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Rediscovery of the type series of the Acadian Masked Shrew, *Sorex acadicus* Gilpin, 1865 (Mammalia: Soricidae), with the designation of a neotype and a reevaluation of its taxonomic status

Neal Woodman

Biological Survey Unit, U.S.G.S. Patuxent Wildlife Research Center, MRC-111, National Museum of Natural History, Smithsonian Institution, P.O. Box 37012, Washington, D.C. 20013-7012, U.S.A., email: woodmann@si.edu

Abstract.—The name *Sorex acadicus* Gilpin, 1865 is currently recognized as the valid name for the Nova Scotian subspecies of the masked shrew, *S. cinereus* Kerr, 1792 (Mammalia: Soricidae), but a holotype for the taxon was never designated, and the location of the type series has been a mystery. The authority for this species, John Bernard Gilpin, was associated with the Nova Scotia Museum, Halifax, NS, but that institution has no Gilpin specimens in its possession, and I could find no record of Gilpin shrews in any other Canadian Museum. I recently discovered a series of Gilpin specimens in the Mammal Collection of the National Museum of Natural History, Washington, DC (USNM), some of which may have been part of the original type series of *S. acadicus*, and I show that these specimens best represent Gilpin's concept of the taxon. From this series, I designate a neotype for *S. acadicus*. I also evaluate the distinctiveness of Nova Scotian *S. c. acadicus* compared with *S. c. cinereus* from Maine, New Brunswick, and New Hampshire and determine that *S. acadicus* should be considered a junior synonym of *S. c. cinereus*.

Keywords: Eulipotyphla, holotype, lectotype, nomenclature, Soricomorpha, subspecies

The modern mammal fauna native to the Canadian province of Nova Scotia includes six taxa of shrews (Soricidae): *Blarina brevicauda talpoides* (Gapper, 1830); *Sorex albibarbis* (Cope, 1862); *Sorex cinereus acadicus* Gilpin, 1865; *Sorex dispar* Batchelder, 1911; *Sorex fumeus umbrosus* Jackson, 1917; and *Sorex hoyi thompsoni* Baird, 1857a. Among these six shrews, the type material of the Acadian masked shrew, *S. c. acadicus*, has remained unknown since its original description as a species (i.e. *Sorex acadicus* Gilpin, 1865), thereby precluding adequate evaluation of its identity and taxonomic status.

Although Gilpin had personal and professional connections throughout eastern North America, *S. acadicus* remained obscure. Most early taxonomic revisions of North American *Sorex* ignored *S. acadicus* (Merriam 1895, Miller 1895, 1912, 1924; Miller & Rehn 1901). Hollister (1911) was the first since Gilpin (1869) to review the taxon or even mention the name. Based on Gilpin's (1865) original description, Hollister (1911) considered *S. acadicus* a synonym of *S. personatus* I. Geoffroy Saint-Hilaire, 1827 (=*S. cinereus* Kerr, 1792). The taxon was subsequently reviewed by Jackson (1928:45), who placed *S. acadicus*

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in synonymy with *S. cinereus cinereus*. Smith (1940) later considered samples of Nova Scotian *S. cinereus* to be distinguishable from other populations of the species using external and cranial measurements, and he recognized *S. c. acadicus* as the valid name for the Nova Scotian subspecies, a status it has retained since (Banfield 1981, Hall 1981, Whitaker 2004, Hutterer 2005).

Protein electrophoretic studies of Canadian shrews demonstrated a strong genetic association between masked shrews from Nova Scotia and New Brunswick (Stewart & Baker 1992), yet *S. c. acadicus* were clearly differentiated from populations assignable to the nominate subspecies *S. c. cinereus* in central and western Canada (Shafer & Stewart 2007). More recent multi-locus DNA analysis showed *S. c. acadicus* nested well within an eastern clade of *S. cinereus* (Hope et al. 2012: supporting online table mmc2). The seemingly contradictory intraspecific molecular relationships so far revealed make it desirable to review morphological differences that have been used to distinguish *S. c. acadicus* from *S. c. cinereus* (Smith 1940).

Recently, I located a series of fluid-preserved *Sorex* that Gilpin donated to the National Museum of Natural History (USNM), Smithsonian Institution, Washington, D.C., some of which plausibly comprised a portion of his type series of *S. acadicus*. Even if they did not, the specimens of *S. acadicus* were obtained, inspected, and identified by Gilpin and, therefore, most closely represent Gilpin's concept of the taxon. The purposes of this paper are to review these specimens, designate a neotype for the taxon, and apply multivariate morphometrics to objectively evaluate the distinctiveness and taxonomic status of *S. c. acadicus* in relation to other northeastern North American populations of *Sorex cinereus*.

Materials and Methods

To distinguish *S. acadicus* from other modern species known to exist in Nova Scotia, I inspected specimens of shrews collected by Gilpin in Nova Scotia and deposited in the USNM. I used box-and-whisker plots to compare measurements of the type series reported by Gilpin (1865) with standard external measurements I recorded from skin labels of 41 *Blarina brevicauda talpoides* from New Brunswick and Nova Scotia, 17 *Sorex albibarbis* from Maine, New Brunswick, and Nova Scotia, 77 *Sorex cinereus* from New Brunswick and Nova Scotia, 32 *Sorex dispar* from New Brunswick, 54 *Sorex fumeus umbrosus* from New Brunswick and Nova Scotia, and 41 *Sorex hoyi thompsoni* from New Brunswick and New Hampshire (see Appendix). Measurements include (Table 1): total length (TOT), tail length (TL), length of hind foot including the claw (HF), and weight (WT). I calculated head-and-body length (HB) by subtracting tail length from total length and proportional length of tail (TL%) by dividing tail length by head-and-body length.

To describe the morphology of the populations currently called *S. c. acadicus* and compare it to those of neighboring populations of *S. c. cinereus*, I inspected 151 specimens of *Sorex cinereus* from Maine ($n = 30$), New Brunswick ($n = 56$), New Hampshire ($n = 37$), and Nova Scotia ($n = 28$; see Appendix) and recorded qualitative and quantitative characters as described by Smith (1940), Junge & Hoffman (1981), Carraway (2007), and Woodman & Fisher (2016). Anatomical terminology follows those references.

For morphometric analyses, I measured specimens with undamaged skulls (see Appendix), comparing *S. c. acadicus* from Nova Scotia ($n = 11$) with samples of *S. c. cinereus* from New Brunswick ($n = 36$), Maine ($n = 24$), and New Hampshire ($n = 36$). I measured 11 cranio-mandibular variables to the nearest 0.1 mm using a

Table 1.—Summary statistics for external and skull measurements of samples of *Sorex cinereus* from Nova Scotia, New Brunswick, Maine, and New Hampshire. Statistics include mean ± SD, and range.

