The Taxonomic Status of Wild *Canis* in Kentucky

John J. Cox,[1] *Morehead State University, Department of Biological and Environmental Sciences, Morehead, KY 40351*

Leslie Meade, *Morehead State University, Department of Biological and Environmental Sciences, Morehead, KY 40351*

David C. Yancy, *Kentucky Department of Fish and Wildlife Resources, Frankfort, KY 40601*

David S. Maehr, *University of Kentucky, Department of Forestry, 203 T.P. Cooper Bldg., Lexington, KY 40546*

Abstract: We assessed taxonomic status of wild canids in Kentucky using 13 cranial measurements on 143 known canid skulls in a multivariate statistical procedure to classify 56 unknown canid skulls from Kentucky. Discriminant function analyses revealed complete separation of canid taxa between coyotes and dogs, although coyote-dog hybrids had significant overlap with coyotes. Hybridization between coyotes and dogs in Kentucky occurred in less than 10% of unidentified canids. Our findings suggest that wild canids in Kentucky are best classified as coyotes, *Canis latrans*.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 55:408–417

The coyote, *Canis latrans*, is an 8–20 kg canid whose pre-settlement distribution primarily included the central plains and deserts of North America (Young and Jackson 1951). Concurrent with human settlement and large predator eradication was the rapid expansion of coyotes across most of North America, including all 48 contiguous states and Alaska (Parker 1995). Associated with the coyote's movement east has been an apparent increase in body size compared to western conspecifics, especially in southeastern Canada and New England, a phenotype often characterized as having wolf and/or dog-like characteristics (Lawrence and Bossert 1969, Nowak 1978, Schmitz and Kolenosky 1985, Schmitz and Lavigne 1987, Thurber and Peterson 1991). In the southeastern United States, the coyote phenotype shows only a slight increase in body size, and is often described as having red wolf characteristics (McCarley 1962).

Rapid acquisition of wolf or dog-like characteristics by the eastern coyote and lack of these changes in other areas of expansion suggests hybridization between coyotes and conspecific canids (Hilton 1978). Coyotes have been reported to hybridize with dogs (Young and Jackson 1951, Kennedy and Roberts 1969, Silver and Silver

1. Present address: University of Kentucky, Department of Forestry, 215 T.P. Cooper Bldg., Lexington, KY 40546-0073.

1969, Mengel 1971), gray wolves (Kolenosky 1971), and red wolves (Paradiso 1968, Gipson et al. 1974). Interspecific aggression and killing of coyotes by wolves may limit hybridization except under intense reproductive pressures (Mech 1966, Peterson 1977, Carbyn 1982). However, hybridization between coyotes and dogs appears to be more probable. Coyote-dog hybrids, or coydogs, are frequently found in areas of recent coyote expansion (Andrews and Boggess 1978, Weeks et al. 1990) or in areas where large populations of dogs occur (Mahan et al. 1978). Feral dogs are often the same size as coyotes and their diets are similar (Gipson and Sealander 1976), suggesting that coyotes, feral dogs, and some free-ranging dogs occur (Mahan et al. 1978). Feral dogs are often the same size as coyotes and their diets are similar (Gibson and Sealander 1976), suggesting that coyotes, feral dogs, and some free-ranging domestic dogs may occupy similar ecological niches (Gipson 1978). Establishment and successful reproduction by coydog populations may be limited due to behavioral and physiological factors (Mengel 1971, Gipson et al. 1974, Gipson 1978).

Coyotes immigrated into Kentucky approximately 50 years ago. Although Barbour and Davis (1974) listed the coyote as "too scarce to be of any economic significance," they have since become well-established statewide with populations greatest in the western portion of the state (Cramer 1995). Although coyotes have been well studied in many parts of their current range, ecological and taxonomic data in Kentucky is lacking. Our objective was to gain an understanding of the taxonomic status and assess the degree of hybridization of this naturalized canid in Kentucky.

We acknowledge the Morehead State University Roger W. Barbour Vertebrate Research Fund for financial support of this project. We thank the California Academy of Sciences, the Academy of Natural Sciences Philadelphia, University of California Berkeley Museum of Vertebrate Zoology, University of Illinois Museum of Natural History at Urbana-Champaign, Cornell University Mammalogy Collection, Austin Peay State University, Murray State University, Eastern Kentucky University, Morehead State University, and the University of Kentucky for allowing use of their mammal collections. A special thanks to R. Fischer of the National Museum of Natural History for assistance during our visit. We also thank the Kentucky Department of Fish and Wildlife Resources, Dr. S. Rundell at Morehead State University, and a number of taxidermists for canid specimens. D. Magrane, G. Gearner, C. Tuerk, and M. Lacki made earlier reviews of the manuscripts. Special thanks to M. Lambat and L. Meade, Jr. for assistance. This paper is contribution 01-09-126 of the Kentucky Agriculture Experiment Station and has the approval of the station director.

