Taxonomic Status of the Coyote in Tennessee

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Abstract: To assess the taxonomic status of the coyote (*Canis latrans*) in Tennessee, the relationship of 61 Tennessee canids (unknown taxonomically) were compared to specimens of coyotes, dogs (*C. familiaris*), and red wolves (*C. rufus*). Twelve skull measurements were used in the assessment. Discriminant function analysis showed a well-defined separation of canid groups sampled. Tennessee canids clustered distinctly and were statistically separable from dog and red wolf groups. Hybridization between taxa was minimal. The wild coyote-like canids occurring in Tennessee are taxonomically coyotes.

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Rhoads (1896) and Kellogg (1939) compiled the first annotated lists of Tennessee mammals. Rhoads (1896) did not list the coyote (*Canis latrans*) in his accounts. Kellogg (1939) reported 1 female specimen taken in Maury County and indicated that it was from a stock of coyotes liberated at Grand Junction (Hardeman County) for the purpose of training hounds. Schultz (1955) and Nowak (1979) summarized the early records of coyotes in Tennessee (many records were not recorded from actual specimens but from sightings by individuals). Paradiso (1966) discussed records of coyotes from the southeastern United States and did not report the occurrence of any specimens from Tennessee. In addition, Hall (1981) did not list any records of Tennessee coyotes. However, in the last decade, reports of coyote-like wild canids have increased steadily. These coyote-like canids have apparently become well-established, especially in western Tennessee, and stock loss due to predation from coyote-like canids have been reported in 30 counties (Cook 1981).

Much natural history and management information relating to coyotes has been collected for many parts of their range in the United States. Bekoff (1977) summarized much of this literature. However, little is known relating

to the taxonomy and natural history of coyotes in Tennessee. Taxonomically, the coyote-like animals in Tennessee could represent coyote, red wolf (*C. rufus*), dog (*C. familaris*), or hybrids of these taxa. The purposes of this study were to examine the taxonomic status of the wild canid in Tennessee and to verify the existence (or nonexistence) of coyotes in the state.

We thank the National Museum of Natural History at Washington, D.C. for the opportunity to examine specimens in their care and the University of Tennessee Medical School at Memphis, Tennessee, for providing dog specimens. Appreciation is extended to the many trappers, hunters, and Tennessee Wildlife Resources Agency personnel for providing the majority of specimens used in this study. The project was financed in part by Federal Aid to Wildlife Restoration, Tennessee Wildlife Resources Agency, W-46R Pittman-Robertson.

Methods

We recorded 28 skull measurements from 61 adult Tennessee wild canids (coyote-like), 100 known coyotes, 37 known red wolves, and 33 known dogs; these measurements were (A) zygomatic width, (B) greatest width across upper P_4 teeth, (C) least distance between alveoli of P_1, (D) greatest width across upper I_3 teeth, (E) greatest antero-posterior length of upper canine taken at base of enamel, (F) least height of jugal at right angles to axis of bone, (G) greatest skull length, (H) greatest distance from maxilla to zygomatic process across the orbit and temporal fossa, (I) greatest length of upper cheek teeth from canine to M_2, (J) crown width of M_2, (K) skull depth, (L) greatest length of the upper molar toothrow, (M) least depth of cranium from frontal to base of M_1, (N) least distance from alveolus of M_2 to depression in front of bulla at base of styloid process, (O) least distance between alveoli of P_1 divided by least height of jugal at right angles to axis of bone, (P) least width between alveoli of M_1, (Q) nasal-maxilla distance taken at median distance between P_1 and P_2, (R) least maxilla width taken dorsally, (S) least distance between alveoli of P_1 divided by greatest length of the upper I_3 teeth, (T) least maxilla width taken dorsally divided by greatest length of the upper molar toothrow, (U) greatest skull depth divided by least depth of cranium from frontal to base of M_1, (V) greatest antero-posterior length of upper canine taken at base of enamel divided by least height of jugal at right angles to axis of bone, (W) length of posterior cusps of P_4 along line at angle to base from back of tooth to point below notch posterior to main cusp on mandible, (X) length of posterior cusps of P_4 along line at angle to base from back of tooth to point below notch posterior to main cusp on mandible divided by least height of jugal at right angles to axis of bone, (Y) greatest length of the upper molar toothrow divided by least distance between alveoli of P_1, (Z) distance from anterior I_1 to jugal at anterior most part of orbit, (Y′) greatest antero-