Nova Scotia	New Brunswick	Maine	New Hampshire
External measurements			
$n = 12$	$n = 65$	$n = 27$	$n = 36$
Total length (TOT)			
108 ± 7	99 ± 6	99 ± 5	96 ± 5
100–122	85–114	91–110	87–107
Head-and-body length (HB)			
64 ± 7	55 ± 6	58 ± 5	54 ± 3
52–77	43–70	48–71	48–64
Tail length (TL)			
44 ± 3	44 ± 2	42 ± 4	42 ± 3
39–48	39–48	31–48	35–46
Proportional tail length (%TL)			
69 ± 11	80 ± 9	73 ± 11	78 ± 7
58–92	60–100	46–90	63–92
Length of hind foot (HF)			
12 ± 2	12 ± 1	12 ± 1	11 ± 1
7–13	10–13	8–13	10–13
Weight (WT)			
3.6 ± 0.5	4.0 ± 1.1	3.6 ± 0.7	4.0 ± 0.9
3.2–4.2	2.9–7.5	2.5–5.5	2.5–6.6
3	62	16	36
Skull measurements			
$n = 11$	$n = 36$	$n = 24$	$n = 36$
Greatest length of skull (GLS)			
17.2 ± 0.4	17.0 ± 0.3	17.1 ± 0.4	16.9 ± 0.4
16.5–17.7	16.3–17.5	16.4–18.0	15.6–17.7
Condylobasal length (CBL)			
16.5 ± 0.3	16.2 ± 0.3	16.4 ± 0.4	16.1 ± 0.3
16.0–17.0	15.6–16.7	15.5–17.1	15.6–16.8
Breadth of braincase (BB)			
7.9 ± 0.2	8.1 ± 0.2	8.0 ± 0.3	8.0 ± 0.2
7.3–8.3	7.7–8.6	7.4–8.6	7.6–8.5
Breadth of zygomatic plate (ZP)			
1.0 ± 0.05	1.0 ± 0.1	1.0 ± 0.1	0.9 ± 0.1
0.9–1.1	0.8–1.1	0.9–1.2	0.7–1.2
Postorbital breadth (PO)			
3.0 ± 0.1	3.0 ± 0.1	3.0 ± 0.1	3.0 ± 0.1
2.8–3.1	2.8–3.2	2.9–3.1	2.8–3.2
Breadth across M2s (M2B)			
3.7 ± 0.1	3.6 ± 0.1	3.7 ± 0.1	3.7 ± 0.1
3.6–3.9	3.5–3.8	3.6–3.9	3.5–3.8
Maxillary breadth (MXB)			
4.2 ± 0.2	4.2 ± 0.1	4.2 ± 0.1	4.2 ± 0.1
4.0–4.5	3.9–4.4	4.0–4.5	4.0–4.4
Postglenoid width (PGW)			
4.5 ± 0.1	4.4 ± 0.1	4.4 ± 0.1	4.4 ± 0.1
4.3–4.7	4.1–4.6	4.2–4.7	4.3–4.6
Length of palate (PL)			
6.8 ± 0.2	6.7 ± 0.1	6.8 ± 0.1	6.6 ± 0.1
6.5–7.2	6.2–7.0	6.5–7.1	6.4–6.8
Length of unicuspid toothrow (UTR)			
2.5 ± 0.1	2.5 ± 0.1	2.6 ± 0.1	2.4 ± 0.1
2.5–2.7	2.4–2.6	2.4–2.7	2.3–2.6
Length of molariform toothrow (MTR)			
3.9 ± 0.1	3.8 ± 0.1	3.9 ± 0.1	3.8 ± 0.1
3.6–4.1	3.7–3.9	3.8–4.1	3.6–3.9

handheld digital caliper or an ocular micrometer in a binocular dissecting scope: greatest length of skull (GLS), condylobasal length (CBL), breadth of braincase (BB), breadth of zygomatic plate (ZP), postorbital breadth (PO), maxillary breadth (MXB), width across the upper second molars, from the buccal edge of the metastyles (M2B); postglenoid width (PGW); length of palate (PL); length of unicuspid toothrow (UTR); length of upper molariform toothrow, from the posterior of M3 to the anterior of P4 (MTR). Variable definitions follow Junge & Hoffmann (1981), Neithammer & Krapp (1990), and Woodman & Timm (1993) Although greatest length of skull and condylobasal length are strongly correlated (Pearson correlation = 0.833), they are not equivalent; both measurements are reported for each taxon because each is used as a character in various authoritative keys and descriptions of *Sorex* (e.g., Junge & Hoffmann 1981).

Multivariate analyses were carried out using Systat 11 (Cranes Software, Bangalore). I used ten log10-transformed skull variables (CBL, BB, ZP, PO, MXB, M2B, PGW, PL, UTR, MTR) in principal components analyses (PCA) and discriminant function analyses (DFA) to contrast the four geographically-defined samples morphometrically and to identify individual variables or suites of variables useful for distinguishing them.

Nomenclatural foundation of *Sorex acadicus* Gilpin, 1865

Historical background.—In a paper read before members of the Nova-Scotian Institute of Natural Science in Halifax on November 2, 1863, John Bernard Gilpin, M.D. (1810–1892), reviewed the species of shrews (Mammalia: Soricidae) he had identified as inhabiting the Canadian province of Nova Scotia. His presentation was subsequently published in the *Proceedings and Transactions of the Nova-Scotian Institute of Natural Science* (Gilpin 1865). In addition to six named species—*Neosorex palustris* (Richardson, 1828), *Sorex* "*thomsoni*" (=*S. thompsoni*), *S. platyrhinus* (De Kay, 1842), *S. personatus*, *Blarina talpoides*, and *B.* "*cineria*" [=*B. cinerea* (Bachman, 1837)]—Gilpin (1865:2) identified a new species, *Sorex acadicus*, based on differences "in size, and especially length of tail, breadth of fore palm, and length of sole."

Gilpin (1865) further mentioned that he had sent three examples of his new shrew (USNM 5086, 5087, 5088) to Spencer F. Baird, then Director of the USNM and Assistant Secretary of the Smithsonian Institution, for identification, and he credited Baird both with recognizing the shrews as representing a new species and with suggesting the name *Sorex acadicus* (Gilpin, 1865:2). In a later paper on the mammals of Nova Scotia, Gilpin (1869) explicitly ascribed authority for the species to Baird. Despite his acknowledgment of Baird's contribution, Gilpin (1865) published the description of *S. acadicus*, and he, not Baird, is the authority for the name.

In September 1861, Baird visited his hometown of Carlisle, Pennsylvania, where he wrote about Gilpin's Nova Scotia specimens in an unpublished manuscript intended to review North American Soricidae (Baird 1861). He initially applied the name *Sorex acadicus* to Gilpin's specimens (Baird 1861:58, 83), but subsequently changed his assessment, instead identifying Gilpin's shrews as *Sorex fimbripes* Bachman, 1837 (Baird 1861:55).

> In the collection of the Smithsonian Institution is a series of shrews sent from Halifax N. S. by Dr. J. B. Gilpin, which I was at first inclined to consider a new species and described in mss. as *S. acadicus*. An examination of the type of *fimbripes* however, shows closer relationship between the two than I had supposed, and although there are appreciable differences, especially in size, I have

come to the conclusion to consider the Halifax species as at least a variety of *fimbripes*.

Bachman's (1837:393) description of *S. fimbripes*, with its long, "considerably" fringed hind feet, in some respects resembles a water shrew (*Sorex palustris* group), although his illustration shows a small- to medium-sized terrestrial species with large feet (Bachman 1837: Pl.24, Fig. 8). Baird's (1861:55, 56) study of what he referred to as the "type" of *S. fimbripes* in the collection of the Academy of Natural Sciences of Philadelphia (ANSP) led him to determine its "general form and character that of *S. cooperi*" (=*S. cinereus* Kerr, 1792). This may have been the original specimen that Bachman (1837) used to describe *S. fimbripes*, but comparison of the external measurements reported by Bachman (1837) and Baird (1861) suggests otherwise. The ANSP specimen appears to have been lost or discarded since then (Ned Gilmore, in litt., 14 February 2018; see also Koopman 1976) and is no longer available for study. Lyon & Osgood (1909:243) had considered USNM 84556 to be the rediscovered "type" of *S. fimbripes* because "an old parchment label with the words '*Sorex fimbripes*. Type' written on it" was found tied to it when discovered in the USNM collection in 1898. Hollister (1911) subsequently identified USNM 84556 as *S. fumeus* Miller, 1895, an identification with which I concur. Hollister (1911:381) discounted the interpretation of this specimen as Bachman's (1837) holotype of *S. fimbripes*, noting that, in the time of Baird, the word "type" could simply refer to an *example* of a species: "Several specimens in the [USNM] collection are marked 'type' which have not the slightest claim, in the modern meaning of the word, to that distinction. Some were even collected after the description was published." I believe that the "types" of *S. fimbripes* in both ANSP and USNM simply represented the example in each institution that had been referred to that species. The USNM specimen may have been identified by Baird based on his inspection of the ANSP specimen. Without a verifiable holotype, Hollister (1911) considered Bachman's (1837) description of *S. fimbripes* to be unidentifiable.

Adhering to common practice at the time, Baird did not designate type specimens (e.g., Baird 1857). Yet, it is clear from Baird's (1861) manuscript that he favored USNM 5086 as the primary example of Nova Scotian *S. acadicus*, even though he ultimately identified the species as *S. fimbripes*. A second specimen (USNM 5087) provides support for most of the same characters he described for USNM 5086, and a third (USNM 5088) illustrated some variation in pelage color.

