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Regional variation in the size of the common shrew *Sorex araneus* in Norway

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We analyzed variation related to region, age, and sex in the length and height of the mandible of the common shrew *Sorex araneus* in Norway (n = 261), with some notes on the length of the tail and on the body weight. Specimens were classified by four age groups according to their date of capture, tooth wear, and reproductive status. Shrews from Finnmark (northernmost Norway) were about 3 % smaller in the two mandible dimensions than shrews from Hordaland (southern Norway), while only minor or no differences were found between the two major samples from Hordaland. Juveniles were, on average, 2-3 % smaller than overwintered adults. In no measurements were males larger than females, but statistical significant sexual dimorphism was found only in body weight. A general deterioration of the climate and habitat quality may be found with increasing latitude, but local gradients (e.g. lowland towards alpine regions) could be equally important for the size of the common shrew.

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Introduction

The common shrew *Sorex araneus* is widely distributed throughout Eurasia, living in different habitats and mostly sympatric with several other species of shrews. It seems to vary in size and colouration and has been described in many forms or subspecies (Skarén 1964, Michielsen 1966). It is in the upper size class of the *Sorex* genus, and may dominate or influence smaller species. For example, the pygmy shrew *S. minutus* reduces its size and population density in sympatry with the common shrew (Michielsen 1966, Malmquist 1985, 1986, Frafjord 1992). Because of its wide distribution, generally high density, and a limited individual dispersal ability, morphological variation in the common shrew is interesting and may reflect environmental adaptation, interspecific competition or evolutionary trends.

In Scandinavia, the length of the upper tooth row of the common shrew increase from southern Sweden to northern Norway (Sulkava et al. 1985). This may indicate either an overall northward increase in size, or an increase in the length of the snout only. Skarén (1964) also reported a geographical variation in the size of the common shrew, but the northward increase was not clear in all measurements. In Norway, a larger coastal subspecies has been claimed to exist, *S. a. bergensis* (Collett 1912, Siivonen 1976), but this has not been verified by other investigations (Skarén 1964). In this study we compare the size of the common shrew from Hordaland and Finnmark counties, in south and north Norway respectively, mainly from measurements of the mandible. Our main objective was to detect geographical variation, if any, in the size of the common shrew,

but we also describe age and sex related size variation.

Materials and methods

The shrews were collected during various studies and stored at the Museum of Zoology, University of Bergen. Most data from Hordaland came from two different valleys, Eksingedalen (60°50'N 6°E, n = 88, April-August 1977 - Otto 1978) and Tysse (60°30'N 5°55'E, n = 44, July-August 1991 - Frafjord 1992) situated about 50 km apart (**Figure 1**). Most data from Finnmark came from the easternmost part of Norway, Pasvikdalen and the region of Kirkenes (69°30'N 30°E, n = 81, July-October 1991 and 1992), in the following denoted Pasvik. Hordaland is in the temperate zone, and most shrews were caught in deciduous forests or on cultivated land. Pasvikdalen lies in the boreal zone with pine and birch forests, but most other parts of Finnmark are subarctic with birch shrub or tree-less tundra.

We measured mandible length (ML) and mandible height (MH) as described in Fredriksen et al. (1992) in a total of 261 specimens. ML was measured from the foramen mentale, but in addition total mandible length (TML) was measured from the base of the incisor (Siivonen 1976) in a part of the material. TML was used to check the position of the foramen mentale, which may also vary geographically (Skarén 1979). Body and tail lengths, and weight were measured in some fresh carcasses as described by Frafjord (1992), to study correlations with mandible dimensions. We also measured tail length in