Methods

To determine taxonomic status of coyote-like wild canids in Kentucky and detect potential hybridization events, we used 19 linear cranial measurements (Fig. 1) previously identified as useful to separate wild and domestic canids (Wayne 1986, Lydeard et al 1988). We performed a linear discriminant function analysis of 143 known canid skulls (101 coyotes, 25 coydogs, and 17 dogs) to classify 56 unknown wild canids from Kentucky and determine which variables were most useful in sepa-

rating canid taxa (Jolicoeur 1959). We obtained known canid specimens from collections across the United States and Canada (Table 1) and subsequently performed a linear discriminant function analysis to confirm their taxonomic classification. Known specimens were selected to be inclusive of widely separated coyote subspecies in order to compensate for exceptionally large or small coyotes encountered in Kentucky. Specimens of Kentucky canids considered as unknowns were obtained from Kentucky Department of Fish and Wildlife Resources personnel, taxidermists, hunters, road kills, and available university specimens. Measurements were taken using a vernier caliper and recorded to the nearest 0.1 mm. Adult specimens were determined using the criteria of Gier (1968). Because juvenile coyote skulls typically

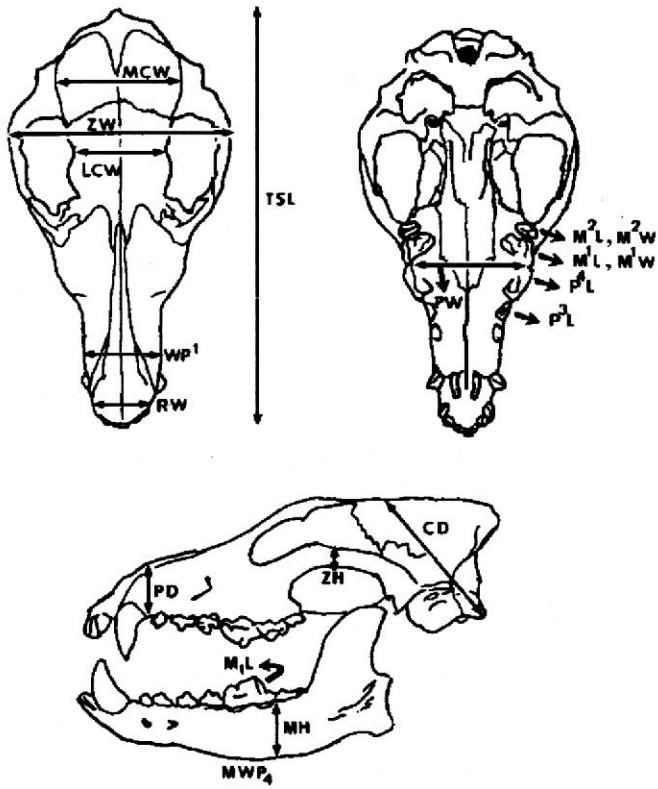

Figure 1. Description of cranial measurements: TSL, total skull length; RW, rostrum width; PW, palatal width; ZH, zygomatic height; MH, mandible height; CD, cranial depth; PD, palatal depth; ZW, zygomatic width; MCW, maximum cranial width; LCW, least cranial width; WP^1, rostrum width at first premolar; M^1L, length of first lower molar; MWP_4, mandible width at fourth lower premolar; P^3L, length of third upper premolar, P^4L, length of fourth upper premolar; M^1L, length of first upper molar; M^1W, width of first upper molar; M^2L length of second upper molar; M^2W, width of second upper molar (modified from Wayne 1986).

Table 1. Sampling locales of canid skulls in the United States and Canada used in a discriminant function analysis of Kentucky canids (1996–1997).

