Taxonomic Assessment of Coyotes and Domestic Dogs in the Southeastern United States

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Abstract: To assess the taxonomic status of coyotes (*Canis latrans*) and domestic dogs (*C. familiaris*) in the southeastern United States, 380 skulls of unknown canids were compared to known skulls of these taxa. Twenty-four cranial characters were employed in a discriminant function analysis to separate statistically unknown canids as to coyote or dog. Hybridization between taxa was minimal. Our results indicate that the predominant wild canid occurring in the southeastern United States is coyote. The method of distinguishing coyotes from dogs based on a ratio of 2 skull features (length of the upper molar tooth row divided by palatal width between the upper first premolars) appears to be useful for separating these taxa.

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In recent years, reports of coyote-like, wild canids have increased in the southeastern United States. Presently, such animals have apparently become well established in many parts of this region (Bekoff 1982). Taxonomically, the coyote-like animal could represent coyote (*Canis latrans*), red wolf (*C. rufus*), gray wolf (*C. lupus*), domestic dog (*C. familiaris*), or hybrids of these taxa. However, the taxonomic status of canids in the southeastern United States is less questionable than once thought. Nowak (1979) found no evidence that gray wolves existed in the southeastern United States in the 20th century and that the species need not be considered in systematic studies in this region. Additionally, wild populations of red wolves do not exist having been extirpated from many states for several decades. Coyote-like canids in the southeastern United States probably stemmed in part from *C. l. frustror* (Lydeard and Kennedy 1988), which is a taxon modified in the 20th century through hybridization with the red wolf (Nowak 1979). Feral dogs also oc-

cur in many parts of the southeastern United States and offer opportunity for hybridization with coyotes. Therefore, wild canids in this region are likely coyotes, dogs, or hybrids of these taxa.

Introgression of domestic dog genes into wild canid populations may have modified canid populations in the southeastern United States. Part of this speculation may have resulted from the reported hybridization of coyotes and red wolves in areas where the 2 species previously coexisted (Nowak 1979) and from reports of introgression of genes between coyotes and wolves and between coyotes and dogs (Gier 1957, Lawrence and Bossert 1967, Silver and Silver 1969, Mengel 1971, Bekoff et al. 1975, Hilton 1978, Mahan et al. 1978). However, at present, little information is available on the taxonomic status of coyotes, feral dogs, or their hybrids in the southeastern United States. With the exception of Smith and Kennedy (1983) and Lydeard et al. (1986), no studies have assessed the taxonomic status of wild canids in this region east of the Mississippi River. Our objective was to examine the taxonomic relationships of coyotes and domestic dogs from 4 southeastern states (Ala., Ga., Miss., and Tenn.,). Additionally, we assessed Howard's (1949) method for distinguishing skulls of coyotes and domestic dogs.

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Methods

We recorded 24 skull measurements from 380 wild adult canids (207 males and 173 females) from Alabama (N = 32; Alabama or Mississippi, N = 2), Georgia (N = 11), Mississippi (N = 51), and Tennessee (N = 280). Additionally, 166 known coyotes and 28 known domestic dogs were assessed. Skull measurements were: (A) greatest skull length, (B) cranial height, (C) least zygomatic process-jugal height, (D) canine diameter, (E) zygomatic width, (F) braincase width, (G) posterior interorbital width, (H) greatest width across I3 at alveoli, (I) anterior interorbital width, (J) width across P4s, (K) width between alveoli of Pls (palatal width between the upper first premolars), (L) canine-M2 length, (M) Pl-M2 length (length of the upper molar toothrow), (N) orbital length, (O) premaxillary-palatine length, (P) premaxillary-M2 length, (Q) skull height at pterygoids, (R) skull height at bullae, (S) skull height at condyles, (T) skull height at palatine, (U) M2 width (descriptions of characters A-U are given in Lydeard et al. 1986; for corresponding descriptions of most characters, see Kennedy et al. 1986), (V) least rostral width, (W) greatest nasal length, and (X) greatest nasal width.

All coyote skulls were examined at the National Museum of Natural History and represented individuals thought to be "pure" coyote from localities west of the Mississippi. Domestic dog skulls examined were at the Memphis State University

Museum of Zoology. Preliminary analysis showed no sexual dimorphism in dogs; therefore, males and females were pooled for statistical analysis. Adult specimens were determined according to criteria of Nellis et al. (1978). Skull dimensions were taken with a dial height gauge and dial calipers to the nearest 0.1 mm.

