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Wolf body mass cline across Minnesota related to taxonomy?

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NOTE / NOTE

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Abstract: Recent genetic studies suggest that in northern Minnesota two species of wolves (*Canis lupus* L., 1758 or western wolf and *Canis lycaon* Schreber, 1775 (= *Canis rufus* Audubon and Bachman, 1851) or eastern wolf) meet and hybridize. However, little morphological information is available about these two types of wolves in Minnesota. We analyzed the mass of 950 female wolves and 1006 males older than 1 year from across northern Minnesota and found that it increased from 26.30 ± 0.56 kg (mean ± SE) for females and 30.60 ± 0.72 kg for males in northeastern Minnesota to 30.01 ± 0.43 kg for females and 35.94 ± 0.45 kg for males in northwestern Minnesota (females: $r^2 = 0.79$, $P < 0.02$; males: $r^2 = 0.63$, $P = 0.06$). These mass differences add morphological information to the identities of eastern and western wolves and support the view that ranges of the two species meet in Minnesota.

Résumé : Des études génétiques récentes indiquent que, dans le nord du Minnesota, deux espèces de loups (*Canis lupus* L., 1758, le loup de l'ouest, et *Canis lycaon* Schreber, 1775 (= *Canis rufus* Audubon et Bachman, 1851), le loup de l'est) se rencontrent et font de l'hybridation. Il existe, cependant, peu d'information morphologique sur ces deux types de loups au Minnesota. Nous avons mesuré la masse de 950 louves et 1006 loups de plus de 1 an dans tout le nord du Minnesota et trouvé que la masse augmente de 26,30 ± 0,56 kg (moyenne ± ET) chez les femelles et de 30,60 ± 0,72 kg chez les mâles dans le nord-est du Minnesota à 30,01 ± 0,43 kg chez les femelles et à 35,94 ± 0,45 kg chez les mâles dans le nord-ouest du Minnesota (females : $r^2 = 0,79$, $P < 0,02$; mâles : $r^2 = 0,63$, $P = 0,06$). Ces différences de masse constituent des renseignements morphologiques additionnels sur l'identité des loups de l'est et de l'ouest et elles appuient le point de vue selon lequel les aires de répartition des deux espèces se recoupent au Minnesota.

[Traduit par la Rédaction]

Introduction

Since Wilson et al. (2000) proposed that wolves of southeastern Canada (*Canis lycaon* Schreber, 1775; hereafter eastern wolves) were distinct from the gray wolf (*Canis lupus* L., 1758) of farther west (hereafter western wolves) based on genetic evidence, there has been much discussion about the subject (Mech and Federoff 2002; Nowak 2003; Wayne and Vila 2003; Wilson et al. 2003; Kyle et al. 2006). However, other than Kolenosky and Standfield's (1975) and Theberge and Theberge's (2004) descriptions of Ontario's Algonquin Park wolves and Nowak's (2003) discussion of skulls, much remains to be learned about morphological differences between eastern and western wolves.

Wilson's et al. (2000) hypothesis implies that the ranges of the two species meet in Minnesota and elsewhere. Taxonomy of Minnesota wolves based primarily on morphology has long been complex. Until 1995, the state was thought to host the subspecies *Canis lupus nubilus* Say, 1823 in its northwestern corner and *Canis lupus lycaon* Schreber, 1775 elsewhere (Young and Goldman 1944; Hall and Kelson 1959; Mech 1970). Mech and Frenzel (1971) proposed, based on the occurrence of black wolves in northeastern Minnesota, that influence of *C. l. nubilus* extended across the state, although Van Ballenberghe (1977) provided evidence of two black wolves from Quebec. Nowak (1995) reanalyzing skull measurements concluded that *C. l. nubilus* inhabited all of Minnesota. Examination of mitochondrial DNA (mtDNA) of northeastern and north-central Minnesota wolves indicated that some wolves shared haplotypes with gray wolves of western Canada and Alaska, while others shared haplotypes with southeastern Canadian wolves (Lehman et al. 1991). Other genetic evidence suggested that Minnesota wolves include hybrids between eastern and western wolves (Mech and Federoff 2002; Kyle et al. 2006).