Species	*N*	Subspecies	*N*	Locale	*N*
Canis latrans	101	*thamnos*	30	Ill.	10
				Ind.	9
				Mich.	5
				Mo.	6
				N.Y.	19
				Ontario	1
		frustror	17	Ala.	5
				Ark.	6
				Mo.	6
		incolatus	5	Alaska	1
				British Columbia	4
		texensis	5	Texas	5
		lestes	8	Calif.	3
				Wyo.	5
		ochropus	10	Calif.	10
Canis familiaris	17			Ky.	17
C. latrans x *C. familiaris*	25				
				Ala.	1
				Ill.	4
				Ind.	2
				Ky.	1
				Maine	5
				Mo.	2
				N.D.	1
				N.Y.	1
				Okla.	2
				S.D.	1
				Va.	1
				W. Va.	4
Unknown canids	56			Ky	56
Total canids	199				

resemble those of western conspecifics (Moore and Millar 1987), they were pooled with adult skulls for all analysis.

Preliminary analysis showed sexual dimorphism within coyotes, and we thus conducted separate analyses by sex. Because of insufficient information on sex for dog, coydog, and unknown specimens, data were pooled for those groups in all analyses. We standardized cranial variables by dividing all measures by total skull length. Upon initial examination, 7 variables (TSL, RW, MCW, LCW, CD, P^4L, M^2L) were eliminated because they did not meet the equality of variance assumption. We used the remaining 12 cranial variables for all subsequent analyses. Statistical analyses were carried out using SAS version 6.2 (SAS 1992).

Table 2. Standardized canonical discriminant function coefficients of canid skull characteristics from the United States and Canada.

Test 1[a]		Test 2[b]		Tests 3[c]	
Character	Function	Character	Function	Character	Function
PW	0.91	PW	0.92	PW	0.91
WP^1	0.67	M^2W	–0.72	WP^1	0.70
ZW	–0.64	WP^1	0.65	M^2W	–0.69
M^2W	–0.63	P^3L	–0.56	ZW	–0.69
		MH	0.54		

a. Analysis using coyotes, dogs, and coydogs as knowns (sexes pooled for all groups) and Kentucky canids as unknowns.
b. Analysis using coyotes, dogs, and coydogs as knowns (males only for all groups) and Kentucky canids as unknowns (sexes pooled).
c. Analysis using coyotes, dogs, and coydogs as knowns (females only for all groups) and Kentucky canids as unknowns (sexes pooled).

Results

Using coyotes (pooled sexes), dogs, and coydogs as knowns and Kentucky canids as unknowns in a discriminate function analysis, 4 cranial characters (PW, WP^1, ZW, M^2W) (Table 2, Test 1) were found to be the best discriminating variables. Among canid groups, separation was distinct between coyotes and dogs; however, some overlap did occur between coyotes and coydogs (Fig 2). All known dogs were classified correctly, while 99% (100) of coyotes were classified correctly; 1% (1) were coydog (Table 3, Test 1). Only 76% (19) of coydogs were classified correctly, the remaining 24% (6) were coyotes. Most unknown canids were classified as coyote (87.5%), with 5 classified as coydog (9%) and 2 as dog (3.5%) ($r = 0.74$, $P < 0.001$).

Using coyotes (males only), dogs, and coydogs as knowns and Kentucky canids as unknowns, 5 cranial characters (PW, M^2W, WP^1, P^3L, MH) (Table 2, Test 2) were found to be the best discriminating variables. All known canid groups were classified correctly (Table 3, Test 2). Unknown canids were classified as coyote (87.5%), with 4 classified as coydog (7%) and 3 as dog (5.5%; $r = 0.83$, $P < 0.001$).

When using female coyotes, dogs, and coydogs as knowns and Kentucky canids as unknowns, 4 cranial characters (PW, WP^1, M^2W, ZW; Table 2, Test 3) were found to be the best discriminating variables. All known dogs, 95% (62) of coyotes, and 94% (15) of coydogs were classified correctly, with 3 (5%) coyotes being classified as coydogs, and 1 (6%) coydog being classified as coyote (Table 3, Test 3). Unknown canids were classified as coyote (87.5%), with 4 classified as coydog (7%) and 3 as dog (5.5%) ($r = 0.78$, $P < 0.001$) (Fig. 3).