Linear discriminant function analysis was used to determine the taxonomic status of unknown wild canids (as coyotes or dogs) and to characterize the general pattern of morphological differentiation among the unknown canids. Biometric routines were carried out with the Statistical Package for the Social Sciences, (Nie et al. 1975). The length of the upper molar tooth row divided by palatal width between the upper first premolars was used to distinguish skulls of coyotes and domestic dogs (Howard 1949). A M/K ratio of ≥ 3.1 characterized coyotes, and a ratio of <2.7 characterized domestic dogs; 2.7–3.0 indicated possible hybrids.

Results

Using coyotes (combined sexes) and dogs as knowns and canids from the southeastern United States as unknowns in a discriminant function analysis (Test 1), 13 characters were found in combination to be useful discriminators (Table 1). Characters A, N, R, E, M, and S were the most useful discriminators based on correlation between discriminating variables and the canonical discriminant function. A

Table 1. Standarized canonical discriminant function coefficients of canid skull characters[a] from the southeastern United States.

Test 1[b]		Test 2[c]		Test 3[d]	
Character	Function	Character	Function	Character	Function
A	−1.13	A	−2.23	E	−1.03
E	−0.69	E	−0.88	R	0.77
S	0.47	S	0.66	F	−0.56
R	0.69	R	0.75	O	−0.70
T	−0.35	L	0.73	M	−0.68
F	−0.17	M	−1.00	K	0.44
M	−0.47	H	0.63	N	0.62
H	0.29	N	1.35	D	0.26
K	0.33	U	0.46	G	0.29
N	0.79	G	−0.30	V	0.59
D	0.19	V	0.60	W	0.38
U	0.21				
V	0.45				

[a]Characters: A–greatest skull length; D–canine diameter; E–zygomatic width; F–braincase width; G–posterior interorbital width; H–greatest width across I3 at alveoli; K–width between alveoli of P1s; L–canine-M2 length; M–P1-M2 length; N–orbital length; O–premaxillary-palatine length; R–skull height at bullae; S–skull height at condyles; T–skull height at palatine; U–M2 width; V–least rostral width; and W–greatest nasal length (see text for more details).

[b]Analysis with canids from the southeastern United States as unknowns, and known coyotes and dogs (sexes combined in all groups).

[c]Analysis with canids from the southeastern United States as unknowns (males), and known coyotes (males) and dogs.

[d]Analysis with canids from the southeastern United States as unknowns (females), and known coyotes (females) and dogs.

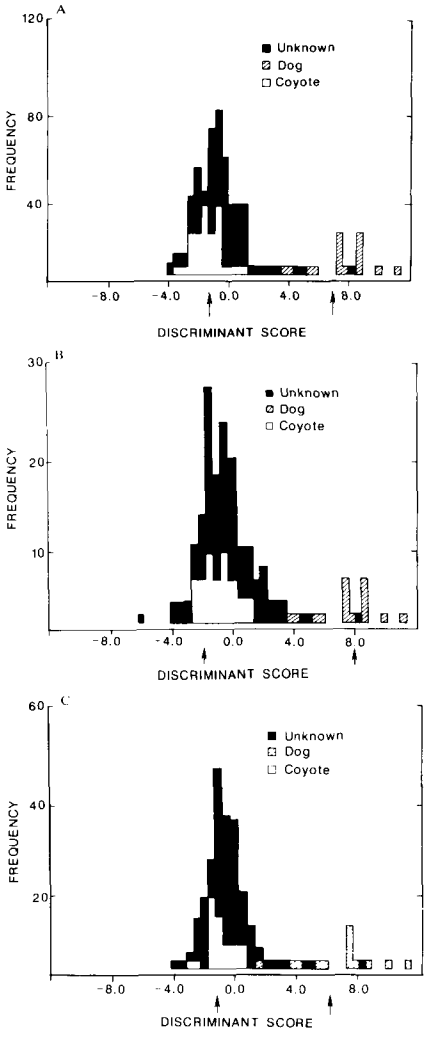

Figure 1. Histograms from discriminant function analyses applied to unknown wild canids from the southeastern U.S. (A) using coyotes (combined sexes) and dogs as knowns, and wild canids as unknowns; (B) using dogs and male coyotes as knowns, and wild canids (males) as unknowns; (C) using dogs and female coyotes as knowns, and wild canids (females) as unknowns. Arrows point to the mean discriminant score for known coyote and dog groups.

histogram of the discriminant scores for each animal (Fig. 1A) indicated that the known groups were distinctly different; 100% of the grouped cases (i.e., known coyotes and dogs) were classified correctly. Of the 380 unknown canids, 97.6% (371) were classified as coyotes, and 2.4% (9) were classified as dogs ($r = 0.93$, $P < 0.001$).