My inspection of these three USNM specimens revealed that USNM 5086 and 5087, both fluid-preserved specimens with the skull removed, are examples of *Sorex fumeus*. USNM 5088 is a fluid-preserved specimen that retains most of its skull, but the anterior rostrum is missing. Based on its smaller remaining unicuspids and on the distribution of pigment on the lower incisor, this individual is *S. cinereus*. Had Baird published his manuscript sooner rather than never, it is unlikely that Gilpin (1865) would have described *S. acadicus*. The composite nature of the series that Gilpin sent to Baird raises the question of whether *S. acadicus* Gilpin, 1865, is a junior synonym of *S. cinereus* Kerr, 1792 or a senior synonym of *S. fumeus* Miller, 1895.

Unfortunately, Gilpin (1865) did not designate a holotype for *S. acadicus*. He wrote (Gilpin 1865:2), "I possess six or eight specimens of this species in alcohol," indicating that he based his description on a larger series of specimens than the three shrews that he earlier sent to Baird in 1861. This type series has not been cited since Gilpin's published description, and the location of his specimens—or even their existence—is a mystery. Yet, the actual

specimens that Gilpin (1865) relied upon are relevant for determining the identity of *S. acadicus* and maintaining nomenclatural stability.

Although Gilpin was associated with the Nova Scotia Museum in Halifax, the Zoology Collection of that institution does not now possess any of his specimens (A. J. Hebda, in litt., 26 May 2017), nor do there appear to be any cataloged Gilpin specimens at the Canadian Museum of Nature, Ottawa (http://collections.nature.ca/en/Search; accessed 8 August 2017), or the Royal Ontario Museum, Toronto (http://gbif.rom.on.ca/ipt/resource.do?r=mamm; accessed 21 August 2017). Surprisingly, the primary repository for Gilpin's extant mammal specimens is the USNM. From 1855 through 1866, Gilpin sent at least eight shipments of mammals to that institution (Baird 1856, 1857b, 1858, 1860, 1862, 1864, 1865, 1872). USNM catalog records indicate that these donations totaled at least 121 specimens of terrestrial mammals and bats, including 40 soricids. Most were taken from near Halifax, but some also came from other parts of Nova Scotia and Newfoundland. Two Gilpin specimens of the sciurid *Tamiasciurus hudsonicus* are now in the collection of the Museum of Comparative Anatomy, Cambridge, Massachusetts, and two other Gilpin squirrels (*Glaucomys sabrinus*) are in the University of Michigan Museum of Zoology, Ann Arbor; all four specimens were obtained by exchange from the USNM (Vert Net: http://portal.vertnet.org/; accessed 8 August 2017; C. Thompson, in litt., 10 August 2017). Thus, USNM is the probable repository of any existing members of the type series of *S. acadicus*, but neither a type specimen nor a type series for *S. acadicus* has been identified in the USNM type catalogs (Lyon & Osgood 1909, Poole & Schantz 1942, Miller & Kellogg 1955, Fisher & Ludwig 2015).

Dating the publication of Sorex acadicus.—Gilpin's 1863 address on Nova Scotian shrews was published in the second issue of the first volume of the *Proceedings and Transactions of the Nova-Scotian Institute of Natural Science* (Gilpin 1865). This work is typically dated as 1867 (Smith 1940, Banfield 1981, Hall 1981, Whitaker 2004, Hutterer 2005), the year that appears on the volume's title page, which would have been published with the fourth (and last) issue of that volume. However, each of the four issues comprising the first volume represents a different operational year. The title page of the "*Bye-laws*" that established the Institute of Natural Science and is sometimes bound with the first volume, is dated 1863. The first issue of volume one is undated, but includes proceedings and correspondence from February through July 1863. Based on the timing of publication of individual issues in later volumes of the *Proceedings and Transactions*, this first issue was probably published in 1864. Gilpin's description of *S. acadicus* appears in the undated second issue, which contains proceedings from November 1863 through May 1864 and was probably published in 1865. The third issue reports proceedings and activities from October 1864 through July 1865, and it was most likely published in 1866. The fourth issue covers October 1865 through August 1866, and it was published with the index and the title page for the volume in 1867. This is the common pattern followed in dated issues of subsequent volumes. Following this sequence, I correct Gilpin's description of *S. acadicus* to the year 1865, not 1867 as commonly cited.

Identification of Sorex acadicus.—Gilpin (1865) provided individual measurements of total length and tail length from five of his specimens of *S. acadicus*, and I used these to calculate head-and-body length and proportional tail length (Table 2). I compared all four measurements to similar measurements from my samples of the six Nova Scotian species (Fig. 1). External

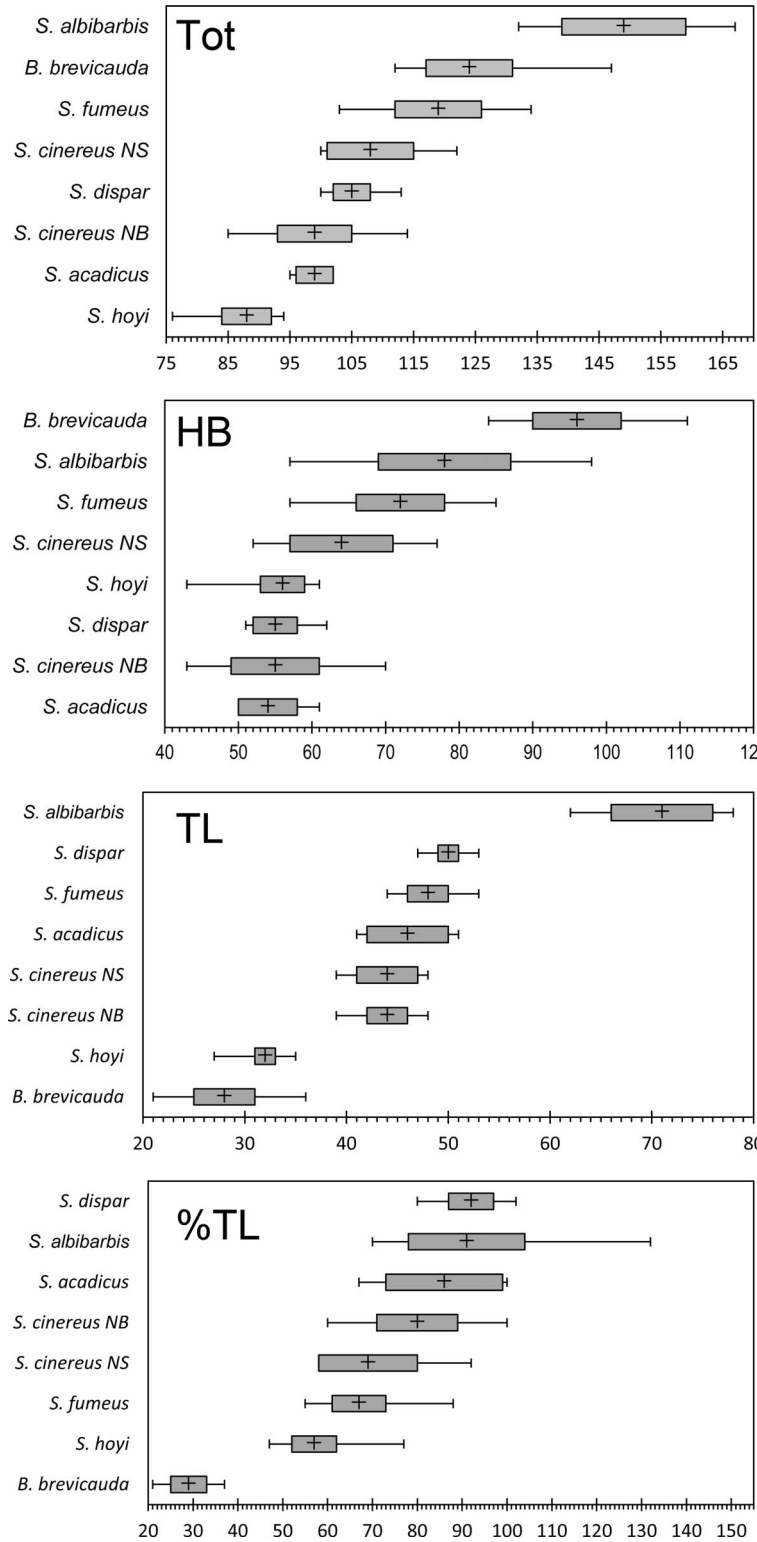

Table 2.—External measurements of the type series of *Sorex acadicus* from Gilpin (1865), converted from inches to mm. HB and %TL were calculated from Tot and TL. See Materials and Methods or Table 1 for abbreviations of measurements.

