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A Comparison of Body Mass of *Canis latrans* (Coyotes) Between Eastern and Western North America

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Abstract - Contrary to previous literature concluding that body size of *Canis latrans* (coyotes) does not increase in North America with decreasing longitude, this study presents data from different regions and concludes that northeastern coyotes are the largest extant version of coyote. Male coyotes from northeastern North America (16.4 ± 1.5 [SD] kg, range = 14.2–20.4) were heavier than females from the northeast (14.7 ± 1.6 kg, range = 11.9–17.9) and were also heavier than male (10.6 ± 1.0 kg, range = 8.8–12.0) and female coyotes (12.1 ± 1.1 kg, range = 10.5–14.1) from outside of the northeast. Female coyotes from northeastern North America were heavier than all male and female western coyotes. Longitude was significantly correlated in both male ($r = -0.786$, $P < 0.0001$) and female ($r = -0.769$, $P < 0.0001$) body mass, whereas there was less of a correlation for latitude and body mass for males ($r = 0.355$, $P = 0.043$) and females ($r = 0.364$, $P = 0.044$). Sixty-two percent ($P < 0.0001$) and 59% ($P < 0.0001$) of variation in body mass of males and females, respectively, could be explained by longitude, while 13% ($P = 0.043$ for males; $P = 0.044$ for females) could be accounted for by latitude.

Introduction

The eastern coyote is often described as a large version of *Canis latrans* (Say); however there is limited amount of work which has summarized coyote body size in northeastern North America (e.g., Gompper 2002, Thurber and Peterson 1991). Previously, Thurber and Peterson (1991), Larivière and Crête (1993), and Peterson and Thurber (1993) provided data, comments, discussion, and theories on the size of *Canis latrans* (eastern coyotes; Lawrence and Bossert 1969). Thurber and Peterson (1991) stated that some of the weights reported in the northeast (e.g., Silver and Silver 1969) were extreme values which contributed to the presumption of larger size of coyotes in northeastern North America relative to other regions of North America. These authors concluded that coyotes in the northeast were showing a phenotypic response to enhanced food supply or larger prey size, possibly involving no genetic selection. Larivière and Crête (1993) countered those claims, believing that the larger size of coyotes in northeastern North America constituted an evolutionary response to larger prey, namely *Odocoileus virginianus* Boddaert (white-tailed deer), and that increased size reflected a genotypic response to prey. Peterson and Thurber (1993), rebutting the comments of Larivière and Crête, concluded that data on body mass of coyotes are infrequently reported and that additional data, such as body

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masses from new areas of the northeast or new genetic analyses, were needed to evaluate whether the northeastern coyote was the largest extant version of coyote.

Body mass is a useful index of size differences among regions because this metric is more commonly reported in the literature than other measurements, such as body length. Thus, a large sample of body masses from different regions should give a good approximation of a species size throughout its range. However, there is not a comprehensive analysis of coyote body masses in the northeast, making it difficult to accurately compare to other regions (Thurber and Peterson 1991). Recently, several authors have reported sizes of coyotes in northeastern North America conducted during ecological and/or morphological studies (Table 1). The objective of this study was to present data on coyote body weights reported from areas of northeastern North America and compare these weights to published studies from other regions within the coyote's range. The null hypothesis was that there is no difference in body mass between coyotes in eastern North America and coyotes from other regions of the species' geographic range in North America.

Methods

I obtained body mass values via three ways. First, I analyzed the literature for published weights on coyote body mass throughout its range, but excluded data from the southeastern United States. The potential of coyotes originating from other areas (i.e., being introduced there; Hill et al. 1987), or being of questionable taxonomic status due to potential hybridization with *Canis rufus* Audubon and Bachman (red wolf) (Gipson 1978, Lydeard and Kennedy 1988, Nowak 1978), precluded analysis for the southeastern US. Second, I attempted to contact furbearer biologists from Rhode Island, Connecticut, New York, New Jersey, and Pennsylvania because there is a paucity of data published on coyote body weights from those states. Third, I obtained samples from eastern Massachusetts, including study sites in north Boston and Cape Cod (J.G. Way, unpubl. data). In my study area, I averaged weights for repeat captures (a capture was either dead [e.g., road-kill] or alive [e.g., trapped and tranquilized]; 5 females and 5 males including 6 radio-collared adults that died—i.e., the 2nd measurement) before including them in the analysis for average mass. Many studies, including the eastern Massachusetts samples reported herein (Table 1), reported live weights of coyotes taken opportunistically during ecological investigations of coyote behavior (e.g., Bowen 1982, Person 1988, Way 2000). Yet other studies analyzed dead (mostly trapped) coyotes for specific reasons such as studying body composition (Huot et al. 1995, Poulle et al. 1995) or condition (Dumond and Villard 2000).