Discussion

Discriminant analysis of known canid taxa revealed strong separation among groups and allowed successful classification of unknown specimens. Of 12 cranial variables in our analysis, only 5 (P^3L, PW, M^2W, WP^1, ZW) were strong discrimina-

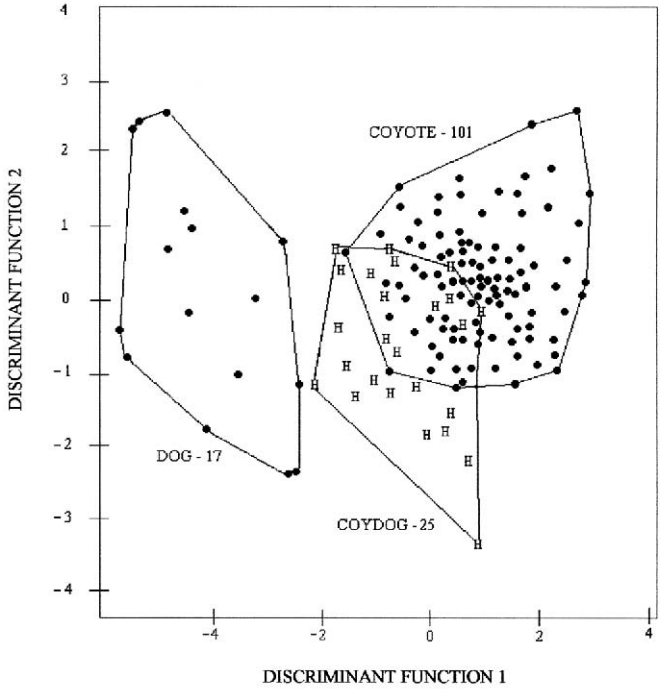

Figure 2. Discriminant values for *Canis latrans* (•), *Canis familiaris* (•), and *C. latrans* x *familiaris* hybrids (H) showing ranges for individuals of each species. Sample size follows the name.

Table 3. Canid discriminant function analysis classification table of known canids from the United States and Canada applied to unknown Kentucky canids.

	Percent of Predicted Group Membership								
	Test 1[a]			Test 2[b]			Test 3[c]		
Group	Coyotes	Dogs	Coydogs	Coyotes	Dogs	Coydogs	Coyotes	Dogs	Coydogs
Coyotes	99	—	1	100		—	95	—	5
Dogs	—	100	—	—	100	—	—	100	—
Coydogs	24	—	76	—	—	100	6	—	94
Unknowns	87.5	3.5	9	87.5	5.5	7	89	9	2

a. Analysis using coyotes, dogs, and coydogs as knowns (sexes pooled for all groups) and Kentucky canids as unknowns.

b. Analysis using coyotes, dogs, and coydogs as knowns (males only for all groups) and Kentucky canids as unknowns (sexes pooled).

c. Analysis using coyotes, dogs, and coydogs as knowns (females only for all groups) and Kentucky canids as unknowns (sexes pooled).

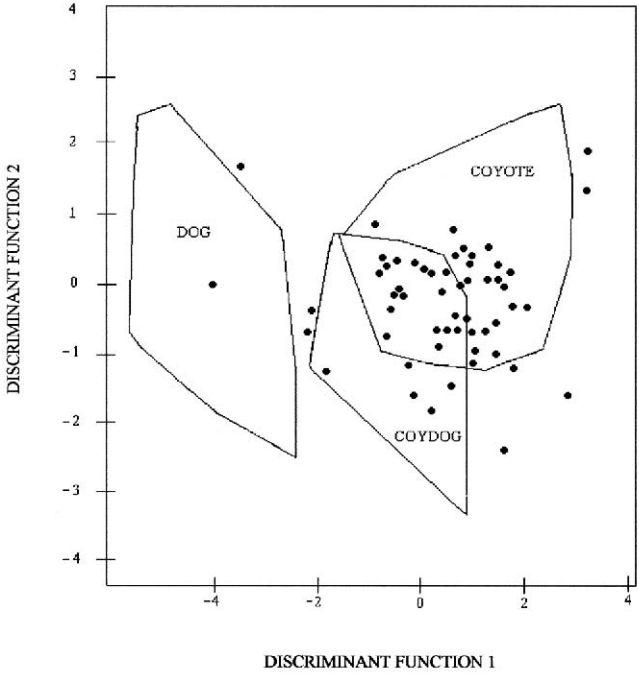

Figure 3. Discriminant values of unknown Kentucky canids (•) in relation to known canid groups.

tors among canid taxa. These results confirm the results of previous studies that found these cranial characters useful to separate canid taxa (Wayne 1986, Smith and Kennedy 1983). The strong discriminating power of palatal width, zygomatic width, and width at premolar one reflect distinct morphological differences associated with crushing power of the cranial structure among canid taxa (Nowak 1979, Wayne 1986). Coyotes are evolutionarily older, tend to have long teeth, long rostrums in relation to palatal width, narrow zygomatic widths, and unpronounced sagital crests, a reflection of their unspecialized morphology and more omnivorous lifestyle. In contrast, wolves are more specialized, tend towards carnivory, and are generally wider across the palate to accommodate larger teeth (Lawrence and Bossert 1967, Nowak 1979). Nowak (1978) has suggested that the coyote's unspecialized morphology has contributed to its recent colonization of North America.