	Original measurements		Converted measurements (mm)			
Gilpin's number	Total length (inches)	Tail length (inches)	TOT	HB	TL	%TL
1.	3 9/10	1 9/10	99	51	48	94
2.	3 9/10	1 ¾	99	55	44	80
3.	3 3/4	1 ¾	95	51	44	86
4.	4	1 3/5	102	61	41	67
5.	4	2	102	51	51	100

measurements vary substantially, rendering them an imprecise means for individual identification (e.g., Stephens et al., 2015), but they provide a general measure of size and body proportions that can be used for distinguishing taxa.

Total length measurements show that *S. acadicus* overlaps extensively in size with my sample of *S. cinereus* from New Brunswick and potentially overlaps with *S. dispar* and *S. cinereus* from Nova Scotia (Fig. 1: TOT). The head-and-body length of *S. acadicus* overlaps with those of all species except *B. brevicauda*, and in absolute length of tail, *S. acadicus* is most similar to *S. cinereus*, *S. dispar*, and *S. fumeus* (Fig. 1: HB, TL). The proportional tail length of *S. acadicus* overlaps with those of all species except *B. brevicauda*, and the mean value for this character is closest to those of *S. albibarbis*, *S. cinereus*, and *S. dispar* (Fig. 1: %TL). Considered together, the external measurements of the type series of *S. acadicus* indicate that the taxon is most consistently similar in size and proportions to *S. cinereus* and is an unlikely match for *S. fumeus*.

Gilpin's (1865:2) type series for *Sorex acadicus* comprised "six or eight specimens of this species in alcohol." Among the 62 extant Gilpin specimens in the USNM Mammal Collection are 25 soricids from Nova Scotia: 11 *Blarina brevicauda talpoides*; 1 *Sorex albibarbis*; 8 *Sorex cinereus acadicus*; 3 *Sorex fumeus umbrosus*; and 2 *Sorex hoyi thompsoni*. Fifteen specimens of Gilpin's soricids are no longer in the USNM collection, and these include 12 *Blarina brevicauda* and 3 now indeterminate species of *Sorex*. Two of the latter were dried skins. The third was preserved in fluid, but was cataloged in the USNM in 1861, well before Gilpin made his 1863 presentation. Therefore, none of the 15 missing specimens plausibly formed part of the type series.

Among the extant fluid-preserved Nova Scotian shrews catalogued in the USNM during or after 1863—and thereby potentially part of Gilpin's type series—are 9 *Blarina brevicauda*; 1 *Sorex albibarbis*; and 5 *Sorex cinereus*. Both *B. brevicauda* and *S. albibarbis* are relatively large shrews that are easily distinguished from *S. acadicus* using external measurements alone (Table 2; Fig. 1), and Gilpin (1865)

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Fig. 1. Box and whisker plots comparing external measurements from the type series of *S. acadicus* (see Table 2) reported by Gilpin (1865) with those from the six species of shrews currently known to inhabit Nova Scotia. This comparison includes two samples of *S. cinereus* from New Brunswick (NB) and from Nova Scotia (NS): TOT, total length of head, body, and tail; HB, head-and-body length; TL, length of tail; %TL, length of tail as a proportion of head-and-body length.

had identified the two species (as *B. talpoides* and *Neosorex palustris*, respectively) as part of the known soricid fauna of Nova Scotia. If Gilpin sent part or all of his type series to the USNM, then they are most likely among the five *S. cinereus*. Three of these masked shrews were originally batch-catalogued in 1863 as USNM 6287 (now USNM 6287, 59647, 59648) (see also Baird, 1864:59). Two others (now USNM 59663, 59664) originally were batch-catalogued in 1885 with two *Blarina brevicauda* and a *Mus musculus* as USNM 13261.

Type material and selection of a neotype.—Based on the Nova Scotian specimens Baird (1861) discussed, his unpublished description of *S. acadicus* most closely matches *S. fumeus* Miller, 1895, although this latter species was unknown at the time. In contrast, Gilpin's (1865) published description more closely matches *S. cinereus* Kerr, 1792, a conclusion supported by his surviving specimens in the USNM. Therefore, *S. acadicus* belongs to a group of small, cryptic species (*Sorex cinereus* group) that continues to be the subject of taxonomic study and revision (e.g., van Zyll de Jong & Kirkland 1989, van Zyll de Jong 1991, Demboski & Cook 2003, Hope et al. 2012). Molecular analyses indicate low genetic divergence among some recognized species within the group and the presence of several cryptic, genetically divergent, unnamed species. Hence, *S. cinereus* as currently understood is likely to prove to be paraphyletic (Demboski & Cook 2003, Hope et al. 2012). Ultimately, it will be desirable to reconcile genetic variation with ecogeographical variation in morphology. Pursuant to that goal, a clear nomenclatorial standard for *S. acadicus* is warranted. Although some of Gilpin's surviving specimens of *S. acadicus* may have been part of his type series, the evidence is insufficient and warrants designation of a neotype rather than a lectotype (ICZN 1999: Articles 74, 75).

Sorex acadicus Gilpin, 1865
(Fig. 2)

1865. *Sorex, Acadicus* Gilpin, *Proceedings and Transactions of the Nova-Scotian Institute of Natural Science* 1(2):2.

1869. *Sorex Platyrinus*: Gilpin, *Proceedings and Transactions of the Nova-Scotian Institute of Natural Science* 2(2):59 (part; not *Otisorex platyrhinus* De Kay, 1842).

1869. *Sorex Acadica*: Gilpin, *Proceedings and Transactions of the Nova-Scotian Institute of Natural Science* 2(2):59 (incorrect gender concordance).

1890. *Sorex richardsoni* Dobson, *Monograph of the Insectivora, Part 3*, Fasc. 1, Pl. 23, Fig. 9 (part; not *Sorex richardsonii* Bachman, 1837).

1911. *Sorex personatus*: Hollister, *Proceedings of the U.S. National Museum* 40(1825):381, April 17 (part; not *Sorex personatus* I. Geoffroy-Saint-Hilaire1827).

1928. *Sorex cinereus cinereus*: Jackson, *North American Fauna* No. 51:40, July 24 (name combination).

1940. *Sorex cinereus acadicus*: R. W. Smith, *American Midland Naturalist* 24(1):219, July 31 (name combination).

Neotype.—USNM 59647, a fluid-preserved body with cleaned skull of an adult individual of unknown sex (Fig. 2), obtained by J. Bernard Gilpin on an unknown date; originally batch-catalogued with USNM 6287 and USNM 59648 as USNM 6287 between 13 March and 17 April 1863. The basioccipital of the skull is cracked, and the posterior surface of the palate, the right annulus tympanus, and the angular process of both dentaries are broken.

*Paraneotypes (*n = *4)*.—USNM 6287, a fluid-preserved specimen, and USNM 59648, a fluid-preserved body with cleaned

