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Note

Further occurrences of melanism in a northern, peripheral, population of Bobcat (*Lynx rufus*)

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Abstract

Although melanism is understood to occur commonly among some felids, it is reported to be most frequent among cat species that occur in humid, tropical, and densely vegetated habitats. Previously, a single record of a melanistic Bobcat (*Lynx rufus*) from eastern Canada (New Brunswick) appeared to be a northern outlier, with all other reports of melanism in this species restricted to the warm, humid, climate of southern peninsular Florida. Here, I document a further five occurrences of melanism in Bobcat from New Brunswick and review evidence that a mutation in an agouti-signalling protein gene may be responsible for melanism in New Brunswick Bobcats.

Key words: Agouti-signalling protein gene; coat colouration; Felidae; genetic mutation; pelage

It has been suggested that an understanding of melanism in felids may shed light on the genetic basis and evolutionary history of pigment diversity and how natural selection has influenced pigment patterns in mammals (Schneider *et al.* 2012, 2015). Furthermore, Candille *et al.* (2007) have noted that an understanding of colour variation in mammals can provide fundamental insights into human biology and disease. Roulin (2014) believes that an increase in the frequency of melanism may reflect either the direct or indirect (i.e., through pleiotropic effects) influence of climate warming.

Although melanism is understood to occur commonly among some felids (Schneider *et al.* 2012), it is reported to be frequent among cat species that occur in humid, tropical, and densely vegetated habitats (Sunquist and Sunquist 2009). This pattern of occurrence would appear to follow Gloger's rule, an ecogeographical rule that states that, among endotherms, more heavily pigmented forms tend to be found in more humid environments, i.e., near the equator (Delhey 2017). Melanism has also been commonly observed in some southern hemisphere felids with distributions that encompass temperate forest, grasslands, open woodlands, and savannah-type habits, including Colocolo (*Leopardus colocolo*), Geoffroy's Cat (*Leopardus geoffroyi*), and Kodkod (*Leopardus guigna*; Sunquist and Sunquist 2009). In fact, among the 23 felid species (out of 37–41) currently recognized in which melanism has been reported to date (Sunquist and Sunquist 2009; Medina and Medina 2019), nearly all have their principal distribution in the southern hemisphere. This is certainly the case for the eight wild cat species in which melanism is reported to be common (Colocolo, Geoffroy's Cat, Jaguar [*Panthera onca*], Jaguarundi [*Puma yagouaroundi*], Kodkod, Leopard [*Panthera pardus*], Oncilla [*Leopardus tigrinus*], and Serval [*Leptailurus serval*]; Sunquist and Sunquist 2009; Schneider *et al.* 2012). Among the remaining 15 species, only Bobcat (*Lynx rufus*) has an essentially northern distribution.

Of the 15 occurrences of melanism in Bobcat previously reported, 13 are from the warm, humid climate of southern peninsular Florida (Regan and Maehr 1990; Hutchinson and Hutchinson 2000; Dubetz 2007). Until now, a single record from eastern Canada (New Brunswick) appeared to be a northern outlier (Tischendorf and McAlpine 1995; but see WMUR News 2020). Here I document further instances of melanistic individuals from the northern, peripheral Bobcat population that occupies New Brunswick, demonstrating a geographic cluster of occurrences, and discuss their significance.

Bobcat occur throughout New Brunswick, where the species approaches its northern range limit (Naughton 2012) and is legally harvested during a November–February trapping season. From 1983 to 2016 (the period during which melanistic Bobcat were obtained in New Brunswick; season closed 1987–1991), 100–800 Bobcat were harvested annually (New Brunswick Fish and Wildlife Branch n.d.)

Tischendorf and McAlpine (1995) reported the first record of a melanistic Bobcat from New Brunswick: a male trapped on 18 November 1983 near Henry Lake, Saint John County. Since then, a further five cases have been recorded (Table 1), all of which I have had an opportunity to examine (four skins, two with skeletons are now in the New Brunswick Museum [NBM] collection; plus the skeleton of one privately held mount; Figure 1). All show the pelage colour pattern described by Ulmer (1941): darkest on the back, lighter on the belly, a scattering of white hairs, and spotting and facial stripes visible and decidedly darker than the background. Older skins that have been exposed to light seem subject to decolourization in the ground colour (i.e., a colour on which other colours are superimposed to create a pattern), such that spotting and facial stripes are more evident on taxidermied animals than fresh-dead specimens that have not been exposed to light for extended periods after death (Figure 2). All New Brunswick melanistic Bobcats were taken in the southcentral and southeastern part of the province (Figure 3) in a landscape mosaic of industrial woodland, cleared forest, agricultural and rough pasture land, and rural communities. Most were trapped, but one was secured as a roadkill. Among the six specimens are three males and two females (sex for one animal unknown).

