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Taxonomic evaluation of the three "type" specimens of the fringe-footed shrew, *Sorex fimbripes* Bachman, 1837 (Mammalia: Soricidae) and recommended nomenclatural status of the name

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Abstract.—John Bachman (1837:391) described the "fringe-footed shrew," *Sorex fimbripes* Bachman, 1837, in his landmark monograph on the North American Soricidae (Mammalia: Eulipotyphla), in which he recognized 13 uniquely New World species. Characters he attributed to *S. fimbripes* resulted in its being interpreted as a tiny, semi-aquatic species and contributed to the complexity of its subsequent taxonomic history. The status and location of the holotype, which should aid in resolving questions about the nature of *S. fimbripes*, instead have added to the confusion. Originally studied by Bachman in South Carolina, the holotype was later thought to have been identified in the Academy of Natural Sciences of Philadelphia (ANSP), and it is currently considered to be in the National Museum of Natural History (USNM), Washington, D.C. To clarify the identity of the species and its holotype, I compared descriptions of the holotype and the ANSP type with the USNM specimen and with eight species of eastern North American shrews. I conclude that the three accounts of *S. fimbripes* refer to three different specimens and that the holotype was probably destroyed during the American Civil War. Bachman's *S. fimbripes* was most likely equivalent to *S. cinereus* Kerr, 1792, *S. fontinalis* Hollister, 1911, or *S. fumeus* Miller, 1895, but without the holotype, its identity cannot be determined definitively, and the name is a *nomen dubium*.

Keywords: *Blarina brevicauda*, *Cryptotis parvus*, nomenclature, Pennsylvania, *Sorex albibarbis*, *Sorex dispar*, *Sorex hoyi*, Soricomorpha

Among the thirteen species recognized by the South Carolinian naturalist and minister John Bachman (1837:391) in his authoritative monograph on North American shrews (Mammalia: Soricidae), eight were species that he described for the first time. The most enigmatic of these animals is his "fringe-footed shrew," *Sorex fimbripes* Bachman, 1837, which he described from a single individual sent to him from the Academy of Natural Sciences of Philadelphia (ANSP) for inspection (Fig. 1). The specimen had been obtained by University of Pennsylvania chemistry professor Walter R. Johnson from "high table-land on a branch of Drury's Run, a tributary of the west branch of the Susquehannah river," Clinton County, Pennsylvania, and donated to the ANSP.

Bachman (1837:392) characterized *S. fimbripes* as "a little less in size than that of Forster's Shrew," *Sorex forsteri* Richardson, 1828 (=*S. cinereus* Kerr, 1792), a comparison that is supported by his

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Fig. 1. Illustrations of *Sorex cooperi* Bachman, 1837 [=*Sorex cinereus* Kerr, 1792] and *Sorex fimbripes* Bachman, 1837 from Bachman (1837:Pl. 24).

measurements of the holotype (Table 1). Of particular note were "its broad, furry, turtle-like feet" whose "edges on the lower surface are fringed considerably" (Bachman, 1837:393, 402). He added that "This species approaches nearer to the Genus *Mygale* of Cuvier, than any other yet discovered in America," thereby drawing an analogy with an aquatic desman (Talpidae: *Mygale* Cuvier, 1800 = *Desmana* Güldenstaedt, 1777) and establishing a convergent relationship, if not a common ancestry, with North American water shrews (i.e., *Sorex palustris* group). Bachman's (1837:Pl. 24, Fig. 8) illustration of *S. fimbripes* suggests a small-bodied species with big feet (Fig. 1), although the

Table 1.—External measurements of the holotype of *Sorex fimbripes* as reported by Bachman (1837), of the ANSP type as reported by Baird (1861), and as measured here for USNM 84556. Abbreviations (see Materials and Methods): HB, head-and-body length; HF, length of hind foot; TL, tail length; TOT, total length (calculated by adding HB and TL); TL%, length of tail relative to head-and-body length.

	Reported measurements (inches)			Converted and calculated measurements (mm)				
	HB	TL	HF	TOT	HB	TL	TL%	HF
Bachman's holotype	2 1/8	1 ¾	½	98	54	44	81%	13
Baird (1861) (ANSP "type")	1.90	1.50	0.49	86	48	38	79%	12
USNM 84556 (USNM "type")	–	–	–	94	54	40	74%	12

exaggerated length of the hind feet is not supported by his measurements (Table 1).

Based on Bachman's (1837) description, Pomel (1848) used *S. fimbripes* as the type species for his aquatic shrew genus *Hydrogale* Pomel, 1848; Baird (1857) grouped *S. fimbripes* with *S. palustris* in his aquatic genus *Neosorex* Baird, 1857; Fitzinger (1858) included it in the aquatic genus *Crossopus* Wagler, 1832 (=*Neomys* Kaup, 1829); Gill (1875) treated it a synonym of the North American water shrew, *S. palustris* Richardson, 1828; and Green (1930:11) considered the taxon as an eastern North American subspecies of *Sorex palustris*.

As knowledge of North American soricids accumulated, Bachman's (1837) description of the physical features of *S. fimbripes* contributed to confusion regarding its identity as a semi-aquatic animal. One of the primary issues is that the one species of water shrew known from Pennsylvania [at that time, *Sorex palustris*; now *Sorex albibarbis* (Cope, 1862)], like all recognized semi-aquatic species of shrews worldwide (Nowak 1999), has significantly larger body size than that ascribed to the fringe-footed shrew. Uncertainty regarding the purported aquatic adaptations of *S. fimbripes* may be hinted at by Bachman's own failure to mention its potential locomotor behavior or habits in *The viviparous quadrupeds of North America* (Audubon and Bachman, 1854:312–313), unlike he did in his accounts for some other soricid species (e.g., *S. longirostris* Bachman, 1837). It is made clearer by Baird's (MS 1861) consideration of *S. fimbripes* as a valid species of ambulatory shrew and its later treatments by other authorities as a synonym of ambulatory *S. personatus* I. Geoffroy Saint-Hilaire, 1827 (=*S. cinereus* Kerr, 1792) (Miller 1895) and as a synonym of ambulatory *S. c. cinereus* Kerr, 1792 (Jackson 1928; Hall 1981; Hutterer 2005). The contrasting characters ascribed to *S. fimbripes* possibly led Merriam (1895) to ignore the name, whereas Hollister (1911) and Handley & Varn (1994) considered *S. fimbripes* as entirely unrecognizable from Bachman's (1837) description.