Theberge and Theberge (2004) summarized wolf body

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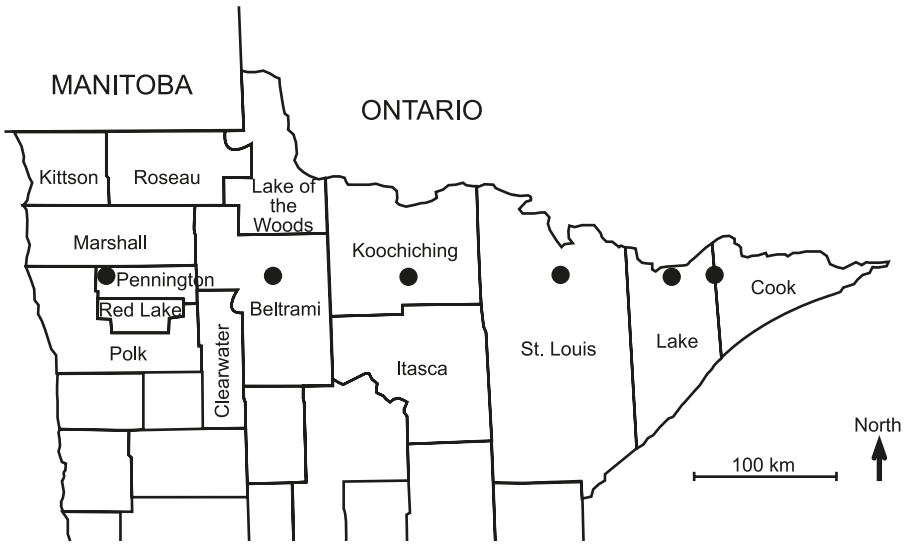
Fig. 1. The northern Minnesota study area. Solid circles represent distances west of Minnesota's northeastern border to which wolf (*Canis* sp.) body mass sampled from the various counties were attributed in Table 1.



mass information for southeastern Canada and concluded that eastern wolves are smaller than western wolves. This implies that if the two species meet in Minnesota, then wolves of eastern Minnesota should be smaller than those of western Minnesota, and a cline in mass across the state might be observed. Therefore, to add new information to the issue and to provide additional information about morphological differences between eastern and western wolves and also on the taxonomic identity of Minnesota wolves, we examined masses of northern Minnesota wolves across their east–west distribution. We hypothesized that wolf masses should increase significantly from east to west. In addition, because the black phase is almost unknown in eastern Canadian wolves (Kolenosky and Standfield 1975; Theberge and Theberge 2004; J.B. Theberge and M.T. Theberge, personal communication) but does occur in western wolves, we also examined the occurrence of black wolves in northern Minnesota for possible inferences about taxonomy.

Study area

Minnesota wolf range is a southern extension of the Ontario and Manitoba wolf range (Fig. 1). As with wolves throughout the contiguous 48 United States, wolves were extirpated from most of southern and extreme northwestern Minnesota (primarily most of Kittson, Roseau, and Marshall counties; Fig. 1) by about 1970, with an estimated 750 remaining (Fuller et al. 1992). As they began increasing after 1970, they gradually spread southward and westward and currently occupy about 67 852 km^2 of the northern third of the state, including the northwestern counties mentioned above (Erb and Benson 2004).[3] Repopulation of the northwestern Minnesota wolf population could have resulted from extant wolf packs from farther east or from those in adjacent southwestern Ontario and southeastern Manitoba, where they had not been exterminated (Fig. 1).