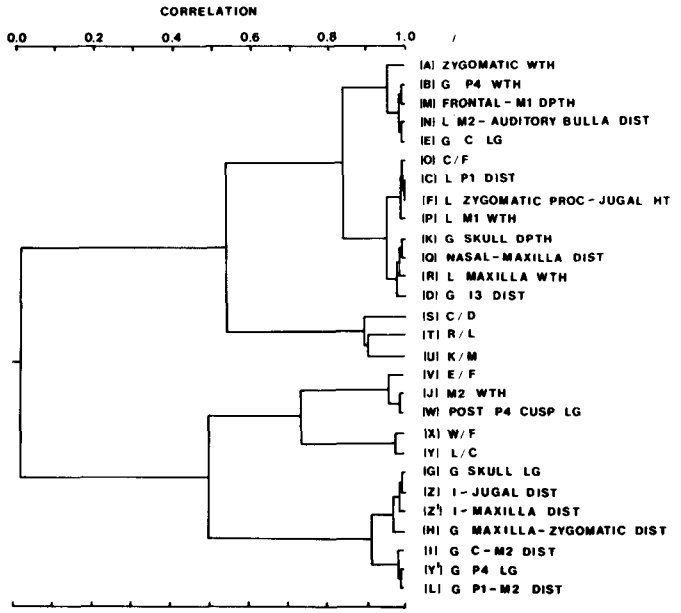

Figure 1. Dendrogram summarizing variation among characters of Tennessee coyotes. A description of characteristics is given in the text.

posterior length of upper P_4 taken at base of enamel, (Z') distance from anterior part of I_1 to maxilla taken ventrally in notch between jugal and M_2.

These characters were selected to include measurements that could be repeated with accuracy and those which have been shown useful in previous systematic studies of canids. Following examination of the relationship among characters (Fig. 1), 17 were eliminated due to high correlations. Subsequent analyses were conducted utilizing 12 characters. These were A, B, G, H, I, J, K, O, S, V, Y, and I/C. The latter character, greatest length of upper cheek teeth from canine to M_2 divided by least distance between alveoli of P_1 (I/C) was added to the character set since the authors found it to be a useful character in other canid analyses. Measurements were taken with dial calipers to the nearest O.1 mm. Adult specimens (those more than 1 year of age) were determined according to the criteria of Gier (1957).

All known coyotes and red wolves and 22 dogs were examined at the National Museum of Natural History. Dog skulls from Tennessee specimens (11) showing characteristics similar to coyotes in size and appearance were provided by the University of Tennessee Medical School. Tennessee canid specimens of unknown taxonomic status were taken primarily by trappers and hunters who made the material available to the authors. A few were taken as road kills by various individuals. Skulls of Tennessee wild canids and the 11

known dog skulls from Tennessee are housed in the Memphis State University Museum of Zoology.

Counties from which specimens were examined and sample sizes were: Carroll, 1; Crockett, 1; Decatur, 1; Dyer, 1; Fayette, 9; Gibson, 3; Hardeman, 9; Henderson, 1; Lincoln, 1; Lauderdale, 3; Madison, 3; Marshall, 1; Obion, 1; Shelby, 13; Stewart, 1; and Tipton, 12.