The holotype of *S. fimbripes*, which should illustrate the characteristics of the species and resolve any question regarding its morphological adaptations, has a confounding and uncertain history of its own that contributes to the mystery of this shrew's identity and the proper application of the name. In an unpublished manuscript, Spencer Fullerton Baird (MS 1861) reported inspecting the "type" of *S. fimbripes* at the ANSP. However, Baird's manuscript description of the specimen does not conform to that of Bachman (1837), raising the question of whether the shrew that Baird studied was actually Bachman's holotype. No specimen matching either Bachman's (1837) or Baird's (MS 1861) description of *S. fimbripes* is in the ANSP collection today (Ned Gilmore, ANSP, in litt., 14 February 2018; see also Koopman 1976).

Almost half a century later, Lyon & Osgood (1909) reported finding the "type"

of *S. fimbripes* in the mammal collection of the National Museum of Natural History (USNM), Washington, D.C. This specimen was catalogued on 29 April 1898 as USNM 84556, and since Lyon & Osgood's discovery, it generally has been represented as the holotype of *S. fimbripes* (Lyon & Osgood 1909:243; Poole & Schantz 1942:185; Fisher & Ludwig 2015:43). However, documentation regarding the origin of the specimen or tracking its inferred transfer among individual researchers or institutions is lacking. Moreover, this specimen differs from Bachman's (1837) description of the holotype (Hollister 1911), and it does not easily fit Baird's (MS 1861) description of the ANSP *S. fimbripes*.

To resolve the identity of the specimens identified as the type of *S. fimbripes*, I compared the characters of the holotype reported by Bachman (1837) with those of the ANSP "type" reported by Baird (MS 1861) and with those of USNM 84556, the USNM "type" according to Lyon & Osgood (1909). I also compared external measurements from these three specimens with those from large samples of shrews known from Pennsylvania. I use these results (1) to address whether any combination of the three reported types represents the same individual and (2) to determine what is the most likely modern identification of Bachman's holotype of *S. fimbripes*.

Materials and Methods

For the purposes of this paper, I employ the word "ambulatory" to refer to terrestrial shrews lacking clear aquatic, fossorial, or scansorial adaptations. The external measurements reported for the holotype of *Sorex fimbripes* by Bachman (1837), those reported for the "type" in the ANSP by Baird (MS 1861), and those recorded by me from USNM 84556 are treated as though they represent three separate individuals, or three separate "types," and I refer to them as such hereafter. Measurements include (Table 1): total external length (TOT), tail length (TL), and length of hind foot including the claw (HF). I obtained head-and-body length (HB) by subtracting tail length from total length, and I calculated proportional length of the tail (TL%) by dividing tail length by head-and-body length and multiplying by 100. The skull of USNM 84556 was removed previously—although the skin is intact—rendering my measures of TOT, HB, and TL% for that specimen less than ideal.

I used plots to visually compare the external measurements and proportional tail length of Bachman's holotype, the ANSP type, and USNM 84556 (Fig. 2). External measurements can vary substantially as a result of intra-observational error, inter-observational error, and post-mortem changes in the body (e.g., Sumner 1927; Blackwell et al. 2006; Stephens et al., 2015). The magnitude of error generally decreases proportionately as the size of the measure increases (e.g., Blackwell et al. 2006), and there is directionality to post-mortem changes (Stephens et al. 2015). Stephens et al. (2015) showed high inter-observer correlations for TL and TOT, indicating they typically vary less than other external dimensions when measured by different people. Otherwise, there is little consistency to this form of error. In the absence of an adequate gauge of inter-observer error, I included an arbitrary error of ±5% (ca. 1–10 mm) in comparisons of TOT, HB, TL, and TL% among the three types (Fig. 2).

The modern mammal fauna native to Pennsylvania includes eight recognized species of shrews (Mammalia: Soricidae): *Blarina brevicauda* (Say, 1822); *Cryptotis parvus* (Say, 1822); *Sorex albibarbis* (Cope, 1862); *Sorex cinereus* Kerr, 1792; *Sorex dispar* Batchelder, 1911; *Sorex fontinalis* Hollister, 1911; *Sorex fumeus* Miller, 1895; and *Sorex hoyi* Baird, 1857 (Merritt 1987). All but two of these species (*C. parvus*, *S.*

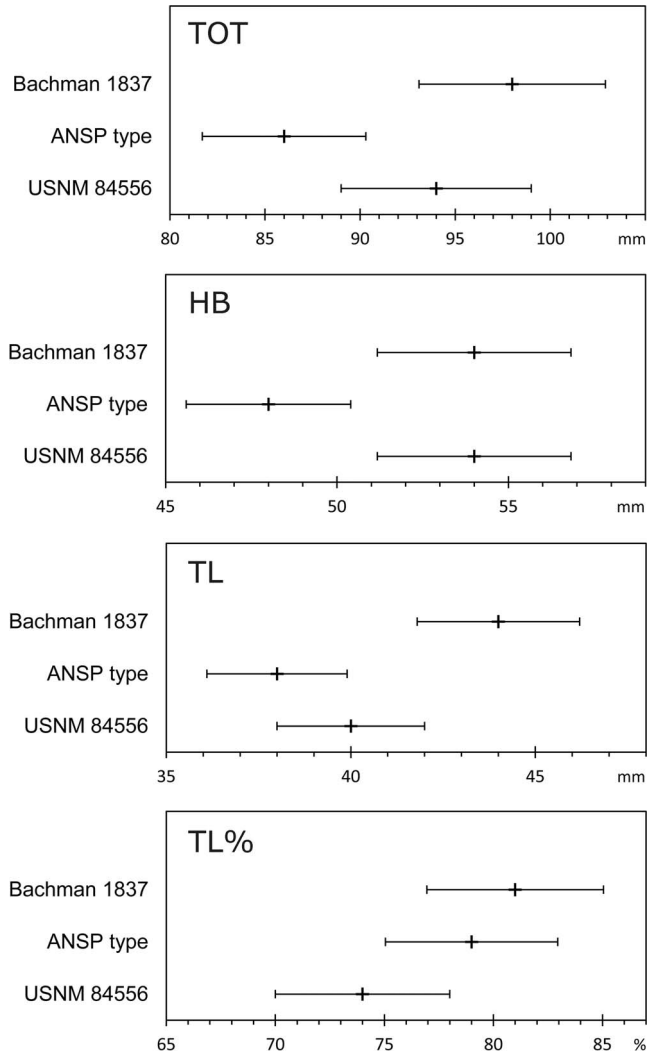

Fig. 2. Plots showing potential similarity of external measurements among the three purported type specimens of *S. fimbripes*. The cross marks the reported measurement; lines represent an error of ±5%. Abbreviations: TOT, total length (mm); HB, head-and-body length (mm); TL, tail length (mm); TL%, proportional length of tail (%).