Investigations of melanism in felids have revealed that this colour morph arose independently among cats on at least eight occasions (Eizirik *et al.* 2003;

Table 1. Occurrences of melanistic Bobcat (*Lynx rufus*) in New Brunswick.

Date	Location	Sex	Confirmation
18 November 1983	Henry Lake, 45.4042°N, 65.6105°W	Male	NBM-MA-4819
~1987	Coburg, 46.0248°N, 64.1179°W	?	Figure 1a
22 January 1998	Little Shemogue, 46.1152°N, 64.0207°W	Female	NBM-MA-5785, Figure 1b
2 December 2000	1.9 km west of Searsville, 47.7125°N, 65.7196°W	Male	NBM-MA-18054
11 January 2013	Gaspereau Forks, 46.2328°N, 65.8508°W	Male	NBM-MA-12400
25 December 2016	0.71 km northeast of Upper Saint-Maurice, 46.48194°N, 64.83611°W	Female	NBM-MA-18069, Figure 1c

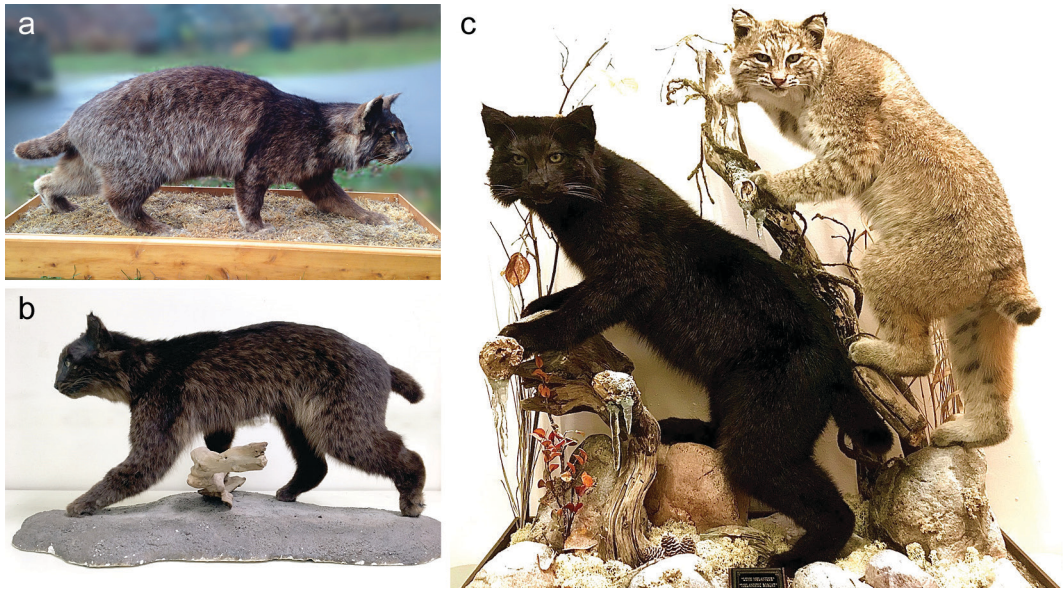

Figure 1. Melanistic Bobcat (*Lynx rufus*) from New Brunswick. a. Coburg specimen. b. Little Shemogue specimen (NBM-MA-5785; skeleton only, mount in private hands. c. Upper Saint-Maurice specimen (NBM-MA-18069) paired with a normal pelage Bobcat. Photos: D.F. McAlpine.