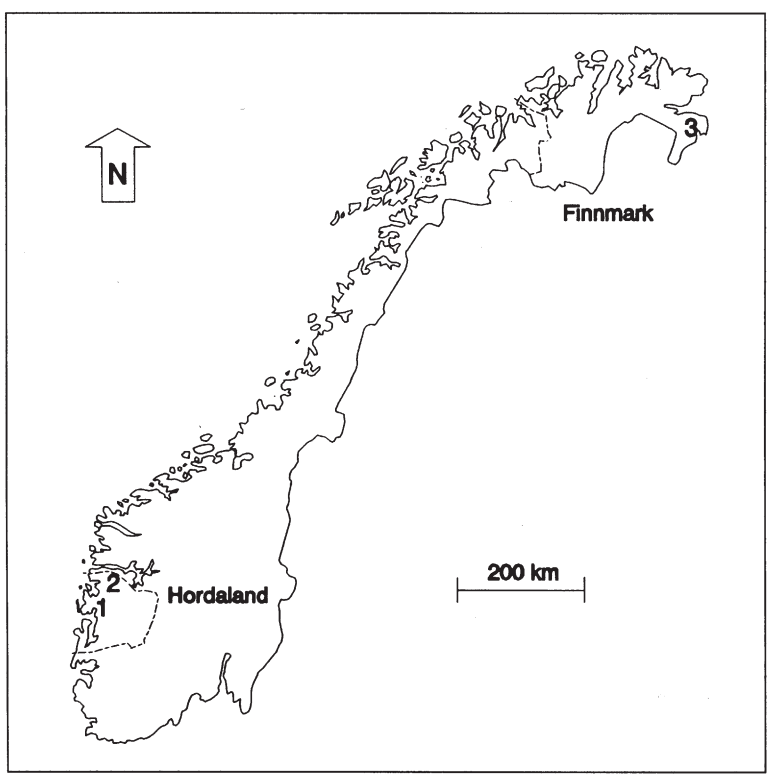

Figure 1
Map of Norway showing the location of Hordaland and Finnmark counties and the three major sampling sites (1 = Tysse, 2 = Eksingedalen, 3 = Pasvikdalen).

some carcasses that had been frozen. Measurements that are compared were all taken by one person. We also include data on weight from common shrews collected at Vadsø, Finnmark (70°10'N 29°40'E, July 1965), found in the Natural History Museum, London. These were presumably weighed as fresh carcasses. Vadsø is situated close to Pasvikdalen, across Varangerfjorden. Comparisons of body length measured by different persons are difficult and not included in this study. Also, measurements of body length in specimens caught in snap-traps are inaccurate and not used.

Shrews were classified as non-breeders or breeders from the size of their reproductive organs, to check the accuracy of the age classes given below. Male breeders: largest testes > 2.5 mm long, male nonbreeders: testes length < 2.5 mm. Female breeders: uterus expanded and/or containing fetuses and/or teats clearly visible. Female nonbreeders: uterus narrow and thin. Tooth wear was estimated by measuring the height of the pigmented area and the total tooth height of the lower first molar (M_1), according to Skarén (1979) and Pankakoski (1989). A tooth wear index (PA) is given as the pigmented area in percent of total tooth height (**Figure 2**). Shrews were divided into four age classes (**Table 1**) from a combination of time of year and tooth wear. Age-1: months June-September and PA > 38 %, age-2: October-January, age-3: February-May, and age-4: June-September and PA ≤ 38 %. Most common shrews have life spans shorter than about 1.5 years and only breed in their second summer (Michielsen 1966), and we consider the number of shrews that had overwintered twice as nil or insignificant. Age-1 males were most numerous in the catches, and were included in all analyses.

Table 1. Number of common shrews caught in each age class by region and in the total sample.

	Age class			
	1	2	3	4
Eksingedalen	36	0	30	18
Tysse	42	0	0	1
Pasvik	71	8	0	2
Total sample	159	25	47	24

The data were not complete in every respect and sample size varies between tests. Statistical methods are one-way ANOVA to examine differences between regions, between age groups, and between sexes, including Scheffé multiple comparison tests to reveal the regions or age groups that differ significantly ($p < 0.05$). Factorial two-way ANOVA are used to examine interactions between two variables. Pearson's correlation coefficients are used to examine relationships between measurements.

Results

Geographical variation

Significant regional differences in mandible length and height were found among age-1 shrews (**Table 2**). Mean ML of age-1 males (**Table 3**) was smaller in Pasvik than both in Eksingedalen and Tysse ($F_{2,88} = 19.65$, $p < 0.001$, and Scheffé test). Mean MH was larger in Tysse than in Eksingedalen and Pasvik, but no significant difference was found between Eksingedalen and Pasvik ($F_{2,88} = 15.75$, $p < 0.001$, Scheffé). Among age-1 females, shrews from Pasvik were smaller than shrews from Eksingedalen and Tysse (ML: $F_{2,45} = 8.78$, $p < 0.001$; MH: $F_{2,45} = 12.37$, $p < 0.001$; Scheffé). Shrews from Pasvik (least in both dimensions) were 2.6-3.6 % smaller than shrews from Tysse (cf. **Table 3**). No signifi-

Table 2. *ANOVA tests for effects of region and sex on mandible length and mandible height in age-1 common shrews.*

Source of variation	Sum of squares	DF	F	p =
	Mandible length			
Main effects	1.71	3	19.76	0.000
Region	1.62	2	28.10	0.000
Sex	0.08	1	2.78	0.098
2-way interactions	0.14	2	0.07	0.780
Explained	1.72	5	11.58	0.000
Residual	3.83	133		
	Mandible height			
Main effects	0.61	3	17.91	0.000
Region	0.58	2	25.81	0.000
Sex	0.36	1	3.23	0.075
2-way interactions	0.47	2	2.09	0.128
Explained	0.65	5	11.58	0.000
Residual	1.50	133		

Table 3. *Mean (mm), SD and sample size (n) of mandible length (ML) and mandible height (MH) by region in age-1 males and females.*

Region	ML Mean	ML SD	MH Mean	MH SD	n
		♂♂			
Pasvik	7.19	0.17	4.53	0.11	44
Eksingedalen	7.38	0.16	4.57	0.12	17
Tysse	7.42	0.17	4.67	0.09	30
		♀♀			
Pasvik	7.24	0.22	4.53	0.10	22
Eksingedalen	7.46	0.14	4.66	0.10	16
Tysse	7.45	0.09	4.70	0.11	10

cant 2-way interaction between region and sex was found (**Table 2**).