hoyi) are documented by museum specimens to occur in Clinton County, and two (*B. brevicauda*, *S. cinereus*) are known from along Drury Run, the type locality of *S. fimbripes* (Kirkland & Levengood 1987; Kirkland & Hart 1999; Sue McLaren, Carnegie Museum, Pittsburgh, email correspondence, 10 April 2018; VertNet database: http://www.vertnet.org/index.html, accessed 9 April 2018). Using box-and-whisker plots (Fig. 3), I visually compared the three reported sets of external measurements and proportional tail lengths for Bachman's (1837) type specimen with similar external measurements obtained from skin labels of 77 *Blarina brevicauda talpoides* (Gapper, 1830) from Pennsylvania; 81 *Cryptotis parvus parvus* from Maryland, Virginia, and West Virginia; 24 *Sorex albibarbis*

Table 2.—Similarity of measurements from Bachman's (1837) holotype of *S. fimbripes*, the ANSP "type," and the USNM "type" (USNM 84556) to measurements of Pennsylvania shrews. "Index" = $2x_{SD} + x_{range}$, where $2x_{SD}$ is the number of species for which the value is within two *SD* of the mean for the species and x_{range} is the number of species for which the value is not within two *SD* of the mean, but is within the range of values for the species. Symbols: *, within two *SD* for the species; X, within the range for the species.

	B. brevicauda	*C. parvus*	*S. albibarbis*	*S. cinereus*	*S. dispar*	*S. fontinalis*	*S. fumeus*	*S. hoyi*	No. of spp.	$2x_{SD}$	x_{range}	Index
Holotype												
TOT				*		X			2	1	1	3
HB		*		*	X	*		*	5	4	1	9
TL				X			*		2	1	1	3
TL%			*	X	*	X			4	2	2	6
HF	X	X		*	*	X	*		6	3	3	9
ANSP "type"												
TOT		X		X		*		*	4	2	2	6
HB		X		X		X		X	4	0	4	4
TL				X		X			2	0	2	2
TL%			*	*	*	X			4	3	1	7
HF		X		*	X	*	*		5	3	2	8
USNM 84556												
TOT				*		X		X	3	1	2	4
HB		*		*	X	*		*	5	4	1	9
TL				*			X		2	1	1	3
TL%			X	*	X	X	X	X	6	1	5	7
HF		X		*	X	*	*		5	3	2	8

from Maine, New Brunswick, New Hampshire, Nova Scotia, Quebec, and Vermont; 299 *Sorex cinereus cinereus* from New Hampshire, New York, and Pennsylvania; 46 *Sorex dispar* from Maryland, New York, Virginia, and West Virginia; 50 *Sorex fontinalis* from Delaware and Maryland; 37 *Sorex fumeus umbrosus* Jackson, 1917 from Maryland, New York, and Pennsylvania; and 42 *Sorex hoyi thompsoni* Baird, 1857 from New Brunswick and New Hampshire (see Appendix 1).

I first evaluated the potential usefulness of each external measurement and proportional tail length for associating the specimens of *S. fimbripes* with recognized Pennsylvania shrew species by counting the number of species that included each measured value from each of the purported type specimens of *S. fimbripes* (1) within two *SD*s of that species' mean (expressed as $2x_{SD}$) or (2) within the species' total range of values if they extended beyond two *SD*s (expressed as x_{range}; Table 2). The larger the number of known species sharing a particular value, the less reliable or useful is the particular measurement for associating any of the three types with living species. From these numbers, I calculated a weighted *index* ($=2x_{SD} + x_{range}$; Table 2). I then calculated a similarity *score* for each measurement within two *SD*s of the species' mean ($=2/index$) and for each measurement beyond two *SD*, but within the observed range for the species ($=1/index$). The *scores* for each measurement were then totaled and the proportion of the total score for all species calculated as a means of evaluating the overall similarity of the external measurements from the three purported types of *S. fimbripes* to those of the eight recognized Pennsylvanian shrews (Table 3). Equal likelihood that a given set of measurements from one specimen matches all eight Pennsylvanian species would yield a score of approximately 0.63 and a percentage value of about 12.5% for each species, so any score above those values indicates a higher likelihood of a match for the specimen (Table 3).

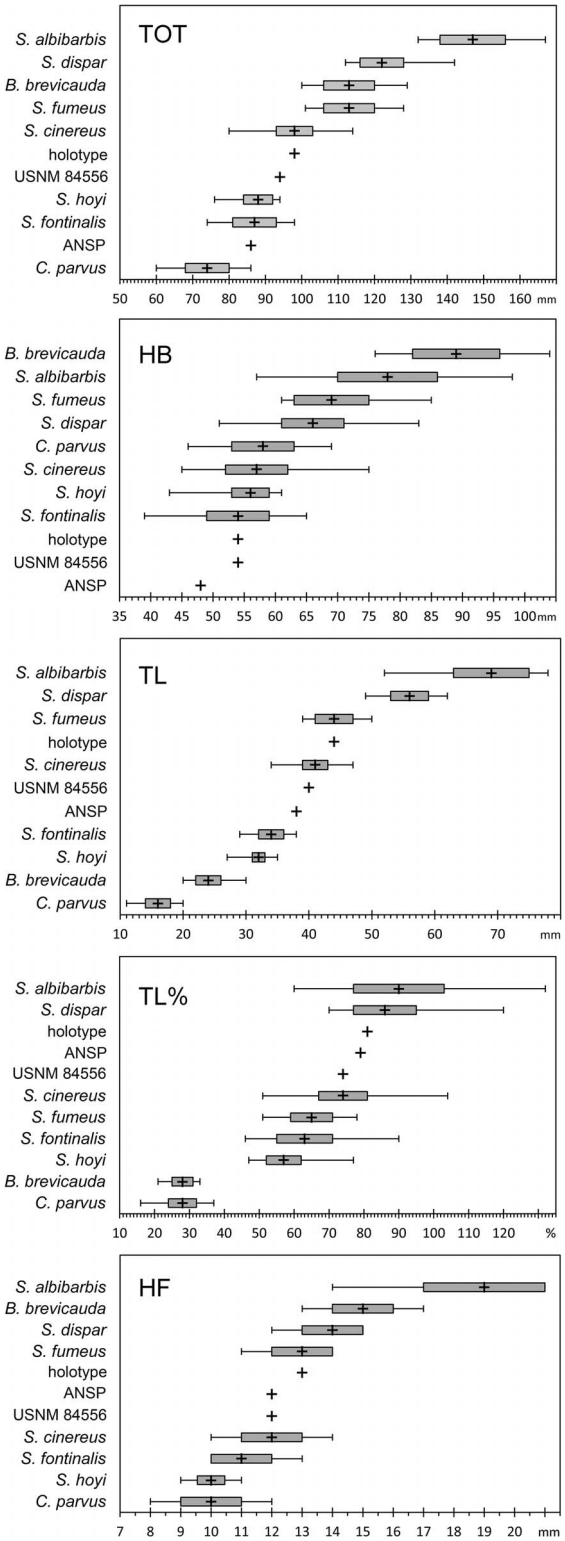

Table 3.—Similarity of measurements reported for Bachman's (1837) holotype of *S. fimbripes*, the ANSP "type," and USNM 84556 relative to Pennsylvania species of shrews. The measurement *index* is calculated in Table 2. The "similarity score" for a measurement within two *SD*s of the mean for a species is calculated as 2/*index*; the score for a measurement beyond two *SD*s, but within the range of values for the species is calculated as 1/*index*. Similarity scores were summed and the proportion of the total score used to evaluate the overall similarity of each purported type to each species.