Our findings support the use of combinations of cranial characteristics as a reliable method to separate closely related canid taxa (Jolicoeur 1959, Lawrence and Bossert 1967, Wayne 1986). Although multivariate statistics are particularly useful for their ability to maximize separation among groups, Howard (1949) provides a more rapid classification method for small sample sizes of canids. Howard's method uses the ratio of the upper molar tooth-row divided by the palatal width to distinguish between coyotes and dogs. Using this method, canids with a ratio of $\leq$2.7 or less are classified as dogs, those $\geq$3.1 are classified as coyotes, and those occurring between

2.7–3.1 are classified as hybrids. Beyond its inherent simplicity, this method can be used in the field without removal of the flesh from skulls. The results of canid classification using the Howard method have been found to be 95% comparable with those obtained from multivariate analysis (Bekoff 1977, Lydeard et al. 1988).

Our results confirm previous findings that indicate minimal occurrence of hybridization (<10%) between coyotes and dogs in the eastern United States (Elder and Hayden 1976, McGinnis 1979, Lydeard and Kennedy 1988, Lydeard et al. 1988, Weeks et al. 1990). The possibility exists that previous hybridization with red wolves has influenced the phenotype of coyotes in Kentucky and elsewhere in the southeastern United States (McCarley 1962). Such hybridization may be expressed in cranial traits and body mass, as coyotes in Kentucky have an average larger body mass than their western conspecifics (J.J. Cox, unpubl. data).

Although reports of coyote-dog hybrids will continue, most are likely the result of misidentification of feral or stray dogs. Coyotes have been in Kentucky for nearly 50 years, and have become prevalent in most parts of the state (Cramer 1995). If coyote hybridization occurs more frequently at the leading edge of colonization fronts, then detection of such events would be difficult after the first few years of invasion. Coyotes have been found to disperse >50 km from established home ranges in Kentucky (J.J. Cox, unpubl. data) and Mississippi (Chamberlain et al. 2000), thus revealing the potential for rapid colonization given the coyote's high fecundity. Based on our findings, wild canids in Kentucky are best classified as *Canis latrans*, coyote.

Literature Cited

Andrews, R.D. and E.K. Boggess. 1978. Ecology of coyotes in Iowa. Pages 249–265 *in* M. Bekoff, ed. Coyotes: biology, behavior and management. Acad. Press, New York. 384pp.

Barbour, R.W. and W.H. Davis. 1974. Mammals of Kentucky. Univ. Press Ky., Lexington, Ky. 322pp.

Bekoff, M. 1977. *Canis latrans*. Mammal. Species 79:1–9.

Carbyn, L.N. 1982. Coyote population fluctuations and spatial distribution in relation to gray wolf territories in Riding Mountain National Park, Manitoba. Can. Field Nat. 96:176–183.

Chamberlain, M.J., C.D. Lovell, and B.D. Leopold. 2000. Spatial-use patterns, movements, and interactions among adult coyotes in central Mississippi. Can. J. Zool. 78:2087–2095.

Cramer, M. 1995. Furbearer highway mortality study. Ky. Dep., Fish and Wildl. Resour., Frankfort, Ky. 21pp.

Elder, W.H. and C.M. Hayden. 1976. Use of discriminant function in taxonomic determination of canids from Missouri. J. Mammal. 58:17–24.

Gier, H.T. 1968. Coyotes in Kansas. Kan. State Coll. Agric. Exp. Sta. Bull. 393: 118pp.

Gipson, P.S. 1978. Coyotes and related *Canis* in the southeastern United States with a comment on Mexican and Central American *Canis*. Pages 191–208 *in* M. Bekoff, ed. Coyotes: biology, behavior and management. Acad. Press, New York. 384pp.

_____ and J.A. Sealander. 1976. Changing food habits of wild *Canis* in Arkansas with emphasis on coyote hybrids and feral dogs. Am. Midl. Nat. 95:249–253.