For comparison of results with other studies (Gipson et al. 1974, Elder and Hayden 1977) sexes were pooled for all analyses. Linear discriminant function analysis was used to indicate the taxonomic status of the unknown Tennessee canids. Step-wise discriminant function analysis was used in order to eliminate less useful characters. Biometric routines were carried out with the Statistical Package of the Social Sciences (SPSS) of Nie et al. (1975).

Results

A dendrogram computed from the matrix of correlations of skull characters showed characters to group into 2 major clusters (A – U; V – L) with four subclusters within each (Fig. 1). All characters within each of the clusters had relatively high correlations. When comparing discriminant function analysis conducted from a set of characters from each of the subgroups (total =12) and the original 28 characters, we saw only minor differences. Since there was a large amount of redundancy in the original character set, we chose to use the 12 character set in subsequent analysis.

Using coyote, dog, and red wolf groups as knowns and Tennessee canids as unknowns in a discriminant function analysis (Test A), 10 characters were found, in combination, to be useful discriminators (Table 1). For the first function, characters I/C, K, J, and A were found to be the most heavily weighted characters based upon standardized discriminant function coefficients. Characters A, S, and O were the most heavily weighted for function 2 (Table 1). A plot of the first 3 discriminant scores for each animal (Fig. 2A) indicated that the known groups were distinctly different from each other. Of the 100 known coyotes, 97% ($N = 97$) were correctly classified (2 specimens were classified as red wolves). All known dogs and red wolves were correctly classified, and 95.1% ($N = 58$) of the unknown specimens (Tennessee canids) clustered with the coyote group. From the unknown group, 1.6% ($N = 1$) clustered with red wolves and 3.3% ($N = 2$) clustered with the dog group.

When discriminant function analysis was applied to the character set using coyote, dog, red wolf, and Tennessee canids as distinct groups (Test B), 9 characters were found, in combination, to be useful discriminators (Table 1). For the first function, characters I/C, K, J, and A (same as in Test A) were found to be the most heavily weighted characters based upon standardized discriminant function coefficients (Table 1). Characters S, O, and A (same as in Test A) were the most heavily weighted for function 2 (Table 1). For

Table 1. Standardized canonical discriminant function coefficients of canid skull characteristics.

Test A[a]			Test B[b]			
Characteristic[e]	Function 1	Function 2	Characteristic	Function 1	Function 2	Function 3
A	0.75564	0.59442	A	0.56763	0.54489	0.72512
B	−0.45430	0.17773	B	−0.52291	0.18041	−0.09802
S	0.30461	−0.58564	S	0.38434	−0.56103	0.59979
O	0.09272	0.52240	O	0.03039	0.56000	−0.01403
G	−0.45274	−0.26931	G	−0.31896	−0.00928	1.10530
H	0.68082	0.38613	H	0.33736	0.49857	−1.73934
I	−0.11119	0.44439	J	0.61165	0.36329	0.30792
J	0.80775	0.21591	K	−0.64829	−0.28507	−0.03555
K	−0.89324	−0.25997	I/C	0.82264	−0.07454	0.23164
I/C	0.90345	−0.25515				

Test C[c]		Test D[d]		
Characteristic	Function 1	Characteristic	Function 1	Function 2
A	0.91050	A	0.67787	0.66365
B	−0.45619	B	−0.51442	−0.11076
S	0.42889	S	0.31253	0.65281
H	0.70609	G	−0.35522	1.08108
I	−0.68743	H	0.39199	−1.76929
J	0.77959	J	0.61427	0.27901
K	−0.93900	K	−0.65861	0.00777
I/C	1.14325	I/C	0.78901	0.28330

[a] Analysis with Tennessee canids as unknowns, and known coyotes, dogs, and red wolves.
[b] Analysis with Tennessee canids as knowns, and known coyotes, dogs, and red wolves.
[c] Analysis with Tennessee canids as unknowns, and known coyotes and dogs.
[d] Analysis with Tennessee canids as knowns, and known coyotes and dogs.
[e] For explanation of characters, see text.

function 3, characters H and G were the most heavily weighted (Table 1).