	Blarina brevicauda	*Cryptotis parvus*	*Sorex albibarbis*	*S. cinereus*	*S. dispar*	*S. fontinalis*	*S. fumeus*	*S. hoyi*
Holotype								
TOT	–	–	–	0.67	–	0.33	–	–
HB	–	0.22	–	0.22	0.11	0.22	–	0.22
TL	–	–	–	0.33	–	–	0.67	–
TL%	–	–	0.33	0.17	0.33	0.17	–	–
HF	0.11	0.11	–	0.22	0.22	0.11	0.22	–
sum of scores	0.11	0.33	0.33	1.61	0.66	0.83	0.89	0.22
% of total score	2%	7%	7%	32%	13%	17%	18%	4%
ANSP "type"								
TOT	–	0.17	–	0.17	–	0.33	–	0.33
HB	–	0.25	–	0.25	–	0.25	–	0.25
TL	–	–	–	0.50	–	0.50	–	–
TL%	–	–	0.29	0.29	0.29	0.14	–	–
HF	–	0.13	–	0.25	0.13	0.25	0.25	–
sum of scores	0.00	0.55	0.29	1.46	0.42	1.47	0.25	0.58
% of total score	0%	11%	6%	29%	8%	29%	5%	12%
USNM 84556								
TOT	–	–	–	0.50	–	0.25	–	0.25
HB	–	0.22	–	0.22	0.11	0.22	–	0.22
TL	–	–	–	0.67	–	–	0.33	–
TL%	–	–	0.14	0.29	0.14	0.14	0.14	0.14
HF	–	0.13	–	0.25	0.13	0.25	0.25	–
sum of scores	0.00	0.35	0.14	1.93	0.38	0.86	0.72	0.61
% of total score	0%	7%	3%	39%	8%	17%	14%	12%

Finally, I $\log_{10}$-transformed the three primary external variables (HB, TL, HF) to equalize the variances and carried out a complete discriminant function analysis (DFA) for all eight species of Pennsylvania shrews using Systat 11 (Cranes Software, Bangalore), with the three purported types of *S. fimbripes* included as unknowns.

Results

Univariate comparisons among the three "types".—Based on the external measurements, Bachman's holotype is the largest of the three types, and the ANSP type is the smallest (Table 1). Total length (TOT) of Bachman's holotype is only 4 mm (4%) longer than USNM 84556, but 12 mm (14%) longer than the ANSP type. Bachman's holotype and USNM 84556 have the same head-and-body length (HB), so the difference between them is in tail length (TL), for which Bachman's holotype is 10% longer. In contrast, the measured difference between Bachman's holotype and the smaller ANSP type is equally apportioned between HB (12.5%

←

Fig. 3. Box-and-whisker plots showing mean ± 1 *SD* and range for external measurements comparing the three purported type specimens of *S. fimbripes* with eight Pennsylvania species of shrews. Abbreviations: TOT, total length (mm); HB, head-and-body length (mm); TL, tail length (mm); TL%, proportional length of tail (%); HF, hind foot length (mm).

difference) and TL (16%). Differences between the ANSP type and the larger USNM 84556 for these three measures are 8 mm (9%) for TOT, 6 mm (12.5%) for HB, and 2 mm (5%) for TL. Relative tail length (TL%) varies by 2–7% among the three purported types, with the greatest difference between Bachman's holotype and the ANSP type. Length of hind foot (HF) varies by no more than 1 mm (8%) among the three specimens.

Given an arbitrary potential error of ±5% in their external measurements, Bachman's holotype overlaps with USNM 84556, but not with the ANSP type, for TOT, HB, and TL (Fig. 2). USNM 84556 overlaps with the ANSP type for TOT and TL, but not HB. All three specimens overlap to some degree for TL%, and they are nearly indistinguishable for HF. These contrasts suggest that Bachman's holotype and USNM 84556 could represent the same specimen, or that the ANSP type and USNM 84556 could be the same, but it is unlikely that Bachman's holotype and the ANSP type are the same individual. Assuming that the likelihood of inter-observer error is lower than ±5% (Stephens et al. 2015), it is probable that all three purported types of *S. fimbripes* are unique specimens.

Univariate comparisons with Pennsylvania species.—Among the five comparisons of external measurements and proportions, tail length (TL) and total length (TOT) of the three purported types overlap with the fewest Pennsylvania species (TL: 2 species each; TOT: 2–4 species; Fig. 3; Table 2). These two measurements are therefore most useful for correctly identifying the three types.

All three types have the highest number of measurement overlaps with *S. cinereus*, with which they each overlap for all five external measures (Table 2). *Sorex fontinalis* has the second highest number: the ANSP type overlaps this species for all five measurements, and Bachman's holotype and USNM 84556 for four measurements each. In both of the latter cases, the non-overlapping measurement is TL, which overlaps instead with *S. fumeus* (Fig. 3; Table 2).

The similarity scores indicate that the most likely identification of the holotype based on its external measurements is *S. cinereus*, followed by *S. fontinalis* and *S. fumeus*, which are nearly equally likely (Table 3). The ANSP type is equally likely to be either *S. cinereus* or *S. fontinalis*, and USNM 84556 is most likely to be *S. cinereus*, followed by *S. fontinalis*.

Multivariate analysis.—The first two canonical variates (CV) from the three-variable DFA explained 99.3% of the dispersion in the model (Table 4). The variables TL and HF contributed strongly and negatively to CV1 and contrasted with positively-weighted HB. CV2 was strongly influenced by both HB and HF. In a plot of factor scores on these first two canonical axes (Fig. 3), the holotype of *S. fimbripes* plots in an area of overlap between the 95% confidence intervals (CI) of *S. cinereus* and *S. fumeus*, the ANSP type is in the overlap between the 95% CIs of *S. cinereus* and *S. fontinalis*, and USNM 84556 occurs near the center of the distribution of *S. cinereus*.