_____, _____, and J.E. Dunn. 1974. The taxonomic status of wild *Canis* in Arkansas. Syst. Zool. 23:1–11.

Hilton, H. 1978. Systematics and ecology of the eastern coyote. Pages 209–228 *in* M. Bekoff, ed. Coyotes: biology, behavior and management. Acad. Press, New York. 384pp.

Howard, W.E. 1949. A means to distinguish skulls of coyotes and domestic dogs. J. Mammal. 30:169–171.

Jolicoeur, P. 1959. Multivariate geographical variation in the wolf Canis lupus. Evolution 13:283–299.

Kennedy, J.J. and J.D. Roberts. 1969. Fertility of coyote-dog hybrids. J. Mammal. 50:830–831.

Kolenosky, G.B. 1971. Hybridization between wolf and coyote. J. Mammal. 52:446–449.

Lawrence, B.L. and W.H. Bossert. 1967. Multiple character analysis of *Canis lupus*, *latrans*, and *familiaris*, with a discussion of the relationships of *Canis niger*. Am. Zool. 7:223–232.

_____ and _____. 1969. The cranial evidence for hybridization in New England *Canis*. Breviora 330:1–12.

Lydeard, c. and M.L. Kennedy. 1988. Morphological assessment of recently founded populations of the coyote, *Canis latrans*, in Tennessee. J. Mammal. 69:773–781.

_____, _____, and E.P. Hill. 1988. Taxonomic assessment of coyotes and domestic dogs in the southeastern United States. Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies 42:513–519.

Mahan, B.R., P.S. Gipson, and R.M. Case. 1978. Characteristics and distribution of coyote x dog hybrids collected in Nebraska. Am. Midl. Nat. 100:408–415.

McCarley, H. 1962. The taxonomic status of wild *Canis* (Canidae) in the southcentral United States. Southwest. Nat. 7:227–235.

McGinnis, H.J. 1979. Pennsylvania coyotes and their relationship to other wild *Canis* populations in the Great Lakes region and the northeastern United States. M.S. Thesis, Penn. St. Univ., University Park, Pa. 227pp.

Mech, L.D. 1966. The wolves of Isle Royale. U.S. Natl. Park Fauna Series. 7:1–210.

Mengel, R.M. 1971. A study of dog-coyote hybrids and implications concerning hybridization in *Canis*. J. Mammal. 52:316–336.

Moore, G.C. and J.S. Millar. 1987. Observations on cranial differences between juvenile and adult eastern coyotes, *Canis latrans*. Can. Field Nat. 101:461–463.

Nowak, R.M. 1978. Evolution and taxonomy of coyotes and related *Canis*. Pages 3–16 *in* M. Bekoff, ed. Coyotes: biology, behavior and management. Acad. Press, New York, 384pp.

_____. 1979. North American Quarternary *Canis*. Univ. Kan. Publ., Mus. Nat. Hist., Monogr. 6:154pp.

Parker, G.R. 1995. The eastern coyote. Nimbus Publ., Halifax, Can. 254pp.

Paradiso, J. 1968. Canids recently collected in east Texas, with comments on the taxonomy of the red wolf. Am. Midl. Nat. 80:529–534.

Peterson. R.O. 1977. Wolf ecology and prey relationships on Isle Royal. U.S. Natl. Park Serv. Monogr. Series. 11:1–210.

Schmitz, O.J. and G.B. Kolenosky. 1985. Wolves and coyotes in Ontario: morphological relationships and origins. Can. J. Zool. 63:1130–1137.

_____ and D.M. Lavigne. 1987. Factors affecting body size in sympatric Ontario *Canis*. J. Mammal. 68:92–99.

Silver, H. and W.T. Silver. 1969. Growth and behavior of the coyote-like canid of northern New England with observations on canid hybrids. Wild. Monogr. 17:1–41.

Smith, R.A. and M.L. Kennedy. 1983. Taxonomic status of the coyote in Tennessee. Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies 37:219–227.

Thurber, J.M. and R.O. Peterson. 1991. Changes in body size associated with range expansion in the coyote *(Canis latrans)*. J. Mammal. 72:750–755.

Wayne, R.K. 1986. Cranial morphology of domestic and wild canids: the influence of development on morphological change. Evol. 40:243–261.

Weeks, J.L., G.M. Tori, and M.C. Shieldcastle. 1990. Coyotes *(Canis latrans)* in Ohio. Ohio J. Sci. 90:142–145.

Young, S.P. and H.H.T. Jackson. 1951. The clever coyote. Wildl. Manage. Inst., Washington, D.C. 411pp.