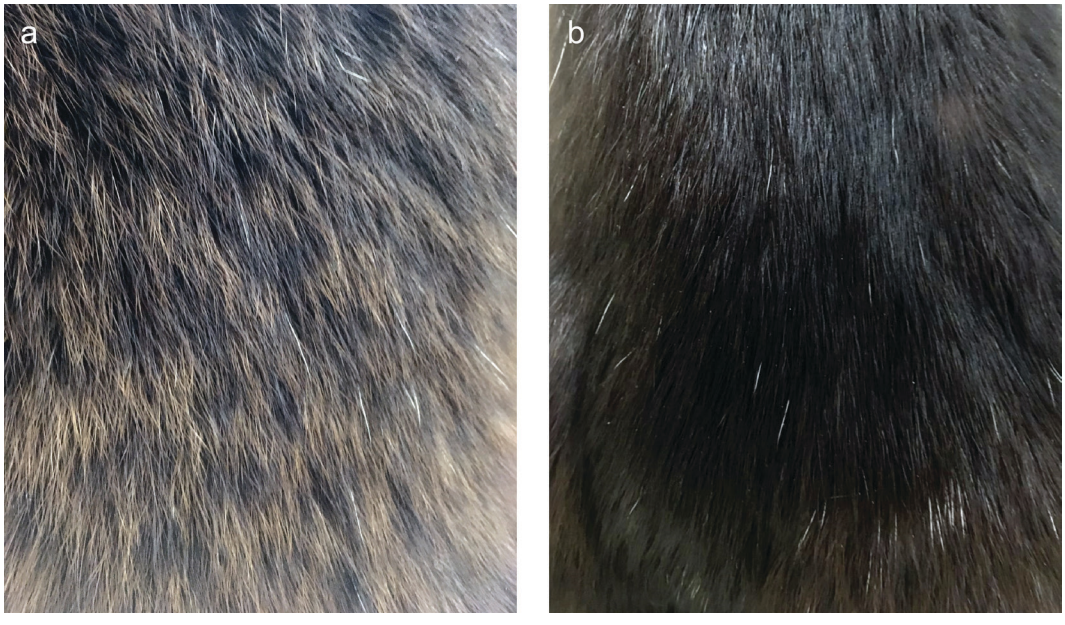

Figure 2. Melanistic Bobcat (*Lynx rufus*) pelage detail. a. Little Shemogue specimen. This mount has been exposed to moderate to high light levels and decolourization of the ground colour has made the pattern more visible than in a live or fresh-dead animal. b. Gaspereau Forks specimen (NBM-MA-12400). This specimen was prepared fresh-dead from a roadkill and has since been exposed to very little light. Photos: D.F. McAlpine.

Schneider *et al*. 2012, 2015). Current evidence suggests that melanism in cats is caused most frequently by a loss-of-function mutation in the agouti-signalling protein (ASIP) gene or, less frequently, by a gain-of-function mutation in the melanocortin-1 receptor (MC1R) gene (Eizirik *et al.* 2003; Candille *et al.* 2007; Schneider *et al.* 2012, 2015). This seems to be in contrast with other vertebrates generally, where MC1R has been found to be the more common cause of melanism (Hubbard *et al.* 2010).

It has been suggest that interspecific hybridization may play a role in melanism. Hybridization is not uncommon among some felid species and has been documented between New Brunswick Bobcat and Lynx (*Lynx canadensis*; Homyack *et al.* 2008; Huynh *et al.* 2019). Sunquist and Sunquist (2009) noted that melanism in Wildcat (*Felis silvestris*) may be the result of introgressive hybridization with Domestic Cats (*Felis catus*), but Schneider *et al.* (2015) found no evidence that hybridization might play a role in the presence of melanism among *Leopardus* species. Hybridization between wolves and dogs is known to produce melanistic individuals; however, the genetic mutation involved, a gain-of-function alteration in the beta-defensin 103 gene, appears to be restricted to canids (Candille *et al.* 2007). Although the genetic origin of melanism in Bobcat has yet to be examined, homozygosity for ASIP is associated with a "ghost pattern" of visible spotting and striping over a dark ground colour (Kaelin *et al.* 2012), as reported here for melanistic New Brunswick Bobcat. Although the presence of still-visible spotting among some melanistic felid species has been reported as evidence that coat pattern formation is more complex in cats than mere ASIP-MC1R gene expression (Kaelin *et al.* 2012), any role that hybridization might play in melanism in New Brunswick Bobcat awaits further investigation.

The ecological basis for melanism in felids is poorly understood. ASIP-induced melanism is recessive, MC1R is dominant. Kingsly *et al.* (2009) have suggested that MC1R-induced melanism should be prevalent when the trait is adaptive, but ASIP-induced darkening would be expected when melanism is deleterious. Kingsley *et al*. (2009) have also hypothesized that natural selection should readily produce a rise in MC1R melanism where it is advantageous. ASIP-induced melanism, although taking more time to rise in frequency in a population when favourable, should also persist in the population for longer when negatively selected. Schneider *et al.* (2012) note that the ASIP coding region is quite variable across felid species and that this mutation may be associated with fewer pleiotropic effects in cats and is, thus, less constrained and, for this reason, more often involved in melanism in felids. Furthermore, the high frequency of ASIP-induced melanism in some tropical