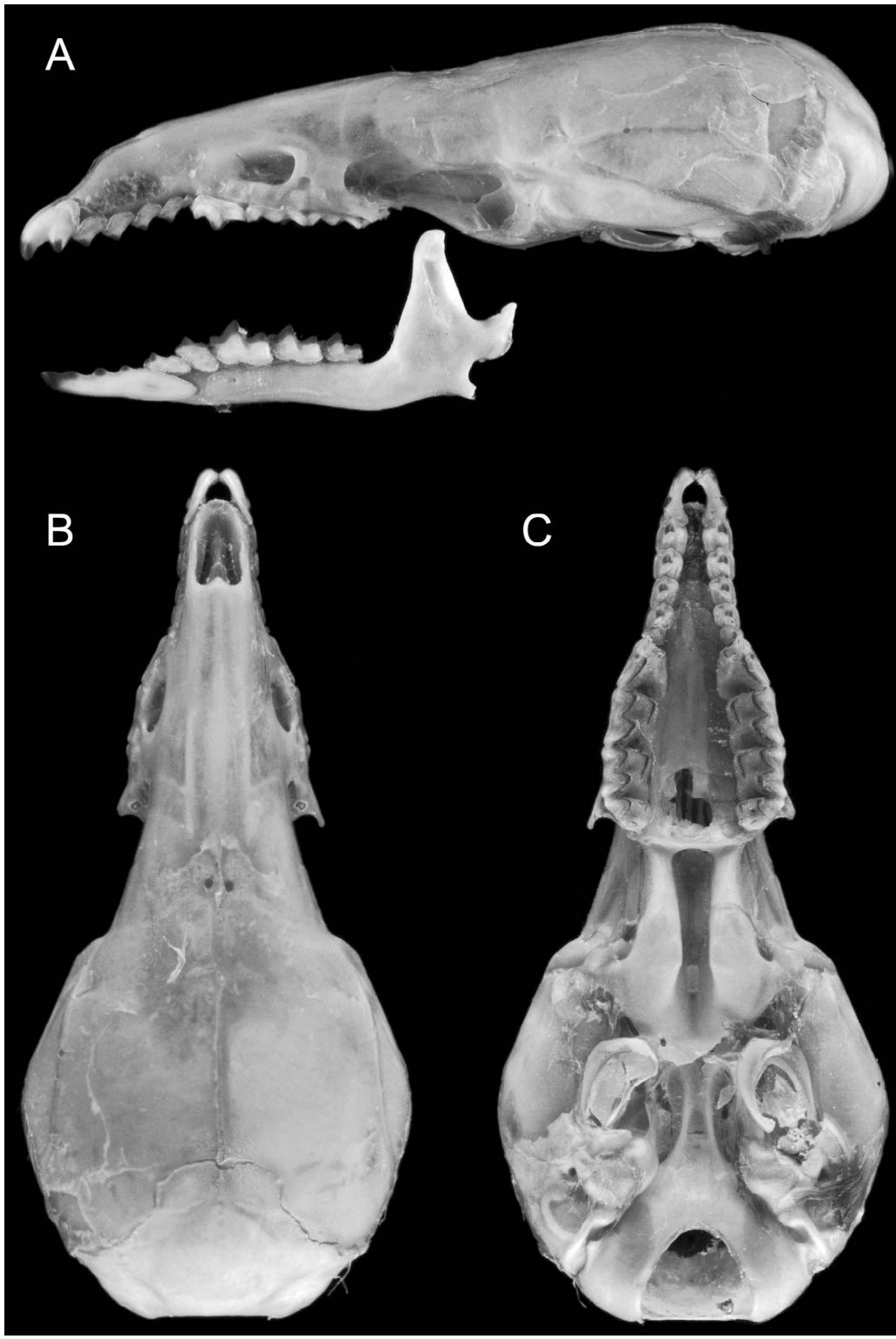
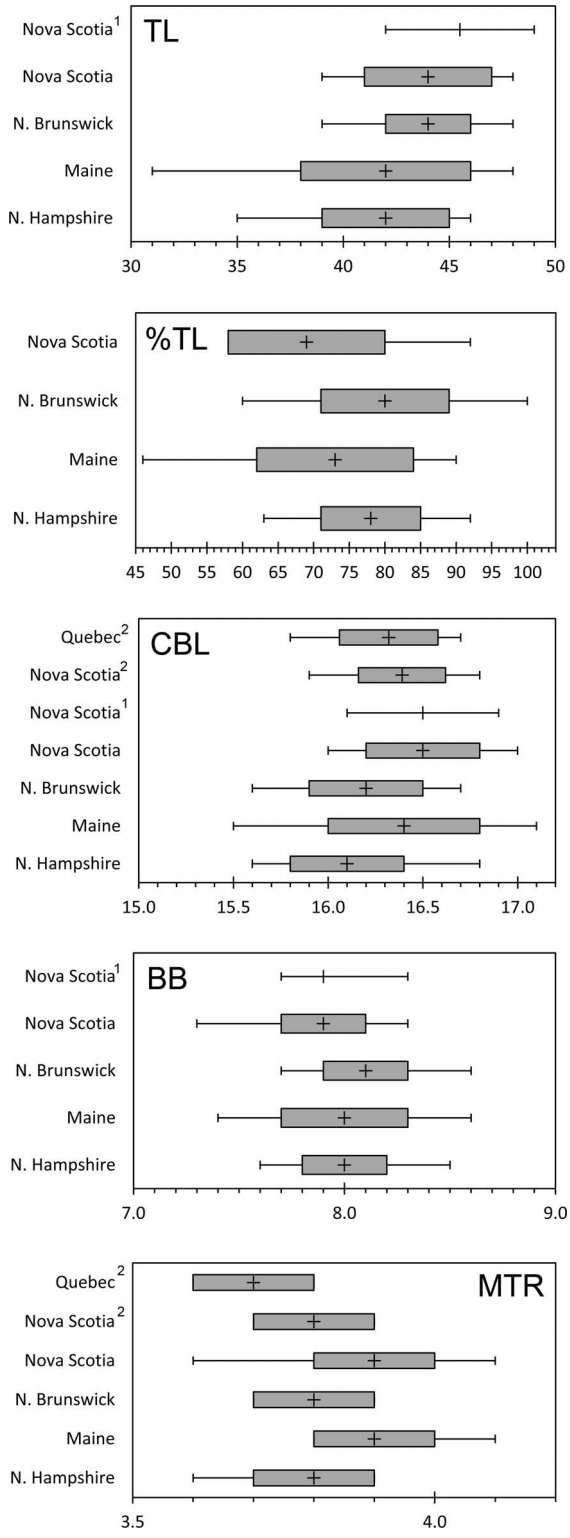


Fig. 2. Photographs of the skull of the neotype of *Sorex acadicus* Gilpin, 1865 (USNM 59647): A, left lateral view of cranium and mandible; B, dorsal view of cranium; C, ventral view of cranium.



skull of an adult; both individuals of unknown sex, obtained by J. Bernard Gilpin on an unknown date at the type locality. USNM 59663, a fluid-preserved specimen, and USNM 59664, a fluid-preserved body with cleaned skull of an adult; both individuals of unknown sex, obtained by J. Bernard Gilpin on an unknown date at an unknown locality in Nova Scotia; both originally batch-catalogued with USNM 13261 (*Blarina brevicauda*) and USNM 59665 (*Mus musculus*) as USNM 13261 on 18 November 1885.

Type locality.—Canada, Nova Scotia, Halifax County, Halifax. Gilpin (1865) originally indicated only that his type series came from "Nova Scotia." Smith (1940:219) stated that "it is highly probable that the type locality is in the vicinity of Halifax, Halifax County," a position with which Miller & Kellogg (1955) concurred. Specimen data in the USNM catalog indicate the neotype came from Halifax; thus, the place of origin of the neotype becomes the type locality, following the International Code of Zoological Nomenclature (ICZN 1999: Article 76.3).

Comparison of *Sorex cinereus acadicus* with eastern *S. c. cinereus*

Uncovering Gilpin's (1865) type series of *S. acadicus* makes it possible to review morphological differences that have been used to distinguish *S. c. acadicus* from *S. c. cinereus* (Smith 1940). The confusing molecular relationships outlined for Nova Scotian masked shrews (Stewart & Baker 1992, Shafer & Stewart 2007, Hope et al. 2012) make such a review desirable. Toward that end, I scored a number of skull and dental characters used elsewhere to distinguish populations of *Sorex*; investigated the mensural characters Smith (1940) used to distinguished *S. c. acadicus*; and applied multivariate morphometrics to identify measurements and combinations of measurements that might justify separation of *S. c. acadicus* as a valid subspecies distinct from *S. c. cinereus*.

Qualitative morphology.—One character used to distinguish the two primary subgenera of North American *Sorex* is the presence (subgenus *Sorex*) or absence (*Otisorex*) of a well-developed post-mandibular foramen on the lingual side of both dentaries (Junge & Hoffmann 1981). However, this foramen is occasionally present on one or both dentaries within many species of *Otisorex*, including *S. cinereus*. Among my northeastern samples of *S. cinereus*, a postmandibular foramen was observed as follows: Nova Scotia—7% of specimens with a foramen on at least one dentary ($n = 15$), but none with a foramen on both dentaries; New Brunswick—19% ($n = 54$) with a foramen on one dentary and 4% on both dentaries; Maine—25% ($n = 28$) with a foramen on one dentary and 7% on both dentaries; New Hampshire—27% ($n = 37$) with a foramen on one dentary and 3% on both dentaries. As in western populations of masked shrews (Woodman & Fisher 2016), the incidence of a distinct postmandibular foramen on the dentary varies among samples from northeastern North America and provides no basis for distinguishing among them.