For the studies where I obtained body-mass values, I retained those with ≥ 10 animals reported to reduce the effects of small sample sizes. Because I excluded studies with weights of < 10 individuals, some cited values from northeastern North America (Kendrot 1998, Messier and Barrette 1982,

Table 1. Reported body masses (kg) of coyotes from different regions of North America. M = male, F = female, T = total, and NA = not available. An attempt was made to only include values from coyotes known to be ≥ 2 yr, but because data from yearlings measured during winter were potentially included, these body masses should be treated as minimum averages.

Location	M	F	Source	Comments
Northeastern coyotes				
Cape Cod/E. MA	17.9	16.0	The author and Way 2000	N = 18M, 17F; 12.3–25 kg for M; 1F = 25.1
Rhode Island	16.6	15.3	C. Brown, RI Fish and Wildlife, Wakefield, RI	N = 21M, 15F; max M = 20.9 kg; F = 21.4 kg
New Hampshire	20.4	17.9	Silver and Silver 1969	N = 15M, 13F
Vermont	17.8	16.6	Person 1988	N = 10M, 7F; max = 21.4 kg
W. MA/Vermont	16.9	14.5	Lorenz 1978	N = 24M, 18F; 5M,1F ≥ 19 kg, max = 25 kg M
Adirondacks, NY	14.2	11.9	Brundige 1993	N = 19T
Maine	15.9	14.5	Hilton 1976	N = 37M, 22F
Maine	15.8	13.7	Richens and Hugie 1974	N = 28M, 20F
Maine–Down East	17.3	15.5	Harrison 1986	N = 60T; max = 20.5 kg
SE Quebec–Gaspe	16.0	14.1	Poulle et al. 1995	N = 28M, 21F; autumn–winter samples
Ontario	14.5	NA	Kolenosky 1971	N = 19M
E. New Brunswick	14.6	13.1	Dumond and Villard 2000	N = 44M, 43F
NB/Nova Scotia	16.6	15.2	Moore and Millar 1986	N = 50M,23F
Nova Scotia	15.4	12.6	Sabean 1993	N = 85M,44F; max = 21.7 kg M
Nova Scotia	16.5	13.7	Parker 1995	N = 89T; max = 25.9 kg M
Prince Edward Is.	16.0	15.0	Parker 1995	N = 90T; max = 25 kg M
Outside of northeastern North America				
Western US	11.4	10.5	Bekoff and Jameson 1975	A general average of western coyotes taking sexual dimorphism into account.
Idaho	10.7	8.9	Barnum et al. 1979	N = 56T
New Mexico	11.6	9.5	Windberg et al. 1997	N = 21M, 13F
New Mexico	11.1	10.1	Young and Jackson 1951	N = 446M, 383F; max = 18.6 kg M; 15 kg F
NE Arizona	10.5	8.8	Witham 1977	N = 10M, 7F; max = 12.7 kg M
Tucson, AZ	11.9	10.2	Grinder and Krausman 2001	N = 6M, 7F; max = 15.5 kg
North-coastal CA	11.6	10.4	Neale et al. 1998	No N given
California	10.9	9.8	Hawthorne 1971	No N, cited from 3 sources within
Kansas	13.3	11.6	Gipson and Kamler 2002	N = 5M,8F
Kansas	14.1	11.8	Gier 1968	No N, cited from 2 sources within
Texas	12.6	10.5	Young and Jackson 1951	N = 46M, 38F
Oklahoma	11.9	NA	Young and Jackson 1951	N = 196M
Iowa	13.0	11.4	Andrews and Boggess 1978	No N given
N. Minnesota	12.5	11.5	Berg and Chesness 1978	N = 204T
Yellowstone N.P.	13.6	11.8	Crabtree and Sheldon 1999	No N, but many captures (pers. comm.)
Jasper N.P., AB	12.1	11.5	Bowen 1982	N = 19M, 20F
Kenai, AK	12.9	11.1	Thurber and Peterson 1991	N = 26M, 28F