The jackknifed classification matrix yielded a correct classification rate of 92% for the eight species of Pennsylvania shrews (Table 4). The highest proportion of correct classifications was 100% each for *B. brevicauda* and *C. parvus*, and no individuals of other species were misclassified as either of those two taxa. The lowest proportions of correct classifications were 58% for *S. fontinalis* and 65% for *S. fumeus*. All three of the purported types were classified by the DFA model as *S. cinereus*. *Sorex cinereus* had a correct classification rate of 96%. The only specimens that were misclassified as *S. cinereus* were individuals of *S. fontinalis* (26% misclassified as *S. cinereus*) and *S. fumeus* (35%). The results of the DFA indicate that the three purported type specimens

Table 4.—Results from complete DFA of transformed variables (see Fig. 5): (A) Correlations (loadings) of input variables with the first two canonical variates (CV); (B) corresponding 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
HB	0.124*	0.911***
TL	−0.999***	0.036
HF	−0.406***	0.887***
Eigenvalues	27.815	7.219
Canonical correlations	0.982	0.937
Proportion of dispersion (%)	78.8%	20.5%

B. Jackknifed classification matrix

	Bb	*Cp*	*Sa*	*Sc*	*Sd*	*Sfon*	*Sfum*	*Sh*	% Correct
Holotype	0	0	0	1	0	0	0	0	–
ANSP	0	0	0	1	0	0	0	0	–
USNM	0	0	0	1	0	0	0	0	–
B. brevicauda	76	0	0	0	0	0	0	0	100
C. parvus	0	76	0	0	0	0	0	0	100
S. albibarbis	0	0	22	0	2	0	0	0	92
S. cinereus	0	0	0	284	0	5	6	1	96
S. dispar	0	0	0	0	41	0	1	0	98
S. fontinalis	0	0	0	7	0	26	0	12	58
S. fumeus	0	0	0	13	0	0	24	0	65
S. hoyi	0	0	0	0	0	3	0	39	93
Total	76	76	22	307	43	34	31	52	92

are most likely individuals of *S. cinereus*, although they are possibly misclassified individuals of either *S. fumeus* or *S. fontinalis*.

Discussion

Bachman's (1837) holotype.—Bachman (1837:392) summarized what he considered to be the relevant features of *Sorex fimbripes*: "No external ears; tail a little shorter than the body; feet broad, fringed at the edges; body of a dark brown colour." Unfortunately, these features are of little assistance in determining the identity of the shrew he was describing. Although North American shrews typically have small pinnae that are often hidden by the surrounding fur, external ears are not entirely lacking even in *Blarina* and *Cryptotis*, in which they are most reduced. Moderate tail length is common for most eastern North American species of soricids (except *Blarina* and *Cryptotis*: Fig. 3), as is a dark brownish coloration of the pelage, particularly for specimens preserved in ethanol for an extended period. The fringed edges of the feet are reminiscent of the feet of water shrews (*S. palustris* group), but in the case of *S. fimbripes*, Bachman (1837:393) further states "the edges on the lower surface are fringed considerably, beneath the palms, with much longer brownish hairs." In contrast, the fringe outlining the feet and digits on water shrews consists of short, stiff, whitish hairs that do not extend to the palms of the hands or soles of the feet. Based on Bachman's (1837) external measurements, his holotype most closely matches *S. cinereus*, although *S. fumeus* (Fig. 3: TL, HF) and *S. fontinalis* (Fig. 3: HB) are also possibilities. These identifi-

cations also agree with Bachman's (1837:392) characterization of *S. fimbripes* as being a little smaller than *S. forsteri* (=*S. cinereus*).

ANSP type.—Baird (MS 1861:55, 56) examined what he believed to be Bachman's holotype of *S. fimbripes*, "a much mutilated specimen in the collection of the Philadelphia Academy." He recognized *S. fimbripes* as a valid species, but noted that the ANSP specimen "is of nearly the same size though rather larger, and with the same general conformation" as *S. cooperi* Bachman, 1837 (=*S. cinereus*), an ambulatory (i.e., not semi-aquatic) species. Baird (MS 1861:55) also equated what was to be called *Sorex acadicus* Gilpin, 1865 (=*S. cinereus*) with *S. fimbripes* based on a small series of *S. acadicus* that John Bernard Gilpin had sent him and that much later proved to be a mixture of two ambulatory species, *S. cinereus* and *S. fumeus* (Woodman 2018). Miller (1895:41) subsequently placed *S. fimbripes* in synonymy with *S. personatus* I. Geoffroy Saint-Hilaire, 1827 (=*S. cinereus*), based on the assessment of Coues (1877), "who has examined the supposed type" and considered it "to be a perfectly normal *Sorex personatus*." In fact, Coues (1877:641) did not inspect the ANSP type of *S. fimbripes*, but referenced Baird's (MS 1861) unpublished manuscript, stating, "in 1861, Baird examined Bachman's type preserved in the Philadelphia Academy and found it to be a species of ordinary 32-toothed *Sorex*, scarcely or not distinguishable from 'cooperi'."

Bachman (1837) used considerable page-space describing the fringed feet of his holotype without indicating any obvious damage to those appendages. In contrast, in describing the "much mutilated" ANSP type, Baird (MS 1861:56) noted, "There is an appearance of unusual breadth to the fore feet, but this in close examination is seen to be due to the twisting of the compressed digits and flattening out by partial crushing, (perhaps by a fall trap) so that their vertical diameters are in a transverse line. . . ." Such damage may have been inflicted between the respective examinations of the same specimen by Bachman and Baird, but, more likely, the difference in condition is additional evidence that the holotype and the ANSP type are two separate specimens. The external metrics of the two types differ by 2–16%, with the ANSP type generally smaller (Table 1, Fig. 2). The difference in the length of the tail is particularly striking because the tails of both Bachman's (1837:393: "tapering to a point") holotype and the ANSP type (Baird MS 1861:56: "distinct pencil at the tip") appear to be complete, and the length of the tail is less likely than the length of the head and body to have been affected by nearly a quarter of a century of dehydration in ethanol.

The external measurements of the ANSP type conform most closely with those of *S. cinereus*, and, secondarily, *S. fontinalis*. Either identification essentially agrees with Baird's (MS 1861) favorable comparison of the specimens with *S. cooperi* (=*S. cinereus*) and with Miller's (1895) placement of *S. fimbripes* in synonymy with *S. personatus* (=*S. cinereus*).

USNM 84556.—In announcing the discovery of the supposed type of *S. fimbripes* in the collection of the USNM, Lyon and Osgood (1909:243) stated:

> The specimen was found in the collection in the early part of 1898 in a bottle with an old-style Museum label, without number, tied around the top, bearing the name "*Sorex fimbripes* (type)." Tied on the specimen itself is an old parchment label with the words "*Sorex fimbripes*. Type" written on it. The writing is perfectly legible, but very faint, and is not likely to last another quarter or half a century. The parchment has to be dried in order to read it. On 19 April 1898, this specimen was entered in the Museum catalogue and given the present number, 84556. No original data accompany the specimen to show where it came from, so that the locality has to be taken from Bachman's description. The writing of the old Museum label and parchment tag is unidentifiable; both labels were written many years ago

and evidently by some one who knew the history of the specimen.