In general, the accessory medial tine on the first upper incisor (I1) of northeastern North American *S. c. cinereus* is small to weakly-defined; the medial tine begins at, or just dorsal to, the pigmented area of the first incisor, and the pigment on the tine is

←

Fig. 3. Box and whisker plots of selected measurements (in mm) comparing *S. cinereus* from Nova Scotia with other geographical samples of *S. cinereus*: TL, length of tail; %TL, length of tail as a proportion of head-and-body length; CBL, condylobasal length; BB, breadth of braincase; MTR, length of molariform toothrow. Additional measurement statistics are from (1) Smith (1940) and (2) van Zyll de Jong (1976).

Table 3.—Factor loadings on the first three factor axes of PCA (see Fig. 4). Variable abbreviations are explained in the Materials and Methods.

	1	2	3
Component loadings			
PL	0.798	0.415	0.113
CBL	0.763	0.405	−0.154
M2B	0.714	−0.439	0.188
MTR	0.692	0.201	0.292
PO	0.622	−0.434	−0.305
PGW	0.615	−0.468	−0.139
UTR	0.607	0.579	0.046
MXB	0.607	−0.537	−0.193
ZP	0.470	−0.008	0.449
BB	0.194	0.354	−0.804
Eigenvalues	3.969	1.725	1.157
Percent of Total Variance Explained	39.686	17.255	11.571

often separated from the main pigmented area (see Junge & Hoffmann 1981, Carraway 2007). In lateral cranial view, about half or less of the length of the fifth unicuspid (U5) is visible in the gap between U4 and the parastyle of the upper fourth premolar (P4). In occlusal view, U3 is typically larger than U4. Also in occlusal view, pigment on the small ridge running from the apex of each unicuspid to its lingual cingulum is only occasionally distinct; more typically it is pale or lacking. Interdenticular spaces on the lower first incisor (i1) are typically deep, and the pigmented apices of the two posterior denticles of that tooth are isolated from each other and from the larger area of pigment on the anterior cusp. In each of these characters, *S. cinereus* in Nova Scotia is similar to examples of the species inhabiting New Brunswick, Maine, and New Hampshire.

Univariate analyses.—Smith (1940) stated that *S. c. acadicus* was distinguished from *S. c. cinereus* by having a longer tail; longer condylobasal length; larger, broader braincase; and longer, less arched maxillary toothrow. I tested these characters by comparing the following measurements among my samples of *S. cinereus* from Nova Scotia, New Brunswick, Maine, and New Hampshire with those of *S. c. acadicus* from Nova Scotia (Fig. 3): length of tail (TL); length of tail as a proportion of head-and-body length (%TL), condylobasal length (CBL), breadth of braincase (BB), and length of molariform toothrow (MTR). Where available, I also included measurement statistics for masked shrews from Nova Scotia and from Quebec (*S. cinereus miscix*) provided by Smith (1940) and van Zyll de Jong (1976).

Tail length of *S. c. acadicus* averages slightly longer than in *S. c. cinereus* from Maine and New Hampshire, but is the same as that in New Brunswick (Table 1; Fig. 3: TL). The magnitude of the average difference (2–3 mm) is trivial, particularly when one considers the likelihood of inter-observer error and variation in external measurements associated with different states of morbidity (Stephens et al. 2015). Although the tail averages longer in the sample from Nova Scotia, its length represents a smaller proportion of head-and-body length there than in the other three samples (Fig. 3: %TL).

The skull averages slightly longer in Nova Scotia than in the other three samples, and it is most similar in mean length to the sample from Maine rather

Table 4.—Results from 4-sample backward stepwise DFA (see Fig. 5): (A) Correlations (loadings) of log-transformed input variables with the first two canonical variates (CV); (B) corresponding post hoc classification matrix; (C) jackknifed classification matrix. Variable abbreviations are explained in the Materials and Methods. Significant correlations are based on Bonferroni probabilities: *, <0.05; **, <0.01; ***, <0.001.

A. Correlation matrix

variable	CV1	CV2
CBL	−0.525***	0.384**
BB	0.057	−0.528***
ZP	−0.343*	0.177
PO	−0.075***	0.359*
M2B	−0.275	0.625***
MXB	−0.108	0.421**
PGW	−0.122	0.376**
PL	−0.766***	0.190
UTR	−0.917***	−0.139
MTR	−0.504***	0.346*
Eigenvalues	0.656	0.423
Canonical correlations	0.629	0.545
Proportion of dispersion (%)	0.565	0.364

B. Classification matrix

	Nova Scotia	New Brunswick	Maine	New Hampshire	% correct
Nova Scotia	6	2	2	1	55
New Brunswick	3	20	7	6	56
Maine	5	6	10	3	42
New Hampshire	3	3	2	28	78
Total	17	31	21	38	60

C. Jackknifed classification matrix

	Nova Scotia	New Brunswick	Maine	New Hampshire	% correct
Nova Scotia	5	2	2	2	45
New Brunswick	4	18	8	6	50
Maine	5	7	9	3	38
New Hampshire	3	4	2	27	75
Total	17	31	21	38	55

than that from neighboring New Brunswick (Table 1). The small magnitudes of the average differences (0.1–0.4 mm), coupled with the overlapping standard deviations and wide ranges, do not permit accurate assignment of individual specimens to any one of the four analytical samples (Table 1; Fig. 3: CBL). The braincase of Nova Scotian *S. cinereus* averages 0.1–0.2 mm narrower than that derived for the other samples (Fig. 3: BB) rather than wider, as suggested by Smith (1940). Length of molariform toothrow varies by no more than 0.1 mm among the four samples (Fig. 3: MTR).

Because the CBL and BB means differ slightly between *S. cinereus* from Nova Scotia and the other samples, I plotted the two variables to explore the degree of differentiation among samples (Fig. 4). I also regressed BB on CBL individually for each sample to determine whether any trends existed within them. The resulting regression lines demonstrate that all four samples exhibit similar, but offset trends of increasing BB with increasing CBL. The slope of the regression for Nova Scotian *S. c. acadicus*,

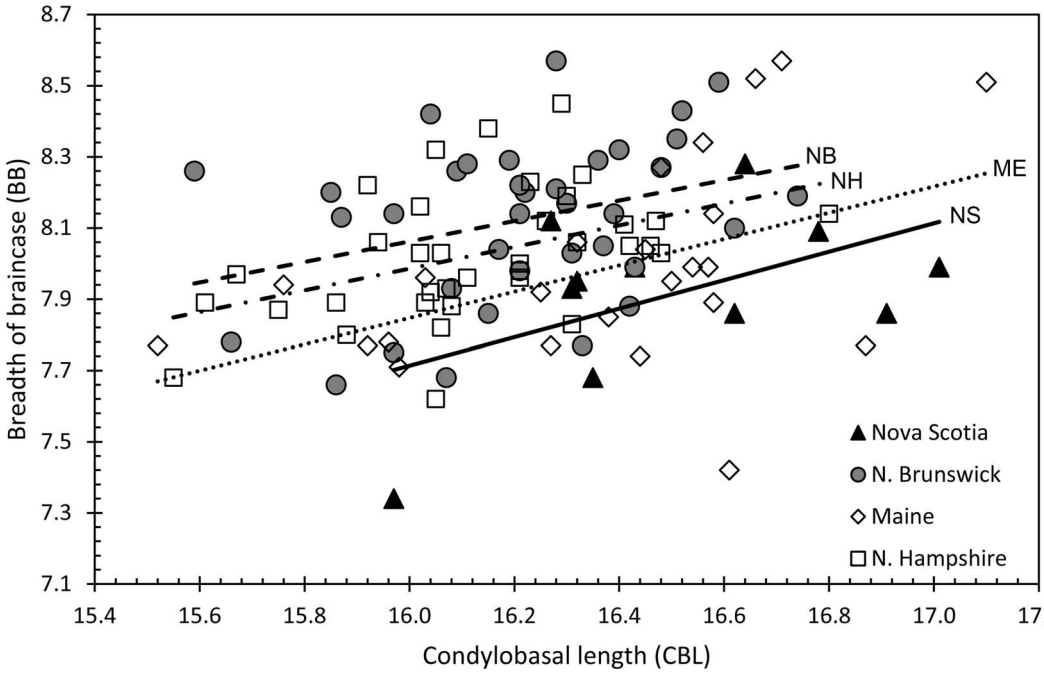


Fig. 4. Bivariate plot of condylobasal length (CBL) and breadth of braincase (BB) among the four geographical samples of masked shrews. Abbreviations for regression lines: NB, New Brunswick ($y = 0.2878x + 3.4566$; $R^2 = 0.108$; $p = 0.050$); NH, New Hampshire ($y = 0.3046x + 3.1124$; $R^2 = 0.1934$; P = 0.007); ME, Maine ($y = 0.3696x + 1.933$; $R^2 = 0.2226$; $p = 0.020$); NS, Nova Scotia ($y = 0.3997x + 1.318$; $R^2 = 0.2537$; $p = 0.114$).

however, is not significantly different from zero ($p = 0.114$; Fig. 4). Moreover, the dispersion of individual specimens around each regression line is broad, and the regressions explain only a small proportion of the variation, with all R^2 values < 0.26. The overlap among the four samples is too great to use these two characters to uniquely distinguish *S. c. acadicus* or correctly identify individual shrews.