Tremblay et al. 1998) and Colorado (Silver and Silver 1969) were omitted. Some studies that I included did not report sample sizes; however, the text (e.g., a region-wide study, or weights reported from trappers) indicated that they met my criteria for inclusion in this report.

To be consistent, because coyotes in northeastern North America do not mature until two years of age (Harrison 1992), I attempted to include values from coyotes known to be ≥ 2 yr, based on body size and dentition (Bekoff and Jamieson 1975, Person 1988, Richens and Hugie 1974). However, data from yearlings measured during winter were potentially included. I did not take the weight of stomach contents into account (Larivière and Crête 1993), assuming that my large sample size (Table 1) would mitigate any variation that existed. The season that coyotes were weighed may confound results because coyotes have been shown to be 27–28% heavier during autumn–winter than spring–summer (Poulle et al. 1995). Therefore, if reported seasonally, I excluded data during the pup-rearing period (April–September; Way et al. 2001) to reduce variation between studies. This criterion caused me to withdraw the data reported by Huot et al. (1995), which were collected predominately during summer.

I used the average body mass of male and female coyotes from each reported study (Table 1) for comparison purposes; thus, each study represented the sampling unit (Thurber and Peterson 1991). Standard deviations of coyote body weights were not reported in many studies (e.g., Silver and Silver 1969), which precluded me from statistically comparing these data (e.g., New Hampshire) to other studies. Instead, I numerically compared the average masses reported for recently established populations in northeastern North America east of longitude 80° (recent range expansion described in Parker [1995] as New England, New York, New Jersey, Pennsylvania, Ontario, and Quebec) to the rest of coyote range. I did not conduct a statistical comparison between coyotes in the northeast versus coyotes from other areas because the line dividing the data was arbitrary. Rather, I correlated coyote body mass with longitude (Fig. 1) and latitude (Fig. 2) using two-tailed bivariate Pearson correlation coefficients (SPSS Inc., Chicago, IL) tests. Because the data were interval-based, I used the Pearson test rather than a non-parametric test for ordinal and/or rank data, such as Spearman's rho (Hinkle et al. 1998). To analyze the proportion of variance in body mass caused by latitude or longitude, I determined the coefficient of determination (r^2) and considered $P < 0.05$ to represent statistical significance.

I obtained latitude and longitude for each study site by one of three criteria: using coordinate values reported from a given study; using an internet website (www.terraserver-usa.com) to estimate an approximate midpoint area from where measurements were taken (e.g., for measurements taken throughout a large western state in the US, I used the geographic center of that state as the coordinate value for the given study); and where specific townships or counties were reported for a given study, I used the internet (www.google.com, www.hometownusa.com, www.hometowncanada.com, or www.terraserver-usa.com) to locate the nearest coordinates to the study site.

Results

Mean (± SD) weights of male coyotes from northeastern North America from 16 studies averaged 16.4 (± 1.5) kg (range = 14.2–20.4), whereas females from 15 of these studies averaged 14.7 (± 1.6) kg (range = 11.9–17.9), or 90% of the mean weight of males. Published weights of male