In short, the identity of USNM 84556 as the holotype of *S. fimbripes* depends upon a faded, hand-written label of unknown origin, and all data associated with that specimen depend upon it being the holotype. A hand-written note regarding USNM 84556 in the USNM Mammal Division Catalog states, "This is the type according to Baird in Coues Bull. U.S. Geol. & Geograph. Survey Vol. III, No. 3." In fact, Coues (1877) referenced Baird's 1861 manuscript, and Baird's (MS 1861) manuscript referenced only his inspection of the ANSP type. Neither made mention of a specimen of *S. fimbripes* in the USNM. Nor, for that matter, did Gill (1872), Miller (1895), or Merriam (1895) claim to have inspected the type of *S. fimbripes* (either at ANSP or at USNM), indicating that the specimen that was later catalogued as USNM 84556 probably had not yet arrived at USNM. Hollister (1911:381) subsequently identified USNM 84556 as *Sorex fumeus* Miller, 1895, an identification that I confirmed based on my inspection of the skull. He also cast doubt on this specimen being the holotype of *S. fimbripes*, stating: "A careful comparison of the specimen with Bachman's description makes it perfectly obvious that it is NOT the single specimen he had before him when he wrote the diagnosis of *Sorex fimbripes*."

USNM 84556 is in poor condition, having lost about half of the fur encircling its midsection. Such a loss of fur is not mentioned in either of the descriptions by Bachman (1837) or Baird (MS 1861). While this might be a consequence of its many years preserved in fluid, it more likely reflects a greater degree of decomposition of the specimen prior to its preservation. The feet of USNM 84556, however, appear undamaged, unlike the description of the ANSP type (Baird, MS 1861). Metrically, USNM 84556 is intermediate in most measurements between Bachman's larger holotype and the smaller ANSP type. For Bachman's holotype, the ANSP type, and USNM 84556 to be the same individual, the specimen would have had to shrink 12% in total length (TOT) and then elongate again by 9% (Table 1, Fig. 2). Some shrinkage resulting from dehydration by the preserving ethanol is not unexpected, but elongation is difficult to account for. Also difficult to explain are similar changes in the measured length of the tail (TL), entirely supported by the caudal vertebrae and, thus, less subject to dehydration and shrinkage. If the change in TOT were simply a result of increasing dehydration of the body over time, one would expect relative tail length (TL%) to gradually increase through time. Instead, TL% decreases.

Bachman may have returned the holotype of *S. fimbripes* to the ANSP, whereupon it was subsequently loaned to USNM, where it remains today. This would account for the presence of a single specimen in Charleston in 1837, in Philadelphia in 1861, and in Washington in 1898. It is much more likely, however, that the three purported types of *S. fimbripes* represent three distinct specimens. Hollister (1911:381) noted that in Baird's time, the word *type* could simply refer to any *example* considered typical of a species: "Several specimens in the 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." Baird himself used the term *type* extremely loosely, generally to refer to any specimen used as a standard of comparison (Carleton et al. 2014:947). Very likely, the "types" of *S. fimbripes* in both ANSP and USNM were simply the examples of that species that each institution had available at the time.

Because it is extant, the identification of USNM 84556 as *S. fumeus* is not in question. This specimen also provides a

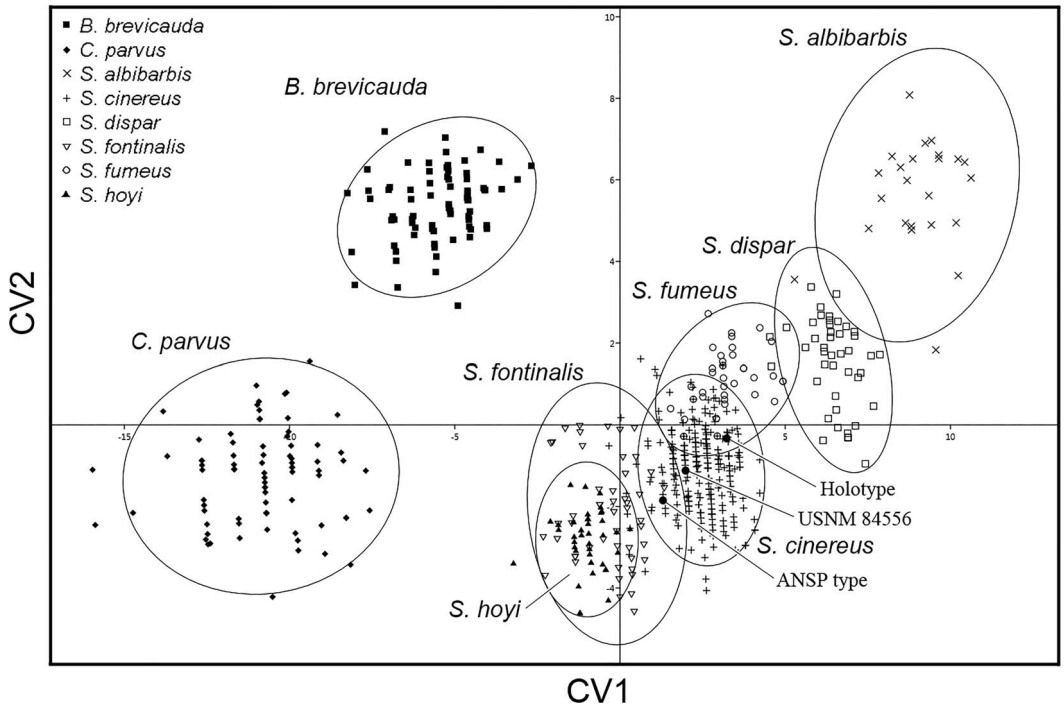

Fig. 4. Plot of factor scores on CV1 and CV2 from DFA of three external variables (HB, TL, HF) to show the relationships of the three "type" specimens of *S. fimbripes* (holotype, ANSP, USNM 84556) relative to eight Pennsylvania species of shrews. The ellipse for each species circumscribes 95% of specimen scores around the species centroid.

single test of the usefulness of external measurements for identifying individual specimens. My analysis of the external measurements of USNM 84556 indicated it was most likely *S. cinereus*, or, possibly, *S. fontinalis*. In length of tail (TL), however, it overlapped with *S. cinereus* and *S. fumeus*. The inconsistency of the identifications based on external measurements of this specimen indicates that such measurements are a poor means of accurately identifying specimens long preserved in fluid, and it further suggests that preservation in ethanol affects the length of the tail less than head and body length.