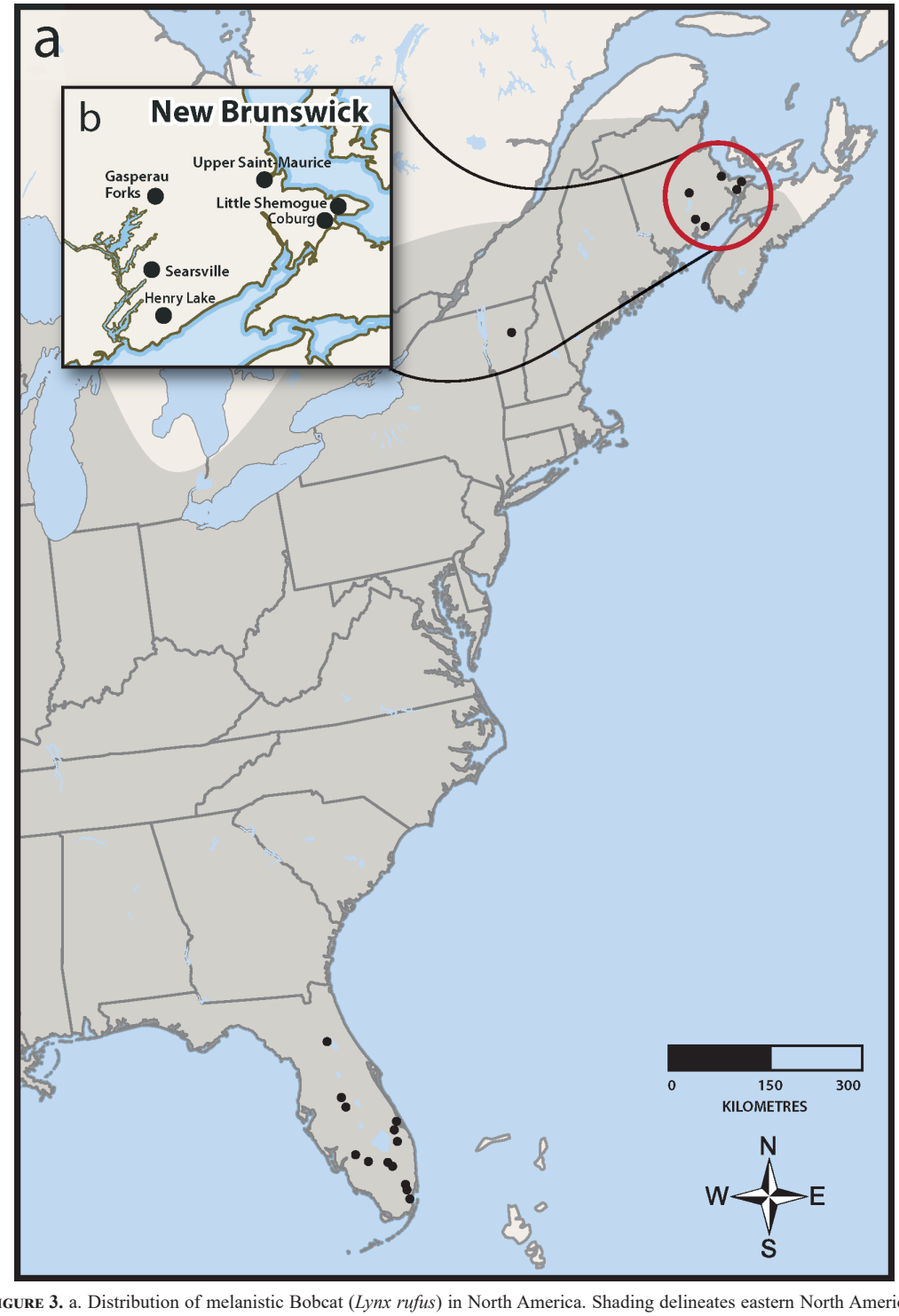

Figure 3. a. Distribution of melanistic Bobcat (*Lynx rufus*) in North America. Shading delineates eastern North American distribution for the species after Naughton (2012). Records for New Brunswick (b) are detailed in Table 1, those for Florida are taken from Regan and Maehr (1990), Hutchinson and Hutchinson (2000) and Dubetz (2007). The Vermont report is from WMUR News (2020).

cat species suggests that this trait may sometimes be adaptive, with recent molecular genetic evidence supporting this (Schneider *et al.* 2015). Although the selective process behind the presence of melanism in New Brunswick Bobcats is unknown, the low frequency of occurrence, the "ghost pattern" of visible spotting in the pelage, and the more common occurrence of ASIP-induced melanism among those felids examined to date (five of eight species), circumstantially suggests that an ASIP gene mutation may be responsible for melanism in these Bobcats.

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