A plot of the first 3 discriminant scores for each animal is given as Fig. 2B. Of the individuals in the known groups, 83.5% were correctly classified. Results showed 82.8% ($N = 82$) of the coyotes grouped in proximity to each other; 14.1% ($N = 14$) of the coyotes clustered with Tennessee canids, and 3.0% ($N = 3$) with red wolves. All known dogs and red wolves were correctly classified. Of the Tennessee canids, 65.6% ($N = 40$) clustered together while 31.1% ($N = 19$) grouped with the coyotes; 1.6% ($N = 1$) clustered with the dog group, and 1.6% ($N = 1$) clustered with the red wolf group.

Results using only coyotes, dogs, and Tennessee canids in discriminant analysis (omitting red wolves) provide a clearer separation of known and unknown groups. With coyotes and dogs as knowns and Tennessee canids as unknowns (Test C), 8 characters in combination were found to be useful

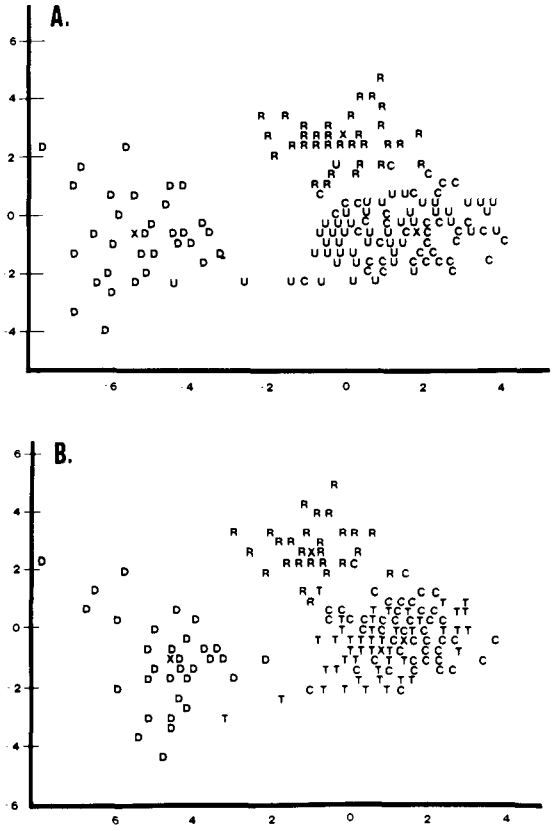

Figure 2. *Discriminant function analyses comparing coyotes, dogs, red wolves, and Tennessee canids. (A) Represents tests which included the Tennessee canids as an unknown group. (B) Represents tests which included the Tennessee canids as a known group. C = coyote; D = dog; R = red wolf; U or T = Tennessee canid.*

discriminators (Table 1). For the first function, characters I/C, K, A, and J (same as in Tests A and B) were found to be the most heavily weighted based upon standardized discriminant function coefficients. From a plot of 2 discriminant scores for each animal (Fig. 3A), all known coyotes and dogs were correctly classified. Of the Tennessee canids, 96.7% ($N = 59$) were grouped with coyotes, and 3.3% ($N = 2$) were classified as dogs.

When treating coyotes, dogs, and Tennessee canids as known groups (omitting red wolves) in discriminant analysis (Test D), 8 characters in combination were found to be useful discriminators (Table 1). For the first function, characters I/C, A, K, and J (same as in other tests) were found to