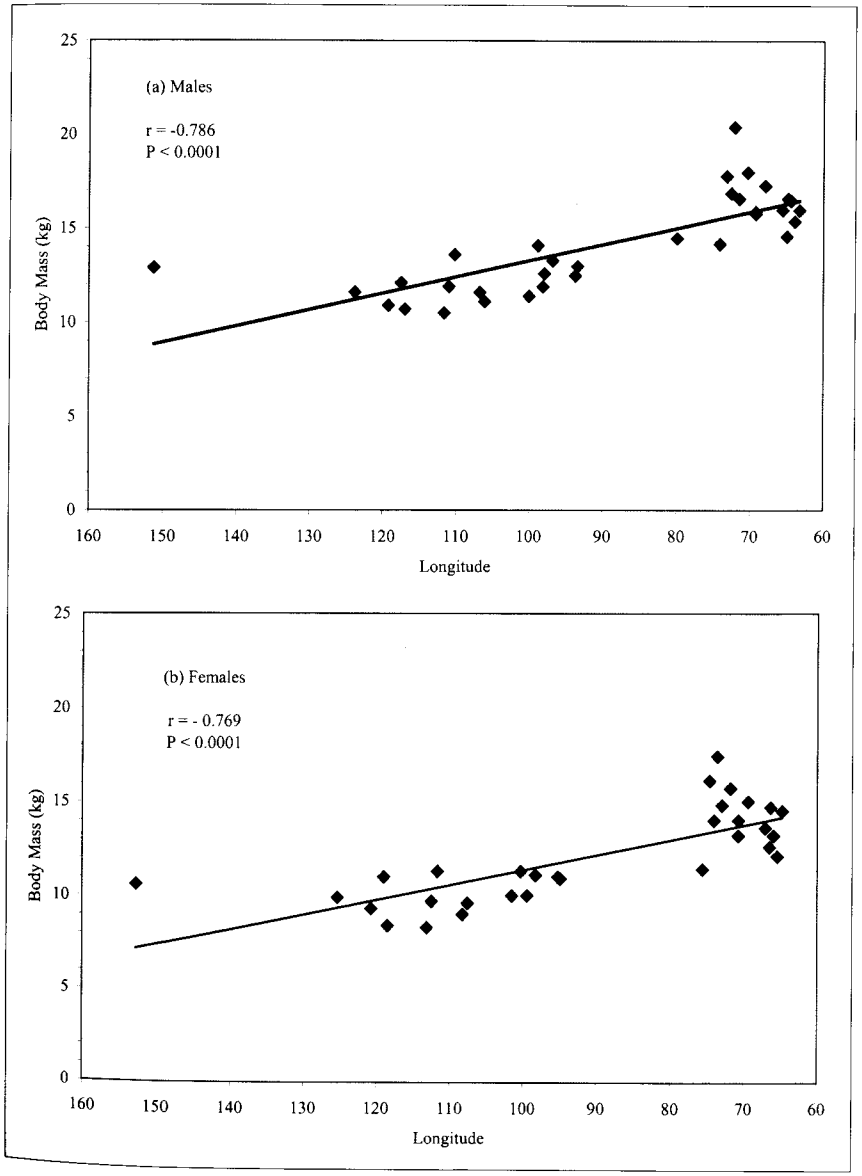

Figure 1. Coyote body masses (kg) in different regions of North America correlated with longitude: (a) male coyote body masses and longitude; (b) female coyote body masses and longitude.

coyotes outside of northeastern North America from 17 studies averaged 12.1 (± 1.1) kg (range = 10.5–14.1), whereas females from 16 of these accounts averaged 10.6 (± 1.0) kg (range = 8.8–12.0), or 88% of the mean weight of western males (Table 1). Male and female coyotes from outside of the northeast averaged 74% and 65% of the mass of male coyotes and 82% and 72% of the mass of female coyotes from the northeast.

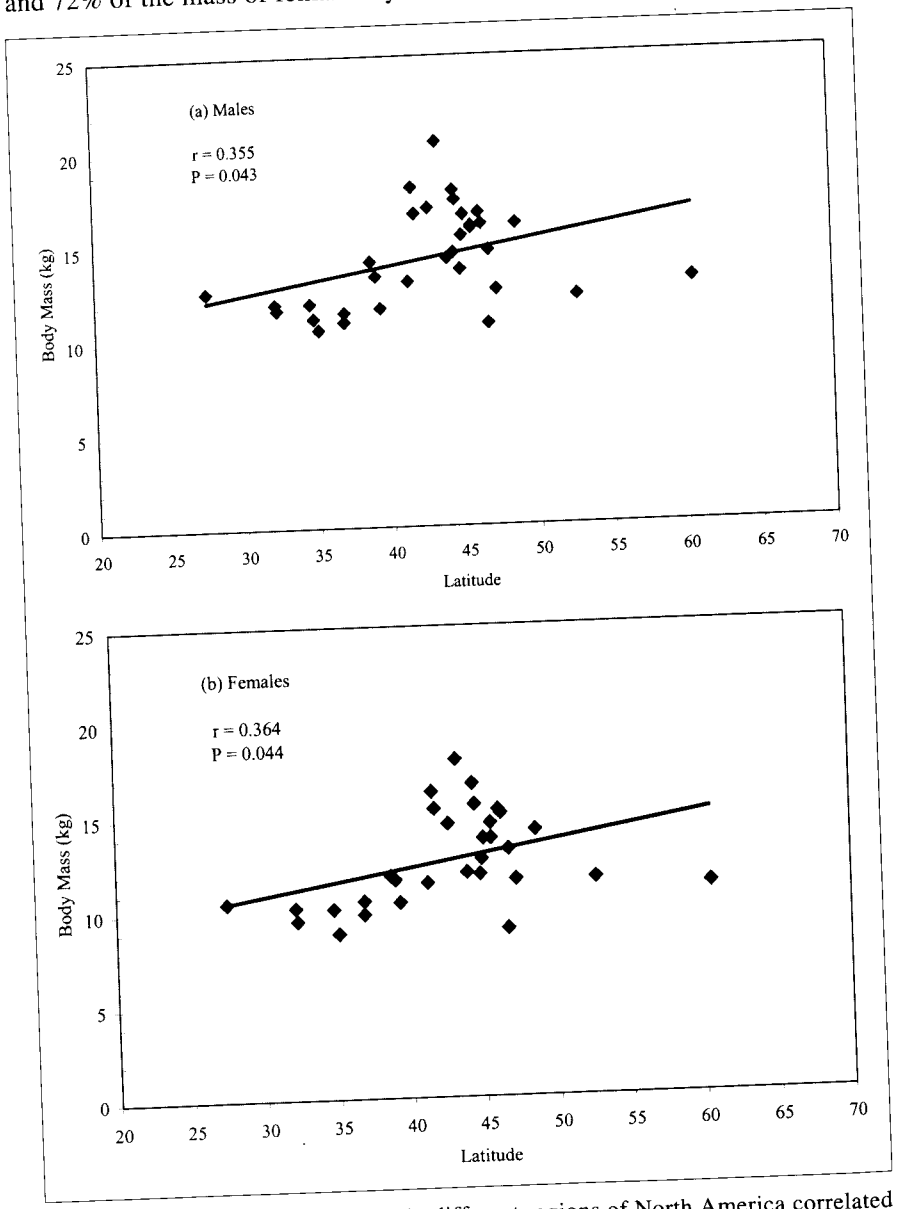

Figure 2. Coyote body masses (kg) in different regions of North America correlated with latitude: (a) male coyote body masses and latitude; and (b) female coyote body masses and latitude.

Eight of the 16 (50%) studies reported on eastern coyotes approximated the values reported by Silver and Silver (1969), with the ranges in these studies approaching (≤ 0.5 kg) or overlapping with the mean mass reported by Silver and Silver. Although not all studies reported ranges in coyote weights, 8 authors (excluding data provided by Kendrot [1998]) documented maximal weights of individual male coyotes ≥ 20 kg, while 4 reported females ≥ 19 kg. Four studies reported coyotes ≥ 25 kg, including 1 female in Massachusetts (Table 1).

Significant correlations existed between male and female body mass and longitude (Fig. 1) and latitude (Fig. 2). Most of the variation in coyote body mass can be explained by longitude, with bigger coyotes occurring in eastern North America (Fig. 1a, b); yet some of the difference in body mass could be elucidated by latitude with coyotes generally larger when further north (Fig. 2a, b; Table 1—although note Alaska as an exception). Sixty-two percent ($r^2 = 0.618$, $P < 0.0001$) and 59% ($r^2 = 0.591$, $P < 0.0001$) of variation in body mass of males and females, respectively, could be explained by longitude, while 13% ($r^2 = 0.126$, $P = 0.043$ for males; $r^2 = 0.132$, $P = 0.044$ for females) could be accounted for by latitude.