Age-1 shrews from Pasvik also had shorter tails than those from Eksingedalen and Tysse; males (mean±SD): 46.1 ± 2.88 mm, 50.8 ± 1.92 mm, and 50.7 ± 3.06 mm, respectively ($F_{1,87}$ = 30.33, p<0.001, Scheffé), females: 45.0±1.94 mm, 49.9±3.0 mm, and 50.7 ± 1.57 mm ($F_{1,46}$ = 31.97, p < 0.001, Scheffé). The tail of the shrews from Pasvik was about 10 % shorter than that of the shrews from Tysse. Body weight was lower in age-1 males from the region of Vadsø than in Tysse males (7.1 ± 0.53 g, n = 26, and 7.6 ± 0.71 g, n = 30, respectively, $F_{1,54}$ = 10.37, p < 0.01). The same trend was found for age-1 females, but the sample size on females was small. Age-1 Vadsø females weighed 7.32 ± 0.30 g (n = 6) and Tysse females 8.06 ± 0.37 g (n = 10).

In shrews from Hordaland, ML, MH, and TML were correlated with each other (ML-MH: r = 0.69, ML-TML: r = 0.85, and MH-TML: r = 0.66, $p < 0.001$, n = 84). However, in the sample from Tysse, ML and MH was not significantly correlated (**Table 4**). In this sample ML was correlated with total length (body + tail) and with weight, but not with body or tail length separately. MH was correlated with weight only (**Table 4**).

The position of the foramen mentale varied slightly between populations, as it moved forward about 1 % (= 0.09 mm) of TML in age-1 males from Pasvik compared to Tysse males (ML in % of TML, $F_{1,44} = 7.31$, $p < 0.01$). The difference in TML was 0.43 mm, i.e. in this dimension Pasvik age-1 males were 4.6 % smaller than Tysse age-1 males ($F_{1,44} = 42.75$, $p < 0.001$). The difference in ML was 0.26 mm.

*Table 4. Pearson's correlation coefficients between mandible length (ML) and height (MH) and body and tail lengths, and weight in common shrews (age-1) from Tysse (n = 43). * = p<0.01, ** = p <0.001.*

	ML	MH
Mandible height	0.30	
Body + tail length	0.44*	0.17
Body length	0.31	0.17
Tail length	0.33	0.03
Weight	0.43*	0.48**

Age related variation

The proportion of pigment on the first molar seems to overlap slightly between shrews of the year and mature, over-wintered shrews caught in the summer (**Figure 2**), but averages of all four age classes were significantly different from each other ($F_{3,249} = 228.0$, $p < 0.001$, Scheffé). We compared PA with breeding status in specimens from the three sub-

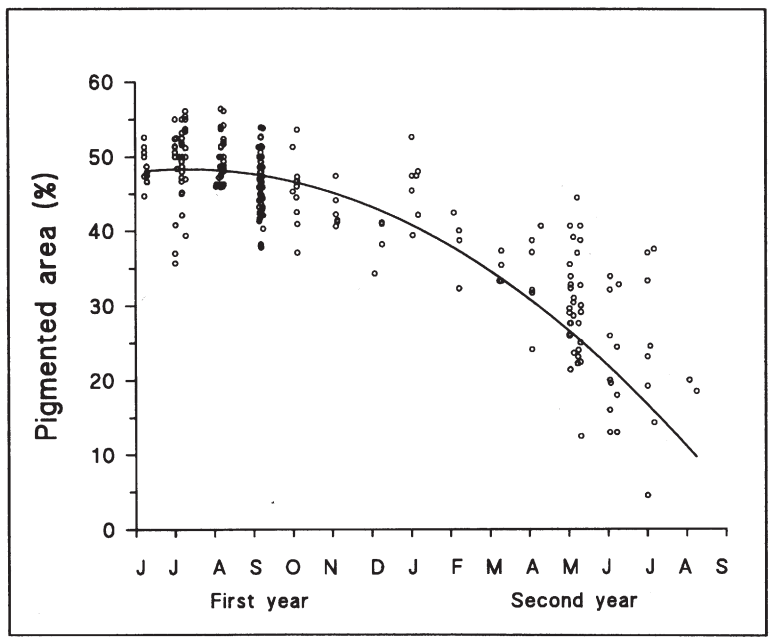

Figure 2
Scatterplot of the proportion of pigmented area on the first molar against time of year in Norwegian common shrews (n = 261). Over-wintered shrews caught during June-August were identified from their mature reproductive status.

