280	M	15.9	Dewey	Coyote
288	F	13.6	Ellis	Coyote
289	F	13.6	Ellis	Coyote
290	M	11.8	Ellis	Coyote x Dog
291	M	9.1	Woodward	Coyote x Dog

Specimen Number	Sex	Weight (kg)	County	Classification
293	M	14.5	Dewey	Coyote
300	F	8.2	Woodward	Coyote x Dog
301	F	12.2	Love	Coyote
306	M	15.4	Love	Coyote
307	M	14.5	Marshall	Coyote
308	M	14.1	Love	Coyote
309	F	12.7	Love	Coyote
326	M	11.3	Bryan	Coyote x Dog
327	F	11.8	Bryan	Coyote
329	F	17.2	Bryan	Coyote
330	F	17.2	Bryan	Coyote x Red Wolf
331	M	13.6	Bryan	Coyote
333	M	15.4	Bryan	Coyote
334	F	13.2	Bryan	Coyote
335	F	10.9	Bryan	Coyote
336	M	17.7	Bryan	Coyote
337	F	10.4	Bryan	Coyote
338	F	9.1	Bryan	Coyote
339	M	14.1	Bryan	Coyote
340	F	10.9	Bryan	Coyote
341	M	17.2	Bryan	Coyote
344	F	8.2	Bryan	Coyote
349	F	10.0	Bryan	Coyote x Dog
350	M	17.2	Bryan	Coyote
355	F	-	Hughes	Coyote
356	F	-	Hughes	Coyote
357	F	-	Hughes	Coyote
358	M	15.9	Hughes	Coyote
359	F	14.1	Hughes	Coyote x Red Wolf
360	F	14.1	Hughes	Coyote
361	M	16.8	Hughes	Coyote
362	M	15.9	Hughes	Coyote
363	F	14.5	Hughes	Coyote x Red Wolf
364	M	10.9	Hughes	Coyote
375	M	-	McCurtain	Coyote
380	M	11.3	Payne	Coyote
381	M	-	Payne	Coyote x Dog
382	M	12.2	Comanche	Coyote
383	F	-	Comanche	Coyote
387	M	-	Payne	Coyote
388	M	-	McCurtain	Coyote
389	M	-	McCurtain	Coyote x Red Wolf
390	M	-	Pushmataha	Coyote
391	M	-	Hughes	Coyote
392	M	-	Hughes	Coyote
393	M	-	Hughes	Coyote
394	M	-	Hughes	Coyote
395	M	-	Hughes	Coyote x Dog
396	M	-	Hughes	Coyote
397	M	-	Hughes	Coyote

V

VITA

Ronald Carl Freeman

Candidate for the Degree of

Master of Science

Thesis: COYOTE X DOG HYBRIDIZATION AND RED WOLF INFLUENCE IN THE WILD CANIS OF OKLAHOMA

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Biographical:

Personal Data: Born in Wagoner, Oklahoma, 13 February 1950, the son of Mr. and Mrs. Carl Matthew Freeman.

Education: Graduated from Muskogee Central High School, Muskogee, Oklahoma, in May 1968; received the Bachelor of Science Degree in Biology from Northeastern Oklahoma State University in 1973; graduate study in Zoology at the University of Oklahoma 1973-74; completed requirements for the degree of Master of Science at Oklahoma State University in December 1976.

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Honorary and Professional Societies: The Wildlife Society; Student Chapter of the Wildlife Society; Oklahoma Ornithological Society; Oklahoma University Chapter of Phi Sigma Honor Society; National Wildlife Federation; Oklahoma Wildlife Federation.