

## Identification of *Sorex monticolus* and *Sorex vagrans* from British Columbia

### Abstract

*Sorex monticolus* and *Sorex vagrans* usually are identified by use of tine characters of the upper incisors. Because not all specimens are clearly identifiable by tine characters, I used four cranial measurements thought to be useful characters by those familiar with the genus *Sorex*. Univariate and bivariate comparisons did not yield reliable methods of discrimination. Discriminant analysis permitted identification of many of the unidentified specimens.

A comparison of qualitative tine character states in members of the two species groups in British Columbia, as identified by discriminant analysis, provided no universal differences in these characters. Using the position of the medial tine relative to pigment levels is still the best means of discriminating between these two species of *Sorex*. Final curation of the collection suggested the level of pigment and size of tine on the upper first incisor were the two characters that varied most consistently with identifications of the two species determined by discriminant analysis. Use of discriminant analysis has proven helpful when attempting to identify other taxa of mammals when key characters are confusing or missing.

### Introduction

The identification of *Sorex vagrans* and *S. monticolus* is problematic (Hennings and Hoffmann 1977; Junge and Hoffmann 1981; van Zyll de Jong 1983; Carraway 1990). The first upper incisors (I1) of these shrews possess a tine or accessory cusp on the medial edge. A combination of the size of the tine relative to the size of the I1, the level and amount of pigment on the tine, and whether a gap occurs between the pigment of the main body of the I1 and the tine are characters that have been used to separate specimens of the two species. Hennings and Hoffmann (1977:9) described *Sorex vagrans* as having "medial tines on [the] first upper incisor situated at approximately the upper edge of the pigment; set off distinctly by a gap in color." In *Sorex monticolus* the "tines are larger, the pigment darker, and the incisors more robust than those of *vagrans*" (Hennings and Hoffmann 1977:14). Illustrations in Hennings and Hoffmann (1977) show that no gap in color is present in *Sorex monticolus*. Although these tine characters often are useful in separating the species, many specimens are intermediate or mixed in character, or are missing key characters due to tooth wear or tooth loss.

Bogan (1977) and Choate (1973) have shown that very similar species can be identified by use of simple morphometric measurements in discriminant analysis. In this study, a small suite of morphometric characters was sought that might permit identification of unidentified shrew specimens (unknowns) by discriminant analysis.

The presence of age variation (Jackson 1928; Rudd 1955), the absence of sexual variation (Rudd 1955), and the presence of size variation that does not follow Bergmann's Rule (Hennings and Hoffmann 1977) have been reported in shrews. These sources of variation were assessed for the sample of specimens in this study to determine whether they might significantly affect a discriminant analysis.

### Methods and Materials

Specimens identified as *Sorex monticolus* (including *S. obscurus*) and *S. vagrans*, housed in the Mammalogy collection at the Royal Ontario Museum (ROM), required updated identification. Use of tine characters as described in existing keys (Hennings and Hoffman 1977; van Zyll de Jong 1983) permitted the conclusive identification of 143 of 244 specimens (59%) from British Columbia, referred to hereafter as knowns.

Four characters were used in discriminant analyses to identify as many unknown specimens as possible. The characters were least interorbital breadth and palatal length described by Hennings and Hoffmann (1977), and width across first upper incisors and width across fourth upper unicuspid suggested by Sarah George (personal communication). Two other characters suggested, respectively, by the aforementioned were not suitable for this analysis. Width across the molars was dropped because it showed significant age variation and its inclusion would have severely limited

sample sizes in discriminant analyses. Sixteen percent of the time condylobasal length could not be measured because of crushed or misshapen braincases. To maximize the number of specimens that might be identified using quantitative methods condylobasal length was removed from analyses. For this reason, the trivariate method of identifying *S. vagrans* and *S. monticolus* described in Hennings and Hoffmann (1977) was not attempted.