Our study area extended across northern Minnesota in an east–west band of about 200 km just south of the state's border with Ontario (Fig. 1). The eastern 80% of the area is primarily forested wilderness and semi-wilderness with many scattered lakes and extensive bogs that grade into brushland and open prairie and farmlands with quaking aspen (*Populus tremuloides* Michx.) groves in the west. The wolves' main prey is white-tailed deer (*Odocoileus virginianus* (Zimmermann, 1780)), but in the extreme northeast, the wolves prey primarily on moose (*Alces alces* (L., 1758)), and in some parts of northwestern Minnesota they also feed on moose (Frenzel 1974; Van Ballenberghe et al. 1975; Fritts and Mech 1981; Nelson and Mech 2006). Wolves also prey on livestock throughout the study area but mostly in the western two-thirds of the study area (Harper et al. 2005).

Methods

We used data on mass and color of wolves older than 1 year live-trapped for a radio-tracking study in northern Cook, Lake, and St. Louis counties from 1968 to 2006 (Mech 2009) and captured for a US Department of Agriculture Wildlife Services depredation-control program from 1975 through 2006 (Fritts 1982; Harper et al. 2005, 2008) in Lake, St. Louis, Koochiching, Itasca, Lake-of-the-woods, Beltrami, Clearwater, Kittson, Roseau, Marshall, Polk, Pennington, and Red Lake counties, arranging the data point for each county or group of counties centrally across the northern Minnesota map (Fig. 1). This research was conducted under both state and federal endangered species permits and complied where applicable with guidelines of the American Society of Mammalogists (Animal Care and Use Committee 1998).

Results

We weighed 950 female wolves and 1006 males older than 1 year (Table 1). Mean (SE) masses of both female

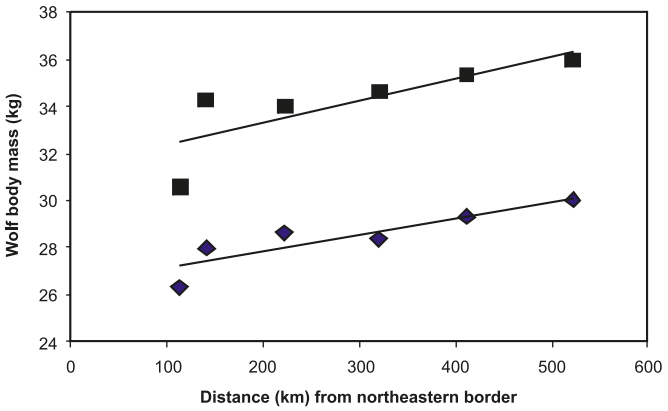
[3] J. Erb and S. Benson. 2004. Distribution and abundance of wolves in Minnesota, 2003–04. Minnesota Department of Natural Resources, Grand Rapids. Unpublished manuscript.

Table 1. Body masses (kg) of adult (nonpup) northern Minnesota wolves (*Canis* sp.) from 1968 to 2006 within approximately 200 km of the Minnesota–Ontario border.

	Females		Males		
County	*n*	Mean (SE)	*n*	Mean (SE)	Distance (km)*
Cook or Lake[†]	32	26.30 (0.56)	36	30.60 (0.72)	114
Lake[‡]	197	27.97 (0.29)	177	34.31 (0.33)	141
St. Louis[‡]	187	28.62 (0.26)	173	33.97 (0.33)	222
Koochiching, Itasca	263	28.35 (0.20)	282	34.64 (0.25)	321
Lake of the Woods, Beltrami, Clearwater	177	29.28 (0.23)	217	35.34 (0.29)	411
Kittson, Roseau, Marshall, Polk, Pennington, Red Lake	94	30.01 (0.43)	121	35.94 (0.45)	522

Note: Data from wolf depredation-control program except where noted.
*West from extreme northeastern Minnesota.
[†]From Van Ballenberghe (1977).
[‡]From depredation-control program and research program (Mech 2009).