Discussion

Data presented in this paper provide further evidence that coyotes inhabiting northeastern North America are larger than their conspecifics from other regions (Nowak and Paradiso 1983, Wayne and Lehman 1992). They are clearly heavier than the nearest subspecies of coyote, *C. l. thamnos*, found in the midwest United States (Berg and Chesness 1978, Parker 1995, Table 1). While much research on coyotes has been conducted, weights of adult coyotes should continue to be reported. For example, it was difficult to locate published studies from many locations in their western range. I predict that if more sources were obtained from other regions (e.g., the desert southwest where coyotes are smaller; Parker 1995) the difference between coyotes in the northeast and other coyote populations would have been even more disparate. Furthermore, coyotes from southern New England appeared to be slightly heavier than ones from northern New England. However, it is also important to stress that masses, although the most commonly reported body measurement, should be treated with caution. Variability in body mass can be attributed to many factors unrelated to the taxonomy of the animal, such as fullness of stomach, animal condition, season, hydration, reproductive success, and age.

Size dimorphism was observed between sexes; males were 11% and 14% (in the east and outside the east, respectively) heavier than females. This is consistent with the literature for canids (e.g., Bekoff 1977, Kennedy et al. 2003, Parker 1995), yet coyote females in eastern North America were 21% heavier than male coyotes from outside the northeast. In fact, coyotes from the northeast were so much larger than the typical reported weight for the species, they would classify in a different size category (based on body

masses) than western coyotes in many review studies with carnivore size guilds. For example, Sillero-Zubiri and Laurenson (2001) excluded coyotes because they reported only large carnivores with a mass of ≥ 15 kg, an average that northeastern coyotes of both sexes exceeded. Moehlman (1989) classified coyotes in the medium-sized canid range, with > 13 kg as the largest category, a value surpassed by every site reporting weights of male coyotes in the northeast and by 13 of 15 (87%) sites reporting weights of female coyotes in the northeast. Furthermore, some coyotes in the northeast would be placed in the large-sized (> 20 kg) category for canids reported by Johnson et al. (1996). Wayne and Lehman (1992) claimed that all canids > 20 kg, a value that northeastern coyotes regularly exceed (Table 1), were identified as wolves in Minnesota and southeastern Canada. Northeastern coyotes approached the size of wolf-coyote hybrids (20.5 ± 0.6 kg for males, 17.5 ± 0.5 females) in southeastern Ontario (Sears et al. 2003).

Thurber and Peterson (1991) stated that coyotes in the northeast were showing a phenotypic response to enhanced food supply or larger prey size. However, others cite that due to a decreased food supply (both large and small prey), coyotes in eastern North America exist at lower densities, have larger home ranges, and generally live in smaller groups than their counterparts in other areas (principally within their historic range [i.e., the area they lived in before their range expansion in the late 1800s; Parker 1995] of the western United States) (Harrison 1992, Parker 1995, Patterson and Messier 2001, Way et al. 2002). Larivière and Crête (1993) believed the larger size of eastern coyotes constituted an evolutionary response to larger prey, and that increased size reflected a genotypic response to prey. However, white-tailed deer are widespread and abundant in most of the United States (Warren 1997), and coyote body size, where reported, is not larger in other areas. Detailed controlled studies of prey abundance and body size between study sites and regions of the coyote's range need to test the plausibility of the phenotypic response (Thurber and Peterson 1991) and genetic selection (Larivière and Crête 1993) theories. Additionally, knowledge of prey body size and any variation between regions should also be included in future comparisons, as coyotes might be smaller where deer are smaller. The high percentage of deer in the diet of coyotes in the northeast (Ballard et al. 1999, Harrison 1992, Harrison and Harrison 1984, Litvaitis and Harrison 1989, Major and Sherburne 1987, Patterson and Messier 2001) could lead to selection for larger body size relative to their historical range where small–medium sized animals (Crabtree and Sheldon 1999), insects, and fruits (Andelt 1985) dominate the diet.