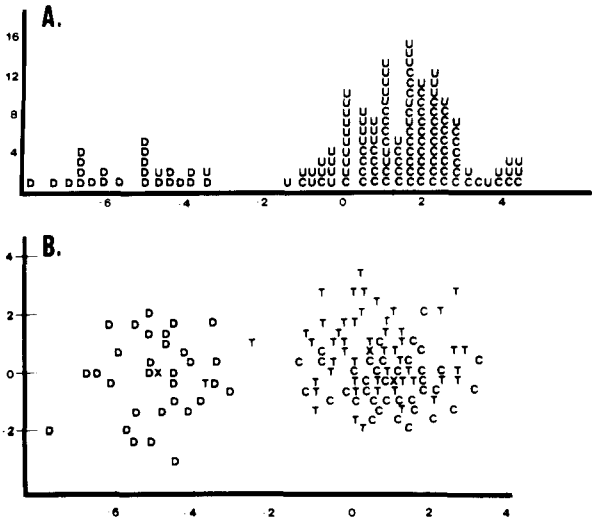

Figure 3. Discriminant function analyses comparing coyotes, dogs, and Tennessee canids. (A) Represents tests which included the Tennessee canids as an unknown group. (B) Represents tests which included the Tennessee canids as a known group. C = coyote; D = dog; U or T = Tennessee canid.

be the most heavily weighted based upon standardized discriminant function coefficients. Characters A and S were the most heavily weighted for function 2 (Table 1). From a plot of the first 3 discriminant scores for each animal (Fig. 3B), for the known groups, 80.3% were correctly classified. Known coyotes were grouped as coyotes (83.8%, $N = 83$) and Tennessee canids (16.2%, $N = 16$). All dogs were clustered as dogs. Of the Tennessee canids, 63.9% ($N = 39$) clustered as Tennessee canids, 32.8% ($N = 20$) grouped with coyotes, and 3.3% ($N = 2$) were classified as dogs.

Results of Tests A–D (while showing some minor rearrangements) present the same generalization: Tennessee canids were statistically distinct from known dogs and wolves; however, they were not statistically distinct from known coyotes. The degree of hybridization between canid taxa in Tennessee is apparently minimal. Data (Figs. 2, 3) indicated only a few animals which might be viewed as intermediate between groups. When red wolves were removed from the analysis and coyotes, dogs, and Tennessee canids were treated as distinct groups, only 1 of 61 Tennessee canids appeared as possibly intermediate between coyotes and dogs. When Tennessee canids were treated as unknowns and coyotes and dogs as distinct groups, no Tennessee specimens were found to be intermediate between the two known groups.

Discussion

Several investigators (Howard 1949, McCarley 1962, Lawrence and Bossert 1967, Paradiso 1968, Gipson et al. 1974, Richens and Hugie 1974, Elder and Hayden 1977, Mahan et al. 1978, Nowak 1979) have used some of the characteristics employed in the present study; however, few attempts have been made to examine the relationships among characteristics in canid groups. Our results (large correlation coefficients between certain variates) indicated that several characteristics clustered together in a manner which suggested a degree of redundancy. Many of the characteristics probably represent adaptive complexes and should not be considered independently. However, our study supports past work in indicating that coyotes, dogs, wolves, and hybrids of these groups can be distinguished using a relatively small number of selected skull characteristics.

Kellogg (1939) summarized the status of the gray wolf, red wolf, and coyote in Tennessee. He gave no current records of wolves in his accounts. Nowak (1979) reported that *C. rufus* was distinct from *C. lupus,* and since there was no evidence that *C. lupus* existed in the southeastern United States in the 20th century, the gray wolf need not be considered in systematic studies concerning the present study. Additionally, with the lack of recent records, it is not surprising to find little evidence of red wolf genes in the Tennessee canid population.

Feral dogs occur in many parts of Tennessee and offer an opportunity for hybridization with coyotes. However, there was little statistical evidence of blending of coyotes and dogs in the state. Our results supported previous studies (Gipson et al 1974, Freeman 1976, Elder and Hayden 1977, and Nowak 1979) which indicated that the coyote is the predominant wild canid in the southeastern United States. Since Tennessee canids cluster distinctly with coyotes and are statistically separable from known dog and red wolf groups, and since hybridization between canid taxa in Tennessee is at best only minor, the wild canid occurring in Tennessee is best referred to as coyote.

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