What happened to Bachman's holotype?—John Bachman was living in Charleston, South Carolina, when the specimen he described as *S. fimbripes* was sent to him from the ANSP. He was closely associated with The Charleston Museum (TCM), which might have been the logical place for him to deposit the specimen, but that institution has no definite record of receiving any mammals from Bachman (Matthew L. Gibson, TCM, email correspondence, 13 March 2018). Bachman also maintained his own collections, which were moved to Columbia, South Carolina, for safe-keeping during the American Civil War. The entirety of these materials was apparently destroyed in February 1865, when much of Columbia burned as confederate soldiers retreated before advancing federal forces: "my whole library and all my collections in Natural History, the accumulation of the labors of a long life, were burnt by Sherman's vandal army…" (Bachman, 1869, quoted in Bachman & Haskell 1888:391–392). Hence, the fate of Bach-

man's (1837) holotype of *S. fimbripes* remains unsubstantiated, but it is likely that it was lost or destroyed.

Conclusions

1. The three specimens that have been reported as "types" of *Sorex fimbripes* Bachman, 1837 represent three different specimens.
2. Bachman's (1837) description of the holotype of *S. fimbripes* includes too few relevant characters to determine its identity with certainty. The specimen was too small to be *S. albiventris* or another water shrew of the *S. palustris* group. Based on Bachman's description of its size and its external measurements, the holotype could have been an example of *S. cinereus*, *S. fontinalis*, or *S. fumeus*. The holotype most likely was destroyed during the American Civil War.
3. The ANSP "type" of *S. fimbripes* described in Baird's (MS 1861) unpublished manuscript was not Bachman's (1837) holotype. It was probably an example of either *S. cinereus* or *S. fontinalis*.
4. USNM 84556, the "type" of *S. fimbripes* discovered by Lyon & Osgood (1909) and still preserved in the USNM, is not Bachman's (1837) holotype, nor is it the ANSP "type" discussed by Baird (MS 1861). Based on my examination of its skull characters, this specimen is referable to *S. fumeus*.
5. Barring the incontrovertible discovery of Bachman's holotype, the name *Sorex fimbripes* Bachman, 1837 is a *nomen dubium* and cannot be convincingly allocated to the synonymy of any Pennsylvanian shrew.

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Appendix 1: Specimens Examined.

All specimens used in this study are from the Mammal Collection of the National Museum of Natural History (USNM), Smithsonian Institution, Washington, D.C.

Blarina brevicauda talpoides (77).—PENNSYLVANIA: Adams Co.: Gettysburg (62821). Allegheny Co.: 1.75 mi W, 0.15 mi S Clinton (288258); west edge of Clinton (288481). Beaver Co.: Junction Highway 30 and Raccoon Creek (288482). Berks Co.: 2 mi W Strausstown (282655–282658); 3 mi NW Kutztown, Schoefer's Mill (282659). Bradford Co.: Leroy Twp., Sunset Road, The Bonett Farm (568261). Bucks Co.: Tinicum Twp., Point Pleasant (568268–568274, 568277–568282, 568286–568299, 568329, 568645, 568650, 568651, 568653, 568654, 569100, 569101); Tinicum Twp., Smithtown, S of Bridge 3 on towpath (568275, 568276). Clinton Co.: Drury Run (57873–57875). McKean Co.: no specific locality (96564–96568). Monroe Co.: Swiftwater (282653); Price Twp., Delaware State Forest, Snowhill Tract Along Poplar Run (568340); Pocono Twp., Crescent Lake Estates (568342, 568343); Pocono Twp., Cransberry Rd, 2/10 mi from Stroud Twp. Line along Tannersville Preserve (568344); Pocono Twp., Crescent Lake Estates, Laurel Lane (568345–568349). Perry Co.: 4 mi SE Shermans Dale (282654). Schuylkill Co.: Minersville (568398, 568400). Somerset Co.: 4 mi SW Somerset (282765–282768). Union Co.: Mifflinburg (219047, 219048). Warren Co.: Columbus, 5 mi E, Bensons Swamp (282769). Westmoreland Co.: Powdermill Nature Reserve, near Rector (568396, 568397).

Cryptotis parvus parvus (81).—MARYLAND: Prince Georges Co.: Oxon Hill (269573, 566405); Patuxent Research Refuge (567524); shore of Lake Reddington (567525); Patuxent Research Refuge (567526, 567528). Montgomery Co.: Bethesda (248696). VIRGINIA: Alexandria: near Alexandria (112194, 112195, 112759). Bath Co.: 9 mi SW Williamsville, Clark's Cave (489611). Caroline Co.: Port Royal (339117). Chesapeake: Lake Drummond, Dismal Swamp (600987). Culpeper Co.: Reva (600976). Cumberland Co.: 1.5 mi NW Cumberland C. H. (293279). Essex Co.: 2.5 mi S Tappahannock (334843–334847); 36 mi NW Tappahannock (334851). Fairfax Co.: 3.3 mi NW Fairfax (334841), Lorton, Hooes Road (600929). Fauquier Co.: High Point, Bull Run Mountain (282324); Casanova, Pageland Farm, Rogues Road 568146–568151, 569087, 569088, 569091). Frederick Co.: Winchester, Miller Street (533960). Giles Co.: 2.25 mi WNW Mountain Lake, Little Meadows, Mountain Lake Biological Station (331041); 1 mi N Mountain Lake (364538); 4.8 mi NW Mountain Lake, Butt Mountain Fields (395306). Gloucester Co.: Routes 633 and 614 (334850). James City Co.: Williamsburg (301318). King William Co.: Port Richmond (334848). Lee Co.: 2 mi WSW Ewing (330855, 330856). Loudoun Co.: Dulles Airport (601173). Louisa Co.: Lake Anna, Rt. 652 (601154, 601155). Mathews Co.: Routes 14 and 3, Telephone Right-Of-Way (334849). Montgomery Co.: Blacksburg (293282). Nelson Co.: no specific locality (254045–254048). Prince William Co.: Buckland (334842). Princess Anne Co.: 6.8 mi SE Pungo, Back Bay National Wildlife Refuge (302717–302720). Rockbridge Co.: 2 mi NE Glasgow (284980). Rock-

ingham Co.: Bridgewater (521111). Shenandoah National Park, Park Headquarters (283569–283571). Spotsylvania Co.: Partlow, 10200 Wallers Road (568660, 569083). Tazewell Co.: Burkes Garden (305971–305984). Wythe Co.: Wytheville, 0.4 mi S of Wytheville Hospital (332319). West Virginia: Greenbrier Co.: 1 mi W Lewisburg (293283); White Sulphur Springs (254041, 254042).