Fig. 2. Relationship between distance west of the northeastern Minnesota border and mean body masses of female (lower line, ◆) and male (upper line, ■) wolves (*Canis* sp.) older than 1 year. Data points represent central points of locations where wolf body masses were sampled (Table 1). Females: $y = 0.007x + 26.39$; $r^2 = 0.79$, $P < 0.02$; males: $y = 0.0093x + 31.44$, $r^2 = 0.63$, $P = 0.06$.



and male wolves increased westward from extreme northeastern Minnesota from 26.30 ± 0.56 kg for females and 30.60 ± 0.72 kg for males to 30.01 ± 0.43 kg for females and 35.94 ± 0.45 kg for males (females: $r^2 = 0.79$, $P < 0.02$; males: $r^2 = 0.63$, $P = 0.06$; Fig. 2). As a contrast to these wolf mass data, we note that mean (SE) masses of adult coyotes (*Canis latrans* Say, 1823) in northern Minnesota ($n = 39$) were 12.8 ± 1.6 kg for males and 11.4 ± 1.3 kg for females ($n = 30$) in autumn (G.J. Smith et al.).[4]

Fourteen of the adult female wolves caught during the radio-tracking study (Cook, Lake, and St. Louis counties) and 20 of the male wolves were black; black females and males weighed a mean of 29.5 and 34.5 kg, respectively. In the depredation-control program, covering all counties in the wolf range, 8 adult females (mean 30.0 kg) and 13 adult males (mean 35.2 kg) were black.

Discussion

Mass of Minnesota wolves increased from east to west in keeping with the hypothesis that the Minnesota wolf population includes both the eastern wolf (*C. lycaon*) and the western wolf (*C. lupus*) (Wilson et al. 2000; Kyle et al. 2006), as well as hybrids between the two (Mech and Federoff 2002). The wolves of extreme northeastern Minnesota weighed the same as recent specimens of eastern wolves of Algonquin Park, Ontario (Theberge and Theberge 2004), some 810 km east, whereas those of northwestern Minnesota weighed the same as those of Riding Mountain National Park, Manitoba (L.N. Carbyn, personal communication), some 300 km northwest of Minnesota. The greatest mass difference was between wolves of extreme northeastern Minnesota (Cook County and eastern Lake County) and those farther west (Fig. 2), suggesting that the purest eastern wolves reside in northeastern Minnesota.

Whether masses of wolves in north-central Minnesota are intermediate because the wolves are a combination of both eastern and western wolves or hybrids between the two cannot be distinguished from present data. Comparison of the distributions of mtDNA haplotypes from eastern Minnesota with those from north-central Minnesota suggest that both types of wolves may be present (Fig. 4 in Lehman et al. 1991). The percentage of eastern wolf haplotypes (referred to as coyote-type mtDNA by Lehman et al. 1991) in 75 wolves from northeastern Minnesota, nearby Ontario, and Isle Royale just off the coast of northeastern Minnesota was 71%, whereas in 58 wolves from north-central Minnesota only 53% were eastern ($\chi^2_{[1]} = 4.17$, $P = 0.04$). Unfortunately, no northwestern Minnesota wolves were genetically sampled, but two of two wolves from Riding Mountain National Park west of Minnesota were western wolves.

We might conclude that most wolves in northwestern Minnesota are western wolves and that this type tends to blend with eastern wolves eastward across the state. This model tends to support the earlier view that northwestern Minnesota wolves differed from those to the east (Young and Goldman 1944). In addition, the occurrence across Minnesota of black wolves known primarily from western populations, and the heavier mass of those black wolves further attest that western wolves extend eastward within Minnesota (Mech and Frenzel 1971) and differ from the individuals of lighter mass from Cook County in extreme northeastern Minnesota.

[4] G.J. Smith, W.E. Berg, D.W. Kuehn, and O.J. Rongstad. Coyote ecology in northern Wisconsin and Minnesota. Minnesota Department of Natural Resources, Grand Rapids. Unpublished manuscript.

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