Multivariate analyses.—The four samples from Nova Scotia, New Brunswick, Maine, and New Hampshire overlap extensively on the plot of factor scores (Fig. 5) resulting from the 10-variable PCA model. All variables loaded positively on the first factor axis, indicating that this axis is an indicator of overall skull size (Table 3). The second factor axis contrasts individuals with longer, narrower skulls and those with shorter, broader skulls (Table 3). The 95% confidence ellipses plotted for each of the four samples overlap extensively, with that for Nova Scotian *S. c. acadicus* almost completely enveloping the other three samples.

The DFA model that exhibited the greatest separation among the four samples of *S. cinereus* was a backward stepwise analysis that incorporated five variables (CBL, BB, M2B, PL, UTR) and yielded an overall correct classification rate of 60% (jackknifed classification = 55%; Table 4). The highest proportion of correct classifications was 78% for the New Hampshire sample, whereas the lowest was 42% for the Maine sample. Individuals from all four samples were misclassified amongst one another. The first canonical variate (CV1) concentrates the New Hampshire shrews toward the positive side of the axis, and the Nova

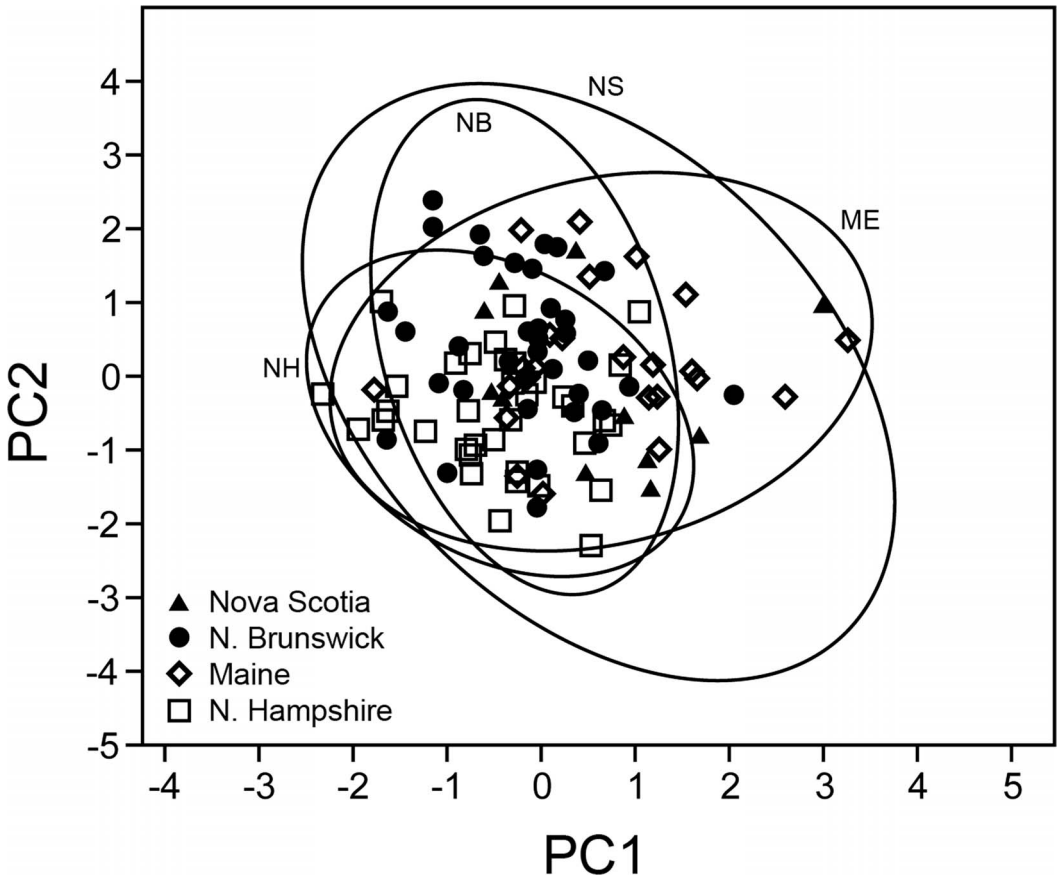


Fig. 5. Plots of individual specimens on the first two principal components from a PCA of 10 variables measured from 4 geographical samples of *Sorex cinereus* (Table 3). Abbreviations for 95% confidence envelopes: NB, New Brunswick; NH, New Hampshire; ME, Maine; NS, Nova Scotia.

Scotia and Maine shrews toward the more negative side (Fig. 6). The second canonical variate (CV2) concentrates Maine shrews toward the positive side of that axis and New Brunswick shrews toward the more negative side. Despite these subtle tendencies, the 95% confidence envelopes of the four samples overlap substantially, with that for Nova Scotian *S. c. acadicus* nearly encompassing those of the other three samples. Neither multivariate technique succeeded in isolating the Nova Scotian specimens, *S. acadicus* sensu Gilpin, 1865, from the three northeastern samples of *S. c. cinereus*.

Discussion

This review of morphological traits and cranial variables, individually and in combination, indicates that *S. c. acadicus* in Nova Scotia morphologically resembles nearby populations of masked shrews classified as *S. c. cinereus*. Had the Nova Scotian masked shrews been distinctive, thereby warranting subspecific recognition, one would expect the Nova Scotian sample to consistently separate from the other three samples of *S. cinereus* from New Brunswick, Maine, and New Hampshire and for those three samples to consistently group