Sorex albibarbis (24).—CANADA: New Brunswick: Albert Co.: 1 mi W Alma, Fundy N.P. (288005); Riverside, 5.3 km N, 3.5 km W Albert, Crooked Creek (528207). Mount Carleton Provincial Park: Mount Sagamook (553303, 553305, 553306); S shore of middle lake of Nepisiquit Lakes (553307, 553308); 2.2 air mi SW of summit of Mount Carleton (553304). Nova Scotia: Digby (150056); James River (150068); Halifax (238165). Pictou Co.: 30 km E Trenton (530829, 530830). Quebec: St. Rose (150079). USA: Maine: Mount Katahdin (117980, 117981). Somerset Co.: N shore Russell Pond (569772). York Co.: Lyman, Massabesic Experimental Forest (600798). New Hampshire: Coos Co.: Bretton Woods (294622, 294772); Lake Umbagog National Wildlife Refuge, Whaleback, 5.1 mi NE Errol (568193). Carroll Co.: Bartlett Experimental Forest (600745). Grafton Co.: South Greeley Pond, along Stream, south side of pond (515062). Vermont: Rutland Co.: Mendon (250165).

Sorex cinereus cinereus (299).—Pennsylvania: Clinton Co.: Drury Run (57870–57872). Monroe Co.: Smithfield Twp., Mosier Knob Road Study Area, below Shawnee Mountains (568335); Pocono Twp., Bog Road, Martino property adjacent to Tannersville Cranberry Bog Preserve (568336); Pocono Twp., Crescent Lake Estates, Laurel Lane (568337–568339). Wayne Co.: Gouldsboro, 3 mi NE; Pocono Peak Lake Preserve (282651, 282652). New York: Catskill Mountains (82945, 83165). Chautauqua Co.: Westfield, Ottaway Park (327879, 341901, 344964). Herkimer Co.: Brandreth (254055). Madison Co.: Peterboro (111041, 111042). Orange Co.: near Highland Falls (82831). Suffolk Co.: Montauk Point (56582, 56584–56586, 56588–56590). New Hampshire: Carroll Co.: Bartlett Experimental Forest (600625, 600626, 600629, 600631–600639, 600641–600643, 600646–600655, 600737, 600740, 600801, 601826–601929, 601931–601973, 603178, 603180, 603188, 603197, 603200, 603203, 603204, 603206–603210, 603212, 603213, 603215, 603219, 603220, 603223, 601780–601825); Center Ossipee (289509–289511, 289513); Ossipee (76393). Coos Co.: Bretton Woods 294616–294620, 294770, 294771); Fabyans (100796, 283433, 289508, 289522); Pinkham Notch (289523, 289524); Stewartstown, 0.25 mi NW of Stewartstown Hollow School (295000). Grafton Co.: North Greeley Pond (515028, 515029, 515031). Hillsborough Co.: Wilton, Mayr Farm (515032). Mount Washington: Summit (150080–150083); Juckerman Ravine (283431, 283432); Hermit Lake (311162). Strafford Co.: 1 mi N and 7 mi W Rochester (600627, 600628, 600644, 600645).

Sorex dispar (46).—New York: Catskill Mountains (83162). Ulster Co.: Slide Mt., N slope, drainage to Cornell Falls from Woodland Valley (555461, 555462); Peekamoose Gulf, S side, 0.75 air mi ESE of Breath Hill Summit (555463); 1.6 Air mi NE Balsam Lake Mt. Summit along trail (555464). Greene Co.: Plateau Mt., at Stony Clove, stream behind Devil's Tombstone (555465, 555466). Schoharie Co.: talus slope on W slope of Reed Hill, 1.5 air mi N of Gilboa (555467, 555468). Virginia: Bath Co.: Burnsville, 5.4 mi SW, Warm Spring Mountain, east slope, Bear Rock Trail (489870); Paddys Knob, ca. 3 mi S; near Highlands Co. line; Little Back Creek (506234). Giles Co.: 4.2 mi NNE Mountain Lake, Big Mountain, Castle Rock (301770); 4.25 mi NNE Mountain Lake, Castle Rock (395900); 4.3 mi NNE Mountain Lake, Castle Rock (364541, 364543, 395292, 395293, 395295–395298, 395301, 395302); 4.7 mi NNE Mountain Lake, Castle Rock Ledge (395901); 1.4 mi ENE Mountain Lake, Bear Cliffs (364593, 364594, 395299, 536032); 1.5 mi ENE Mountain Lake, Bear Cliffs (395899, 395902, 395903); 0.7 mi SSW Mountain Lake, Route 700 (599949); 0.75 mi SSW Mountain Lake, Route 700 Talus (395294); 0.35 mi S Mountain Lake (364542). West Virginia: Raleigh Co.: Winding Gulf, SW of Pemberton (160787). Randolph Co.: Spruce Knob (600937).

Sorex fontinalis (50).—Delaware: Kent Co.: Bombay Hook Wildlife Refuge (287772). Maryland: Anne Arundel Co.. Annapolis, 3 mi NW Wooded Area Epping Forest (310695); Severn Run, Allan Davis Farm (273373). Baltimore Co.: Loch Raven (283661–283665); Lake Roland, 5 mi N Baltimore (279635–279645). Cecil Co.: Fair Hill (505344). Dorchester Co.: Cambridge (246488). Montgomery Co.: Ashton (276123); Montgomery Co.: Bethesda, 0.25 mi from Wilson Lane (290876); 3/10 mi E and 1 mi N Boyds (329369); Cabin John, North Bank of canal at Lock 11, opposite Plummers Island (252545); Chevy Chase (262467); Rockville (282112); 2 mi W Rockville (314035–314042). Prince Georges Co.: near Beltsville, Cold Spring Swamp (85438, 85439); Greenbelt (289218, 505318); Hyattsville (76587, 76593, 76709, 136194, 136195); Oxon Hill (566404); Patuxent Research Refuge (567503–567507).

Sorex fumeus (37).—Maryland: Allegany Co.: Mount Savage, Bruce House Farm (506892, 506893); Bittinger (97780–97782); Finzel, 6 Mi N Frostburg (97113–97117, 97778). Frederick Co.: 1 1/2 Mi N Wolfsville (505345, 505347, 505348). New York: Catskill Mountains (83163, 83164). Lake George

(110811). Madison Co.: Peterboro (111040, 111043, 111044). Orange Co.: West Point (254056–254065). Warren Co.: Lake George (35461, 55945, 55946). PENNSYLVANIA: Clinton Co.: Renovo (57876–57879).

Sorex hoyi thompsoni (42).—CANADA: NEW BRUNSWICK: Mt. Carleton Provincial Park, Mt. Sagamook (553310–553328); Tabusintac River, 7 mi upstream from Highway 11 (553329, 553330). USA: New Hampshire: Carroll Co.: 44.0732°N, 71.2891°W (600630); Bartlett Experimental Forest (600744, 601995–602007, 603183, 603191, 603199). Coos Co.: Bretton Woods (294773); Lake Umbagog National Wildlife Refuge, Whaleback, 5.1 mi NE Errol (568192, 568198).