When discriminant function analysis was applied to the character set using dogs and male coyotes as knowns and wild canids (males) as unknowns (Test 2), 11 characters were useful discriminators (Table 1). Characters A, N, M, E, R, and L were the best discriminating characters. All known coyotes and dogs were classified

correctly, (Fig. 1B), and 93.0% (193) of the unknown, male canids were classified as coyotes; 7.0% (14) were classified as dogs ($r = 0.97, P < 0.001$).

When treating dogs and female coyotes as known groups and female wild canids as an unknown group (Test 3), 11 characters were useful discriminators (Table 1). Characters E, R, O, M, and N were the most heavily weighted characters based on standardized discriminant function coefficients (Table 1). All known dogs and female coyotes were classified correctly (Fig. 1C). Of the unknown female wild canids, 97.7% (169) were classified as coyotes, and 2.3% (4) were classified as dogs ($r = 0.95, P < 0.001$).

Using the M/K ratio to assess skulls of known groups (coyotes and dogs), 98.2% (163) of the coyotes had ratios ≥ 3.1 (1.8% were between 2.7 and 3.0, $N = 3$), and all dogs had ratios <2.7. Of 207 unknown males and 173 unknown females, 19 animals (Ala. = 1 male; Miss. = 1 male; Tenn. = 8 males, 8 females, 1 unknown sex) had ratios between 2.7 and 3.0. The individuals having ratios between 2.7 and 3.0 also had intermediate discriminant function scores (grouped as intermediates between knowns, Fig. 1). Ninety-five percent (361) of the unknowns were classified as coyotes or dogs based on ratio values. Considering all coyotes that grouped as intermediates between knowns as hybrids (Fig. 1), a maximum of 12.6% (males, $N = 26$) and 10.4% (females, $N = 18$) hybridization is suggested.

Discussion

Various combinations of characters have been used to separate canid groups. Howard (1949) and Lawrence and Bossert (1967) found no single feature that would successfully distinguish canid taxa. However, several studies (e.g., Lawrence and Bossert 1967, Mengel 1971, Gipson et al. 1974, Richens and Hugie 1974, Mahan et al. 1978, Freeman and Shaw 1979, Smith and Kennedy 1983, Lydeard et al. 1986) have shown multiple character analysis (linear discriminant techniques) to reliably identify canids. Our results also show several characters in combination can separate canid groups. Characters found to be most heavily weighted based on standardized discriminant function coefficients in our study are among the characters reported in previously mentioned investigations as useful discriminators for canid groups. Discrepancies between best discriminators across studies may be due to high correlations among many characters (Smith and Kennedy 1983). Our study supports their conclusion that coyotes, dogs, and hybrids of these groups can be distinguished using a relatively small number of selected skull characters. These measurements include characters that reflect the length and width of the rostrum, maxilla, and palatine bones.

Hybridization between the coyote and the domestic dog was noted as early as 1885 (Seton 1929). Hybrids between these 2 species are found in the wild (Mengel 1971); but, in general, the percentage is low. Our results suggest little evidence of coyote and domestic dog hybridization in populations east of the Mississippi River and is within the range reported for Tennessee (Smith and Kennedy 1983, Lydeard

et al. 1986) and other parts of the southeastern United States; for example 0.006% in Louisiana (Goertz et al. 1975), 10.0% in Missouri (Elder and Hayden 1977), 13.0% in Oklahoma (Freeman and Shaw 1979), 13.0 and 16.0% in Arkanses (Gipson et al. 1974), and 0.008% in several southern states west of the Mississippi River (Nowak 1979). Nowak (1979) discussed the influence of the domestic dog on wild *Canis* of the southeastern United States and concluded that there was no statistical blending of wild canids and domestic dogs and no suggestion of introgression from the domestic dog into any of the wild populations. Mengel (1971) noted the lack of evidence for any typical hybrid swarm (i.e. the persistence of a hybrid population, consisting of Fl's and backcrosses) of dogs and coyotes. Fears of a larger and aggressive coyote-dog hybrid resulting from introgression of the domestic dog into coyote populations have not been realized, and stabilized populations of coyotes and domestic dog hybrids are apparently unlikely in the future. There is substantial evidence that the predominant wild canid occurring in the southeastern United States is coyote.

Bekoff (1977, 1982) indicated that the method (M/K) proposed by Howard (1949) for distinguishing skulls of coyotes and dogs was about 95% reliable. Our results suggest a comparable level of accuracy. Howard (1949) indicated this technique could be employed using most any measuring device and that skulls could be differentiated even with flesh present and under field conditions. Since the M/K ratio has a high degree of reliability and can be used in combination with distinguishing external features of canids, it should provide investigators and managers in the southeastern United States with a useful technique for readily identifying coyotes and dogs under most conditions.

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