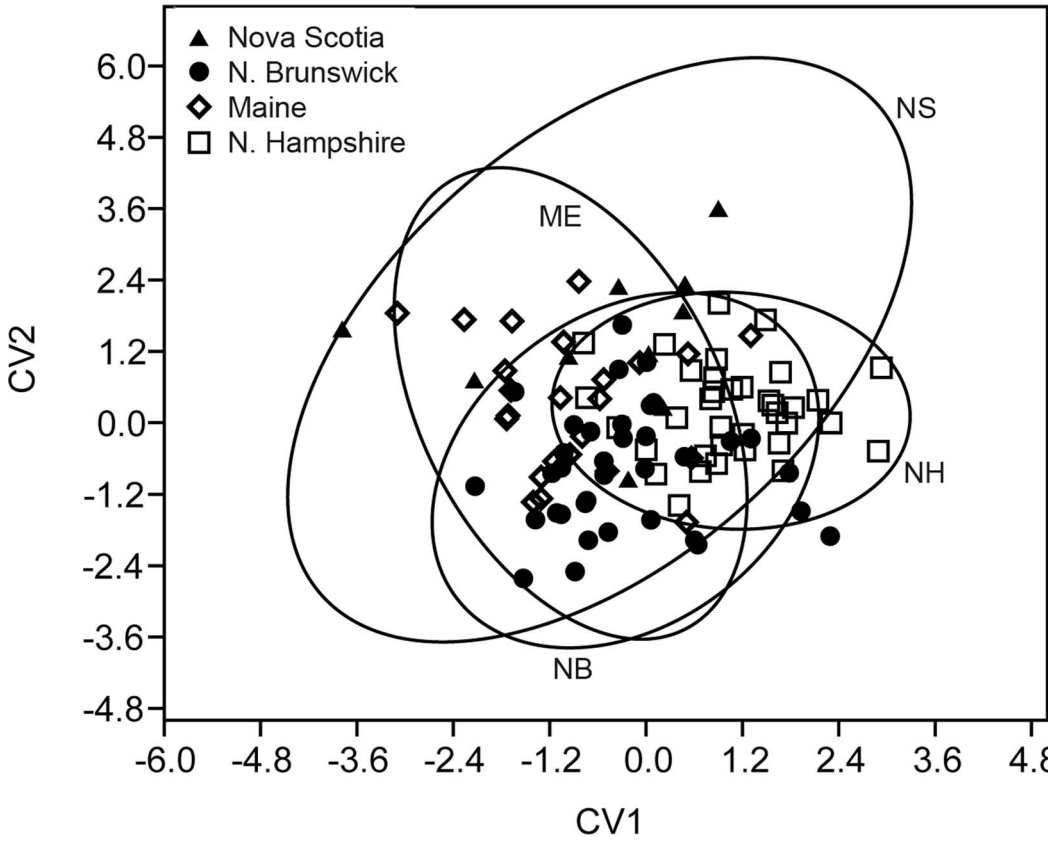


Fig. 6. Plots of individual specimens on the first two canonical variates (CV) derived from a 4-group backward stepwise DFA (Table 4). Abbreviations for 95% confidence envelopes: NB, New Brunswick; NH, New Hampshire; ME, Maine; NS, Nova Scotia.

together. Instead, all four geographic samples are indistinguishable from each other.

My data support the position of Jackson (1928) that *S. acadicus* Gilpin, 1865, does not warrant separation as a distinct taxon, but is most appropriately considered a junior synonym of *S. c. cinereus*. This evaluation of the taxonomic status of *S. acadicus*, could not have proceeded without the empirical understanding of Gilpin's taxon that is provided by the type and the original series.

Acknowledgments

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Appendix: Specimens Examined

All specimens are cataloged in the collection of the Mammal Division, U.S. National Museum of Natural History (USNM), Smithsonian Institution, Washington, DC. Highlighted Nova Scotian specimens are part of the original type series of *Sorex acadicus*.

Blarina brevicauda talpoides ($n = 41$)

New Brunswick: Albert Co., 5.3 km N, 3.5 km W Riverside-Albert (528211). Carleton Co.: Moose Mtn, 15 km NE Upper Kent (553347). Kings Co.: Hampton (150046–150048). Northumberland Co.: Tabusintac River, 7 Miles Upstream From Highway 11 (553339, 553340, 553348–553350). Restigouche Co.: Mt. Carleton Provincial Park (553331–553338, 553341–553346).

Nova Scotia: Antigonish Co.: James River (150040–150045). Colchester Co.: 23 km N, 2.0 km W Truro (528210); 25.0 km N, 7.4 km E Truro (530832–530834). Digby Co.: Digby (150036–150039). Inverness Co.: 7.5 km N, 2.0 km E Margaree Valley (530831). Kings Co.: 9.5 km N, 18.0 km W Kentville, Canada Creek (528208, 528209).

Sorex albibarbis ($n = 17$)

New Brunswick: Albert Co.: Alma, 1 Mi W; Fundy N.P. (288005); 5.3 km N, 3.5 km W Riverside-Albert (528207); Restigouche Co.: Mount Carleton Provincial Park (553303–553308).

Nova Scotia: Digby Co.: Antigonish Co., James River (150068); Digby (150056); Halifax Co., Halifax (238165); Pictou County, Trenton, 30 km E (530829, 530830).

Maine: Piscataquis Co.: Mount Katahdin (117980, 117981); Somerset Co.: N shore Russell Pond (569772); York Co.: Lyman; Massabesic Experimental Forest (600798).

Sorex cinereus cinereus

Maine ($n = 30$): Aroostook Co.: Fish River Lodge, 1.5 mi E of Eagle Lake (South Shore Eagle Lake, 1.5 mi E of Rt 11) (570904–570906, 600199, 600201, 600205, 600207, 600208, 600211); Presque Isle (283030–283034). Franklin Co.: 2 mi N Kennebago Lake (503985); Kennebago (564003). Hancock Co.: Brooklin (172697); Southwest Harbor (186725). Knox Co.: North Haven Island (149509, 149600). Oxford Co.: Lake Umbagog National Wildlife Refuge, Stranger House, 7.1 mi NE Errol (568175, 568176). Piscataquis Co.: Sebec Lake (149034, 149035). Sagadahoc Co.: Small Point (149508). Somerset Co: N shore Russell Pond (569778); Pittston Farm (602284); Pittston Farm, 0.2 mi SW on Northern Road from junction with Seboomook Road (600825). York County:

Lyman, Massabesic Experimental Forest (600794–600796).

Specimens used for morphometric analyses: 149034, 149508, 149509, 149600, 172697, 186725, 283031–283034, 503985, 568175, 569778, 570904–570906, 600201, 600205, 600208, 600211, 600794–600796, 600825.

New Brunswick ($n = 56$): Kings Co.: Hampton (150072, 150397). Restigouche Co.: Mt. Sagamook, Mt. Carleton Provincial Park (552929, 552931–552955, 552957–552973; 552977, 552978, 552981, 552982, 552987, 552996, 553006, 553010, 553015–553017).

Specimens used for morphometric analyses: 150397, 552931, 552934, 552936–552939, 552941–552943, 552945, 552947, 552950–552952, 552955, 552957–552962, 552964, 552966, 552968, 552969, 552973, 552977, 552981, 552982, 552987, 552996, 553006, 553010, 553015, 553017.

New Hampshire ($n = 37$): Carroll Co.: Bartlett Experimental Forest (600629, 600631–600636, 600648–600655, 600737, 600740, 600801, 601780–601798).

Specimens used for morphometric analyses: 600629, 600631–600636, 600648–600655, 600737, 600740, 600801, 601780–601796, 601798.

Nova Scotia (*S. c. acadicus*; $n = 28$): No Locality (59663, 59664). Annapolis/Queens Co.: Kedgemakooge (Kejimkujik) Lake (245436, 245438, 245458, 245459, 243916). Antigonish Co.: James River (150063, 150067, 150069, 150070, 150398). Digby Co.: Brier Island (234125); Digby (150055, 150058–150060); Little River (234121–234123). Halifax Co.: Halifax (**6287**, **59647**, **59648**, 303332, 303333). Inverness Co.: Margaree Valley, 7.5 km N, 2.0 km E (530820). Victoria Co.: Englishtown, 5.0 km SE, SE Slope Kellys Mountain (530821, 530822).

Specimens used for morphometric analyses: **59647, 59648**, 59664, 150059, 150063, 150070, 150398, 245438, 530820, 530821, 530822.

Sorex dispar ($n = 32$)

New Brunswick: Restigouche Co.: Mt. Carleton Provincial Park (553242–553273).

Sorex fumeus umbrosus ($n = 54$)

New Brunswick: Albert Co.: 5.3 km N, 3.5 km W Riverside-Albert (528196–528206, 530823, 530824). Kings Co.: Hampton (150073, 150074). Northumberland Co.: Tabusintac River, 7 Miles Upstream From Highway 11 (553241). Restigouche Co.: Mt. Carleton Provincial Park (553083–553085, 553092, 553100, 553102, 553104, 553107, 553113, 553114, 553118, 553125, 553127, 553130, 553146, 553151, 553175, 553201, 553206, 553222). York Co.: 0.5 mi S Fosterville (601151).

Nova Scotia: Antigonish Co.: James River (150061, 150062, 150064–150066, 150071). Colchester Co.: 23 km N, 2.0 km W Truro; West North Creek (528191–528195); 25.0 km N, 7.4 km E Truro (530827, 530828). Digby Co., Digby (150054, 150057). Pictou Co.: 30 km E Trenton (530825, 530826).

Sorex hoyi thompsoni ($n = 41$)

New Brunswick: Northumberland Co.: Tabusintac River, 7 Miles Upstream From Highway 11 (553329, 553330). Restigouche Co.: Mt. Carleton Provincial Park (553310–553328).

New Hampshire: Carroll Co.: Bartlett Experimental Forest (600744, 601995–602007, 603183, 603191, 603199). Coos Co.: Bretton Woods (294773); Lake Umbagog National Wildlife Refuge (568192, 568198).