Coyotes in the northeast do not appear to be coy-dogs (i.e., a hybrid of a coyote and domestic dog) because they consistently gave birth in early April, which is when wild canids normally whelp (Harrison and Gilbert 1985, Parker 1995, Way et al. 2001). Mengel (1971) found that coy-dogs have a phase-shifted reproductive cycle, typically breeding during the fall

and whelping in mid-winter, both of which are 2–3 months prior to the annual cycle displayed by coyotes. Because coyotes normally only breed during mid-to-late winter, their reproductive cycles do not overlap with coy-dogs. Furthermore, the prospect of a female coy-dog raising offspring in mid-winter in northeastern North America is slim, especially considering that male coyotes are not in reproductive condition during the fall, indicating that the sire would have to be a domestic dog, which does not contribute to pup-rearing. Mengel (1971) concluded that introgression of *Canis lupus lycaon* Schreber (gray wolf) genes into a coyote population seems much more likely to explain the peculiarities of the larger coyotes in New England. However, domestic-dog genes have been incorporated into coyotes in the southeastern United States (Adams et al. 2003b). Additional research, including understanding the behavior of coyotes in the southeast (e.g., documenting when they whelp), is needed to elucidate the effects of coy-dogs on wild *Canis* populations.

Genetic data is sorely needed to clarify the origins of coyotes in the northeast since this analysis might give insight into the larger body mass of coyotes in that region. Thurber and Peterson (1991) stated that wolf-coyote hybridization has been verified only in captivity where behavioral barriers may have artificially deteriorated (Kolenosky 1971, Schmidtz and Kolenosky 1985a). It is well documented (Kolenosky 1971; Kolenosky and Standfield 1975; Schmitz and Kolenosky 1985a, b; Schmitz and Lavigne 1987; Theberge and Theberge 2004) that wolves found near eastern coyote habitat (i.e., southern Ontario) are smaller (ca. 25–30 kg) than in other areas such as Alaska (Mech et al. 1998, Thurber and Peterson 1991), Minnesota (Mech 2000), Yellowstone National Park (Phillips and Smith 1996), and the Rocky Mountains (Pilgrim et al. 1998) where the two species are sympatric. This perhaps could influence hybridization as wolves may not be as dominant and aggressive towards coyotes (see Crabtree and Sheldon 1999, Peterson 1995) where they are closer in physical stature—i.e., southern Ontario. Schmitz and Kolenosky (1985b) stated that hybridization between the coyote and wolf may have resulted when there was a breakdown in reproductive barriers such as interspecific agonistic behavior and differing habitat preferences that normally maintained these species in reproductive isolation. As Moore and Parker (1992) indicated, this shift may have occurred at the turn of the century when wolves were being exterminated from the northeastern US and southeastern Canada and coyotes were colonizing these regions. Further, Wilson et al. (2000, 2003) reported that the wolves found in southeastern Canada may be the same species as red wolf, or *Canis lycaon* as they proposed. This wolf is thought to be more closely related to the coyote than the gray wolf because both are theorized to have evolved in the New World versus the Old World origin of the gray wolf. Thus, the genetic similarity of the coyote and *Canis lycaon* might facilitate hybridization, especially when populations are low in an area. In fact, the

biggest threat currently facing the red wolf in the southeast US is hybridization with coyotes colonizing the periphery of the North Carolina red wolf recovery area (Adams et al. 2003a).

This study found that the coyotes in northeastern North America are larger than coyotes from other regions. There was a wide range of weights reported for coyotes throughout northeastern North America, and all sites in the northeast averaged higher than for studies from western North America. Although Bergmann's rule (i.e., larger body size with increasing latitude) has been posited to explain the larger body sizes of mammals in colder climates, findings from this study indicate that longitude accounts for > 4 times the amount of variation in coyote body mass than does latitude. This suggests that phenotypic selection in response to use of large ungulates and/or possible genetic influences of hybridization with southern populations of wolves might explain larger relative body sizes of coyotes in eastern North America in comparison to similar latitudes in the west. A comprehensive genetic analysis would provide additional insight into taxonomy of this unique canid and the reasons for larger body sizes in the northeastern portion of the coyote's geographic range.

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