Skin characters were not used because shrew skins are prone to rapid degradation in the field and standard external measurements are prone to measuring error. Dried specimens do not permit reliable friction pad or digital callosity counts (van Zyll de Jong 1983).

Characters were measured using a Wild Heerbrugg dissecting microscope furnished with a 120 gradation ocular micrometer. Reported measurements are given in millimetres.

The museum specimens used in this study were assumed to be representative of the populations sampled. All analyses were considered significant at the 5% level.

Analysis of variance (ANOVA), multivariate analysis of variance (MANOVA), and Tukey's studentized range test analyses were performed using the GLM procedure in Statistical Analysis System (SAS Institute Inc. 1985). Because of limited sample sizes, multiple range tests could not be performed to more fully explore variation associated with age, sex, and/or species.

All specimens were aged by use of Rudd's (1955) age categories based on tooth-wear characters of the upper third premolar and upper three molars. The three gradations within each numbered category (e.g., -2, 2, and +2) of Rudd's tooth-wear descriptions were pooled to increase sample sizes.

Variation attributable to sex was tested in both age class 3 of *S. vagrans* and age class 2 of *S. monticolus*. Specimens were taken from a single age class to minimize the influence of age. Sexual variation was significant in the sample of *S. vagrans*, but was not significant in *S. monticolus*.

I used a simplified approach to search for some indication of geographic variation in *S. monticolus*. Three subsets were defined based on latitude: 49° 00' to 52° 59' = southern group; 53° 00' to 54° 59' = central group; and 55° 00' to 60° 00' = northern group.

A multi-group discriminant analysis was done using BIOSTAT II (Pimentel and Smith 1986) with the five groupings warranted by the results of ANOVA and MANOVA. The sexes in *S. vagrans* were separated into two groups in the multi-group discriminant analysis. Significant differences between the geographically-defined subsets led to three groups of *S. monticolus* in the multi-group discriminant analysis. Data from all localities were pooled for *S. vagrans* because all were from southern latitudes.

To develop a quantitative method to identify unknowns, a second discriminant analysis (DISCRIMINANT) was run using Statistical Procedures for the Social Sciences (SPSSX 1986). All discriminant analyses were run assuming equal group priors. The groups defined for the multi-group discriminant analysis were pooled for the two-group discriminant analysis. The two groups represented each species sample. The resulting unstandardized coefficients and constant of the two-group discriminant analysis permit the identification of unknown specimens from British Columbia (Choate 1973; Bogart 1974).

After surveying a number of specimens from both species groups, easily discernible gradations in characters became evident. Five tine characters were recorded:

1. Tine size was scored as small (1), medium (2), or large (3).
2. Tine pigment was scored as none (1), light (2), medium (3), or dark (4).
3. Pigment gap was scored as obvious (1), vague (2), or absent (3).
4. Tooth pigment was scored as pale (1), medium (2), or dark (3).
5. Pigment level relative to the tine was scored as below (1), at (2), mid-way up (3), or above (4) the tine.

Although subjective in nature, I found these character states discrete enough to be reliably assigned to all specimens. The percentage occurrence of the different tine states was tabulated for all specimens identified as *S. monticolus* or *S. vagrans* by discriminant analysis to ascertain differences between the two species. The specimens included all knowns (clear tine characters) and all unknowns (mixed or missing tine characters) diagnosed by discriminant analysis. The intent of this exercise was to determine whether a subset of the five characters would be sufficient to clearly discriminate between the two species.

TABLE 1. F-Test and Tukey studentized range test results for subsets of *Sorex* measurements to determine the affect of sex and geographic areas on skull characters.

Character and variable	Sex Comparison		Geographic Area
	<i>S. vagrans</i>	<i>S. monticolus</i>	Central=C, North=N, and South=S
	Age class 3 (n = 22)	Age class 2 (n = 21)	<i>S. monticolus</i> Age class 2 (n = 20)
<b>Least Interorbital Breadth</b>			
F	13.20	0.42	3.17
p	0.002	0.53	0.07
Tukey			C N S
<b>Palatal Length</b>			
F	18.30	0.19	7.23
p	0.0004	0.67	0.005
Tukey			C N S
<b>Width across First Upper Incisors</b>			
F	1.45	6.32	7.60
p	0.24	0.02	0.004
Tukey			C N S
<b>Width across Fourth Upper Unicuspid</b>			
F	3.03	0.15	5.87
p	0.10	0.70	0.01
Tukey			C N S
<b>MANOVA</b>			
F	5.41	2.33	2.87-4.23
p	0.005	0.10	0.01-0.02

## Results

The sexes of *S. vagrans* significantly differed for least interorbital breadth and palatal length (Table 1). Females were relatively larger than males for all four characters in *S. vagrans*. MANOVA also showed a significant difference between the two sexes (Table 1).

The sexes of *S. monticolus* showed significant differences in width across first upper incisors, although the MANOVA did not support this difference between the two sexes (Table 1). Males were larger than females for width across first upper incisors.

The three groups used to assess age variation included 14 female *S. monticolus* from the northern region (age classes 1-3), 20 male *S. monticolus* from the central region (age classes 1-3), and

20 male *S. vagrans* from the southern region (age classes 2-4). None of the three samples showed significant differences between age classes for least interorbital breadth, palatal length, width across first upper incisors, or width across fourth upper unicuspid. Width across the upper molars showed significant age variation in the male *S. monticolus* from the central region, thus, this character was not included in this study.

Palatal length, width across first upper incisors, and width across fourth upper unicuspid were significantly different between the three geographic samples of *S. monticolus* (Table 1). These differences are present at the univariate and multivariate levels of analysis.

None of the means of single characters are distinct among groups or between species (Table 2). Bivariate plots were made of all six of the

TABLE 2. Univariate statistics for four variables of *Sorex vagrans* and *S. monticolus*. The five samples include central, northern, and southern groups of *S. monticolus* and female and male groups of *S. vagrans*.

<i>Sorex monticolus</i> (males, age class 2)				
Character Measured (mm)	Geographic Region			Range
	Central (n = 4) X ± 2 SD	Northern (n = 9) X̄ ± 2 SD	Southern (n = 7) X ± 2 SD	
Least Interorbital Breadth	3.74 ± .32	3.70 ± .20	3.62 ± .28	3.2-4.0
Palatal Length	7.59 ± .64	7.28 ± .28	7.35 ± .44	6.6-8.1
Width across Upper Incisors	1.48 ± .24	1.47 ± .18	1.48 ± .30	1.3-1.9
Width across Upper Fourth Unicuspid	2.37 ± .34	2.38 ± .14	2.33 ± .22	2.1-2.6

<i>Sorex vagrans</i> (south region, age class 3)			
Character Measured (mm)	Sex		Range
	Female (n = 8) X̄ ± 2 SD	Male (n = 14) X ± 2 SD	
Least Interorbital Breadth	3.53 ± .32	3.32 ± .24	3.2-3.8
Palatal Length	6.96 ± .50	6.60 ± .36	6.3-7.3
Width across Upper Incisors	1.38 ± .14	1.33 ± .14	1.2-1.5
Width across Upper Fourth Unicuspid	2.16 ± .22	2.06 ± .20	1.9-2.3

measurement pairs. None of the pairs showed separation sufficient to confidently identify specimens using this technique.

The classification of unknowns by the multi-group discriminant analysis and the two-group discriminant analysis were virtually identical. Two of six specimens misclassified in the two-group discriminant analysis differed from those misclassified in the multi-group discriminant analysis. In the two-group analysis three *S. monticolus* and three *S. vagrans* were misclassified. All three specimens of known *S. vagrans* that were misclassified were females (Figure 1).

By measuring four skull characters, calculating a discriminant function score for the first canonical variate, and plotting the score on Figure 1, over 90% of the specimens in this study were easily identified as a member of one of the two species groups. The equation to calculate the discriminant function score is:

$$X = 2.011757(\text{least interorbital breadth}) + 2.246716(\text{palatal length}) - 0.832296(\text{width across first upper incisors}) + 3.848037(\text{width across fourth upper unicuspid}) - 30.97091,$$

where X is the discriminant score, the first four numeric values are the unstandardized discriminant coefficients, the fifth value is the constant, and the character names represent the values

of the respective characters measured on each specimen. Characters should be measured by use of a dissecting microscope with an ocular micrometer because small errors in measurement can have a substantial effect on the calculated discriminant score (Choate 1973). The constants in the above equation double and quadruple measurement errors. Furthermore, the size and delicacy of the shrew skull virtually prohibit accurate measurement using calipers or without some means of magnification.

The two-group discriminant analysis provides a practical method to identify unknown specimens. The stacked histogram (Figure 1) shows some overlap among members of the two species in the discriminant function 1 scores. Specimens with discriminant scores greater than -0.6131 were identified as *S. monticolus*, while those with values less than -0.7721 were identified as *S. vagrans*. Specimens with discriminant scores between these values were misidentified, as were two extreme outliers.

The qualitative characters of *S. monticolus* (Table 3) tend toward the high character state for all five characters (more than 80% of specimens exhibiting characters at level 3 or more for all characters except tooth pigment). *S. vagrans* show a broad range of character states for virtually all of the characters. More than 90% of specimens exhibit

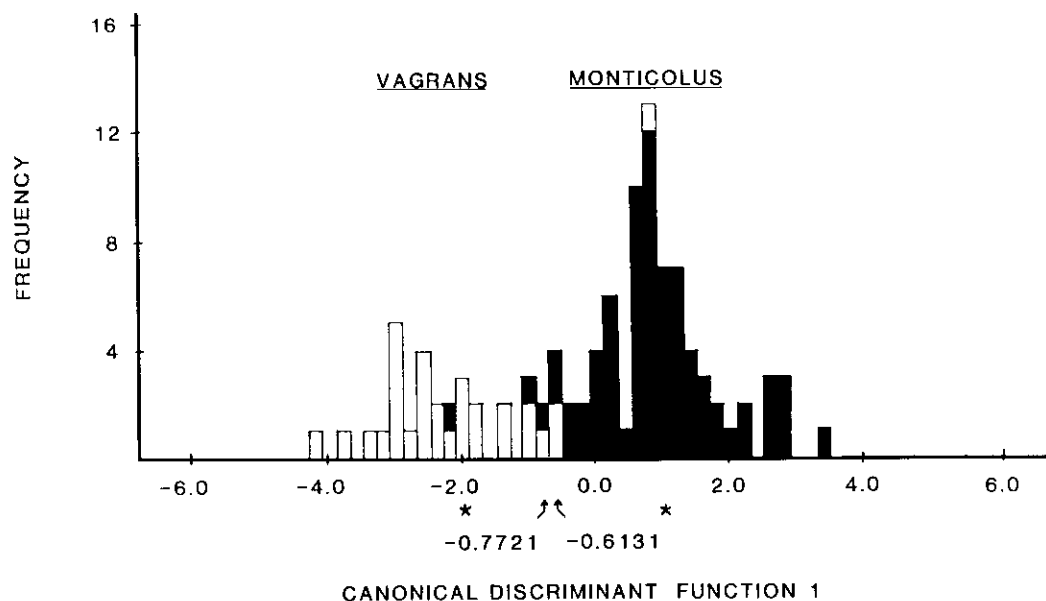


Figure 1. Stacked histogram of *S. vagrans* and *S. monticolus* canonical discriminant function 1 scores. Group centroids are marked by an asterisk. Arrows mark the discriminant scores that represent the maximal discriminant score that will reliably identify a *S. vagrans* (left arrow) and the minimal discriminant score that will reliably identify a *S. monticolus* (right arrow).

TABLE 3. Summary of qualitative tine characters exhibited by specimens as identified by multi-group discriminant analysis. Percentage is calculated from the sum of scored individuals for each species and character.

Species	Character State	Character									
		Tine n	Size %	Tine n	Pigment %	Cap n	Clarity %	Tooth n	Pigment %	Pigment n	Level %
<i>Sorex monticolus</i>	1	7	7	1	1	2	2	6	6	2	2
	2	8	8	13	13	11	11	73	75	5	5
	3	82	85	75	76	84	87	18	19	8	8
	4	0	0	9	9	0	0	0	0	84	85
	Unscored	5		4		5			5		3
<i>Sorex vagrans</i>	1	35	42	4	5	32	39	18	22	21	25
	2	31	37	40	48	42	51	63	76	31	37
	3	17	20	37	45	8	10	2	2	26	31
	4	0	0	2	2	0	0	0	0	6	7
	Unscored	6		6		7		6		5	

character states ranging from 1 to 3. For each of the five qualitative characters, more than 20% of the *S. vagrans* specimens appear in two or more separate character states. There is no clear distinction between the characters or combination of characters associated with the incisors that clearly distinguish all *S. monticolus* from all *S. vagrans*.

## Discussion

Rudd (1955) maintained that sexual variation had no significant affect on cranial morphology, and others (Carraway 1990) have made similar assumptions in their work. In this study, *S. vagrans* showed significant sexual variation for least

interorbital breadth and palatal length (Table 1). Carraway (personal communication) believes that the sex of about 10% of all *Sorex* found in museum collections is misidentified. If the specimens housed at the ROM follow this generality, the sexual variation in this sample may be even more significant than this analysis suggests. This significant sexual variation and the resulting significant multivariate effect for Rudd age category 3 suggests that data should be examined for dimorphism.

Although many others have reported age variation in shrews (Jackson 1928; Rudd 1955), only width across upper molars showed any significant difference among age categories. There was no statistical difference at the multivariate level for the four characters used in this study. Admittedly, the sample sizes are small. The results do, however, suggest that age variation should be routinely explored before assuming any significance.

Although the significant groupings resulting from Tukey's studentized range test vary from character to character, the measurements for the central group are consistently the largest, whereas those of the southern sample are the smallest (Table 1). Although there is no evidence of Bergmann's Rule (Smith 1980), coastal versus inland location, elevational differences, rainshadow effects, or other parameters may be correlated with the morphological differences exhibited in the specimens examined. A larger sample size, preferably of a single subspecies, is necessary to further explore the possible factors correlated with morphological variation.

The classifications of the two-group and multi-group discriminant analysis differed for only six specimens. It is not surprising that the three differently classified *S. vagrans* in the two-group discriminant analysis were females; the larger female *S. vagrans* are more likely to be classified as *S. monticolus* than are the smaller males. The three differently classified *S. monticolus* clearly exhibited *monticolus* key characters.

The use of discriminant scores for the first canonical variate has proven useful in identifying mouse and bat species that exhibit confusing key characters (Choate 1973; Bogan 1974). Despite significant multivariate differences in sex and geographic groupings, the classification results of the

multi-group and two-group discriminant analyses were identical in rate of successful classification of the known specimens.

Those specimens whose discriminant score values are between  $-0.7721$  and  $-0.6131$  should be considered *S. vagrans* ? or *S. monticolus* ?, rather than as *Sorex* sp. *S. vagrans* and *S. monticolus* are readily distinguished from other *Sorex* species by shared dental characters (van Zyll de Jong 1983). By assigning a question mark to a tentative identification, a higher level of systematic information is retained in the museum collection.

The characters described by Hennings and Hoffmann (1977) may be individually striking when examining specimens of *S. vagrans* or *S. monticolus*. When originally examining specimens, I found concentrating on the darkness of the pigment, and the presence or absence of a break in the pigment between the tine and the main body of the incisor confused identification decisions. While performing final curation after completion of the analyses described here, I found that the level of pigment on the main body of the I1 and the size of the tine were the two characters that seemed to vary most consistently with discriminant analysis diagnoses. Concentrating only on the variation between these two characters greatly simplified identification decisions.

Distinctive tine characters led to the prompt identification of *S. monticolus* and *S. vagrans* 60% of the time. When tine characters were absent or became mixed in nature, the use of four easily measured cranial characters and the results of a discriminant analysis permitted the identification of a further 35% of the shrews awaiting curation. For collections lacking large series of specimens, a quantitative identification tool for the cranial material of these two very confusing species provides a means of assigning specific nomenclature to museum specimens.

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## Appendix I

### *Sorex monticolus*.—

British Columbia. (n = 75) Alta Lake (1); Bennett (1); Chezacut Lake, Chilcotin, Range 3 (1); Cultus Lake (2); First subalpine *Betula* community near Ray's Road, 59° 51' N, 136° 40' W (4); Glacier (4); Golden (1); Hope-Princeton Highway (1); Lakelse Lake, Range 5 (4); Manning Park (3); McClinton Creek, Graham Island (1); Mount Revelstoke (3); Mount Revelstoke National Park (1); North Vancouver (2); Nulki Lake, Range 4 (5); Point Grey (2); Repeat alpine moist grass community N Den Site D, 59° 40' N, 136° 31' W (1); Repeat alpine *Salix* community N Den Site D, 59° 40' N, 136° 31' W (3); Repeat subalpine *Salix* community at Den Stream, 59° 48' N, 136° 37' W (12); *Salix* experimental Den Site D, 59° 40' N, 135° 31' W (1); Seal Cove, Prince Rupert (5); Second alpine grass community S Den Site D, 59° 40' N, 136° 31' W (2); Second alpine roadside community at Den Site D, 59° 40' N, 136° 31' W (2); Second alpine *Salix* community S Den Site D, 59° 40' N, 136° 31' W (5); Second subalpine *Salix* community in F-08's typical area, 59° 40' N, 135° 31' W (1); Sixteen Mile Lake, Quesnel (3); Vancouver (1); Vermillion Crossing (3).

### *Sorex vagrans*.—

British Columbia. (n = 30) Bolean Lake, 7 mi. NE Falkland (1); Cameron Lake, Vancouver Island (1);

Coldstream, Okanagan (4); Cowichan Lake, Vancouver Island (1); Duncan, Vancouver Island (2); Goldstream (1); Huntingdon (3); Mount Revelstoke (1); Mount Revelstoke National Park (3); Okanagan Landing (5); Point Grey (3); Quatsino (1); Sugar Lake (1); Vancouver (1); Vernon (2).

### Unknowns. —

British Columbia. (n = 86) Balsam Lake (1); Beaver Pit, Glacier National Park (1); Beaver River, Glacier National Park (1); Bolean Lake, 7 mi. NE Falkland (1); Cameron Lake, Vancouver Island (3); Coldstream, Okanagan (3); Cranbrook (3); Creston (3); Cultus Lake, Okanagan (1); Departure Bay (1); Duncan, Vancouver Island (1); Eagle Bay, Shuswap Lake (1); Field (1); First alpine *Salix* community, near Nadahini River, 59° 41' N, 136° 33' W (1); Glacier (3); Goldstream, Vancouver Island (1); near Haines Road (3); Huntingdon (1); Lakelse Lake (3); Lulu Island (3); Manning Park (2); McClinton Creek, Graham Island (4); McClinton Creek, Masset Inlet (1); Mount Coakley, Vancouver Island (2); Mount Revelstoke (1); Mount Revelstoke National Park (14); No locality (2); Okanagan Landing (2); Point Grey (2); Seal Cove, Prince Rupert (4); Silver Star Mountain, 12 mi. NE Vernon (1); Sixteen Mile Lake (5); Sooke (1); Sugar Lake (3); Summit Lake (1); Vancouver (3); Wynndel (2).