samples (Pasvik, Eksingedalen and Tysse). In breeders, 26 specimens had PA < 38 % and 7 had PA > 38 %. In non-breeders, 1 had PA < 38 % and 85 had PA > 38 %. Thus, 8 specimens (7 + 1) or 6.7 % were "misclassified" to reproductive group when the division was made at PA = 38 %. However, they may not have been misclassified to age class, because, e.g., the 7 breeders with PA > 38 % may have been individuals breeding in their first summer. The distinction of age classes 1 and 4 seems to be reasonable, grouping most specimens correctly. Specimens of the age-1 class from Tysse had 6-7 % less tooth wear than those from Eksingedalen and Pasvik ($F_{2,157}$ = 10.85, $p < 0.001$, Scheffé).

Among shrews from Eksingedalen, age-1 males had significantly smaller ML (2.3 %) than age-3+4 males (combined, see also **Table 5**). Average ML of age-3+4 males was 7.55 ± 0.14 mm ($F_{1,48}$ = 16.24, $p < 0.001$, compare age-1 males in **Table 3**). MH of age-3+4 males was 4.71 ± 0.12 mm, or 2.9 % larger than age-1 males ($F_{1,37}$ = 16.52, $p < 0.01$). No significant differences between age-1 and age-3 + 4 females from Eksingedalen were detected. ML of age-3 + 4 females was 7.52 ± 0.16 mm ($F_{1,21}$ = 1.13, $p > 0.05$) and MH was 4.67 ± 0.08 mm ($F_{1,21}$ = 0.03, $p > 0.05$).

Sex related variation

The proportion of females varied from 26.8 % at Tysse, 31.2 % in Eksingedalen, to 34.2 % in Pasvik. No significant sexual dimorphism in the mandible was found (**Tables 2** and **5**), although males were smaller than females in all three regions (**Table 3**). In the total sample of age-1 specimens, ML of males (7.30 ± 0.21 mm) was 99.2 % of females (7.36 ± 0.20 mm). MH in males (4.58 ± 0.12 mm) was 99.1 % of females (4.62 ± 0.12 mm). The 2-way interaction between sex and age was not significant (**Table 5**). Females from Tysse (age-1) were 5.7 % heavier than males ($F_{1,41}$ = 6.29, $p < 0.05$).

Discussion

Region explained more of the variance in mandible size of Norwegian common shrews than age or sex, but the residual sums of squares were relatively large which means that the analysis failed to account for a large proportion of the variation (**Tables 2** and **5**). Shrews from Finnmark were about 3 % smaller than shrews from Hordaland, and overwintered adults were 2-3 % larger than juveniles in their first summer. It is well known that overwintered shrews increase in body size and weight in their second summer (Skarén 1964, Andersson & Hansson 1966, Michielsen 1966), but the increase of the mandible found in our study was comparatively small. No significant sexual dimorphism in mandible size

Table 5. ANOVA tests for effects of age and sex on mandible length and mandible height in common shrews from Eksingedalen.

Source of variation	Sum of squares	DF	F	p =
	Mandible length			
Main effects	0.34	3	5.20	0.003
Age	0.33	2	7.72	0.001
Sex	0.02	1	0.90	0.346
2-way interactions	0.05	2	1.18	0.315
Explained	0.39	5	3.59	0.006
Residual	1.44	67		
	Mandible height			
Main effects	0.19	3	4.64	0.005
Age	0.19	2	6.97	0.002
Sex	0.02	1	1.40	0.242
2-way interactions	0.07	2	2.73	0.073
Explained	0.26	5	3.88	0.004
Residual	0.89	67		

was found, supporting Michielsen (1966) and Pankakoski (1989), but we found evidence of a small, reversed sexual dimorphism in body weight. The fact that male common shrews are not larger than females is unusual for a mammal, and may reflect the aggressive and territorial nature of female shrews (Michielsen 1966, cf. Cantoni 1993).

The northward reduction of both mandible size, tail length and weight support a theory of an overall reduction in size, but the reduction in the size of the body may have been smaller than the reduction in extremities such as the snout or tail (remember also the weak correlations between mandible size and body size and weight). Reduced extremities may be an adaptation to a colder climate (or less snow cover in winter time), while a reduced body size may be an adaptation to reduced food availability. Competition with other species of shrews is not likely to differ between northern and southern Norway. The common shrew dominate catches in both south and north Norway (Linn 1954, Andersson & