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Identifying Norwegian shrews (Soricidae) from non-dental mandibular characters

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A method for discriminating between 6 species of Norwegian shrews (Soricidae) based on a few characters in the lower mandible is described. Length, height, and one angle were measured in cleaned mandibles (n = 297). When plotting angle/length on height, most species were clearly separated. In addition, the position of the condyle relative to the infracondylar notch was used to separate one species of *Neomys* from the 5 species of *Sorex*. In the *Sorex* species, mandible length had most discriminating power, followed by mandible height, angle, and angle/height. A classification table to distinguish between the species is given.

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INTRODUCTION

In Norway, five species of *Sorex* and one species of *Neomys* have been found (Heggberget 1990). The distribution of most of these is poorly known, probably due to their similar morphology which makes identification difficult, and their concealed way of living. Most numerous are the Common and Pygmy Shrews, *Sorex araneus* L. and *S. minutus* L. Their distribution covers most of the country (Heggberget 1990). Only a few specimens of Masked Shrew *S. caecutiens* Laxmann, Graves Shrew *S. isodon* Turov, and Least Shrew *S. minutissimus* Zimmermann have been found, and their distribution and abundance in Norway are not really known (Heggberget 1990). The Water Shrew *Neomys fodiens* (Pennant) is probably distributed throughout the country (Heggberget 1990), but there are still many gaps in our knowledge (Solheim 1990).

Shrews are normally distinguished by colour, overall size, relative length of tail, and teeth characters (e.g. Siivonen 1976, Corbet & Southern 1977). Ruprecht (1971) identified four species of *Sorex* on the mandible length and height, although with difficulty for some of the species. Geographical variation in skull measurements has been found in several species (Skarén 1979, Junge et al. 1983, Malmquist 1985, Sulkava et al. 1985), and such measurements have been used to identify sub-species (de Jong 1980).

This paper describes a method of species identification based on a few characteristics of the mandible. The mandible is the most persistent bone in shrews, and thus the method may be used for species identification in archaeological material, in studies on the diet of predators, etc.

MATERIAL AND METHODS

A total of 297 specimens from the museum collection at the University of Bergen (*S. araneus, S. minutus,* and *N. fodiens* from western Norway), and from collections at two museums in Finland (the Biological Museum at Iisalmi and the Zoological Museum at the University of Oulu) (*S. caecutiens, S. isodon,* and *S. minutissimus*) were examined. Length, height, and angle (Fig. 1) were measured along the outer surface of the mandible by a Wild stereomicroscope with an ocular micrometer at magnification 6x and 12x. The mandibular angle was read by projecting the mandible on a semi-circle by a mirror. Statistical methods includes analysis of variance (ANOVA) and Sheffé multiple comparison test, and discriminant analysis and Wilk's lambda. Significance level is 0.05 if not otherwise stated.

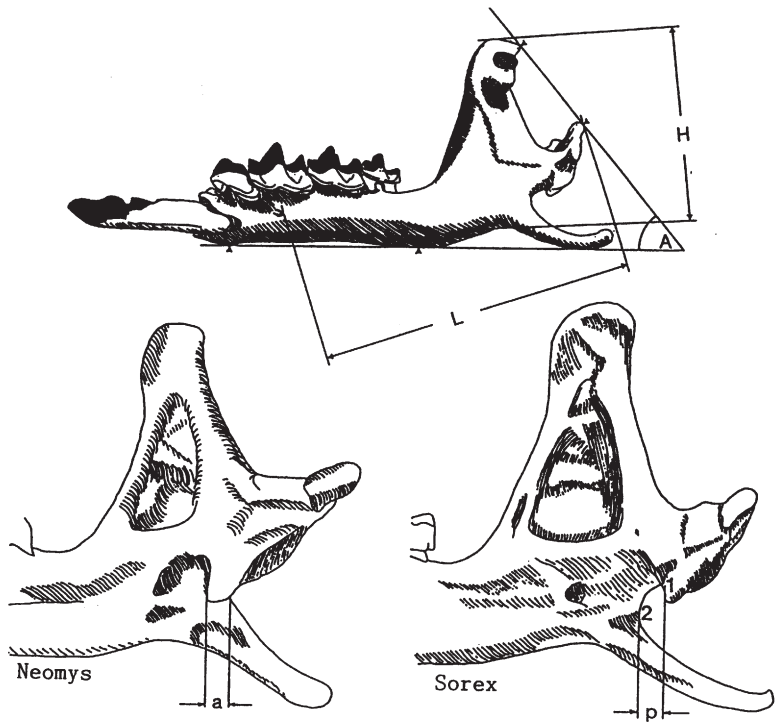

Fig. 1. Dimensions measured in the lower mandible, and relative position of the condyle (1) to the infracondylar notch (2) (a = anterior, p = posterior). L = mandible length (from mental foramen), H = mandible height, A = mandible angle, ▲ = «touch» points in measuring the angle.

RESULTS AND DISCUSSION

The ranges in mandible length were relatively short, and overlap between most species was small or absent (Fig. 2). The overlap and coefficient of variation were somewhat larger in mandible height, and largest in mandible angle (Table 1). The three dimensions varied significantly ($p<0.001$) with species; length (F = 2040.2), height (F = 2072.3), and angle (F = 226.3), but all species were not significantly different from each other in all measurements.

Mandible length in *N. fodiens* and *S. isodon* was not significantly different. Mandible height was not significantly different in *S. araneus* and *S. isodon,* nor in *S. minutus* and *minutissimus.* Differences in the angle were not significant in 4 of the 15 possible combinations of species; *S. isodon, S. caecutiens* and *S. minutissimus* were not different from each other, and *N. fodiens* was not different from *S. minutus.* Thus, mandible length distinguished best between most species.

The six species were most easily separated with little overlap in distributions when angle was divided by length and plotted against height (Fig. 3). The distribution of *S. isodon* was close to the

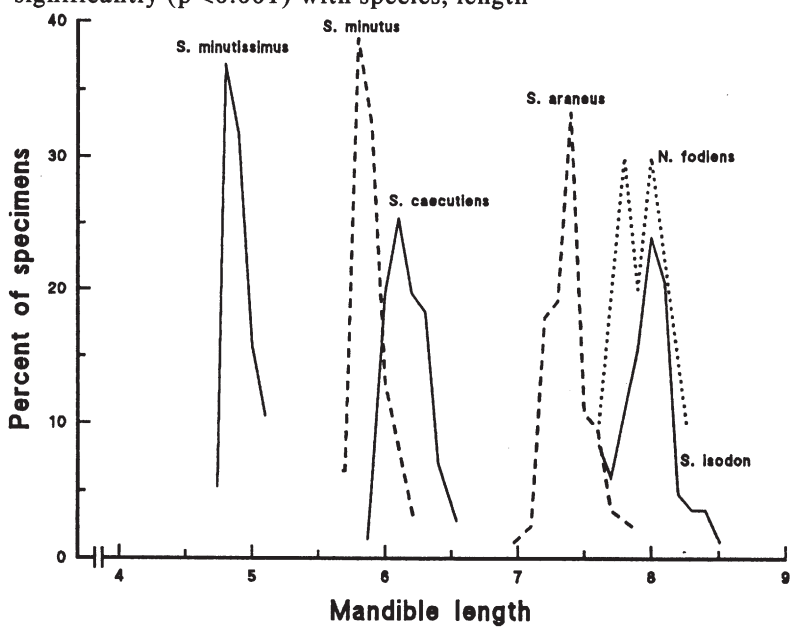

Fig. 2. Mandible length (mm) in 6 species of shrews.

Table 1. Mean ($\overline{X}$), standard deviation (SD), and coefficient of variation (CV) of length, height, and angle of the lower mandible by species (mm).

Species	Length			Height			Angle			n
	$\overline{X}$	SD	CV	$\overline{X}$	SD	CV	$\overline{X}$	SD	CV	
N. fodiens	7.94	0.17	2.17	4.44	0.18	4.00	31.1	2.92	9.40	10
S. isodon	8.01	0.20	2.51	4.68	0.11	2.35	39.0	2.52	6.45	82
S. araneus	7.43	0.16	2.09	4.65	0.13	2.82	47.6	2.80	5.89	84
S. caecutiens	6.21	0.16	2.52	3.60	0.09	2.41	39.3	2.76	7.20	71
S. minutus	5.89	0.11	1.80	2.98	0.09	2.97	31.8	2.49	7.82	31
S. minutissimus	4.93	0.10	2.05	3.08	0.10	3.18	38.8	2.25	5.80	19

distribution of *S. araneus* on one side, and to the distribution of *N. fodiens* on the other side (Fig. 3). *N. fodiens* was somewhat confusing in the otherwise clear separation between the species (Fig. 3, note small sample size), but this species is easily identified on the position of the condyle relative to the infracondylar notch (Fig. 1).

Angle/length and height were included in a discriminant analysis (excluding *N. fodiens*), and since Wilks' lambda was very small (0.006, $\chi^2 = 1466.1$, d.f. = 8, $p<0.001$) their discriminating power was high. Only 1 specimen (0.4%) was mis-classified to species in this analysis: one *S. araneus* was wrongly classified as *S. isodon*. Mandible length, height, angle, and the proportion angle/length were included in a stepwise discriminant analysis which maximized Mahalanobis' distance. Mandible length was entered on step 1, e.g. had most discriminating power, and the other dimensions were entered on steps 2—4 in the order given. These variables classified 100% of the specimens correctly (excluding *N. fodiens*).

A table of classification including the position of condyle, mandible length and height, and mandible angle divided by length (Table 2), distinguishes between the 6 species with nearly 100% certainty. The three dimensions

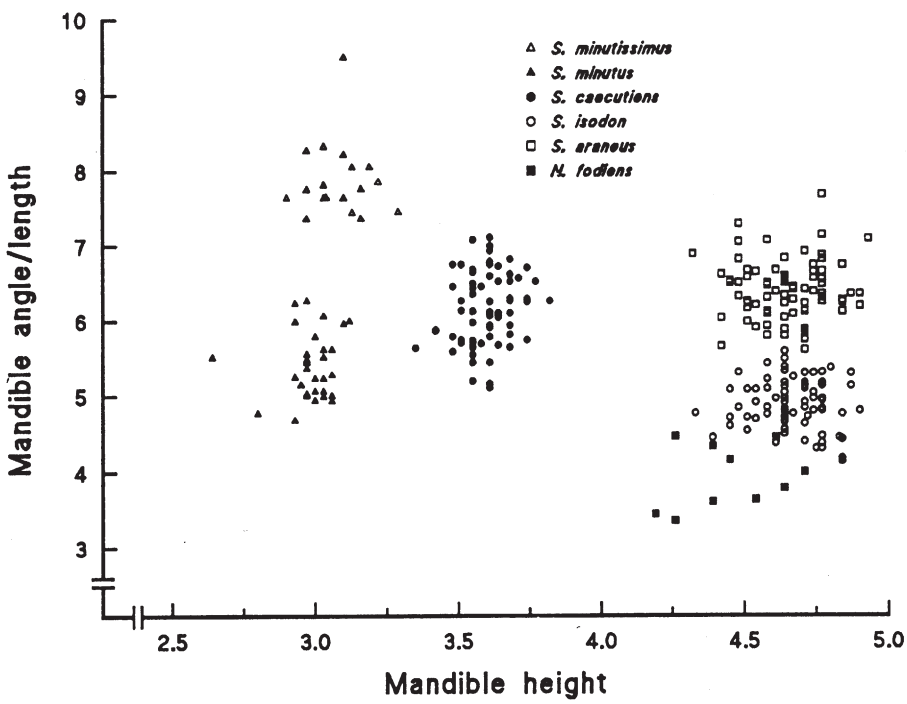

Fig. 3. Relation between mandible angle/length and mandible height in 6 species of shrews.

Table 2. Identification table for Norwegian Soricidae.

1a The protruding part of the condyle is anterior to infracondylar notch (Fig. 1)	*N. fodiens*
1b The protruding part of the condyle is posterior to infracondylar notch	2
2a Mandible height <4 mm	3
2b Mandible height >4 mm	5
3a Mandible height <3.3 mm	4
3b Mandible height >3.3 mm	*S. caecutiens*
4a Mandible length <5.5 mm	*S. minutissimus*
4b Mandible length >5.5 mm	*S. minutus*
5a Mandible angle/mandible length <5.6	*S. isodon*
5b Mandible angle/mandible length >5.6	*S. araneus*

and one character are easy to study on cleaned mandibles, and may also be applied to carcasses of shrews in cases of overlapping morphological characteristics.

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SAMMENDRAG

Bestemmelse av norske spissmusarter

Dette arbeid beskriver en ny metode til å bestemme 6 norske spissmusarter (5 *Sorex* pluss vannspissmus *Neomys fodiens)* ved hjelp av ulike målinger av underkjeven, og gir en bestemmelsestabell.

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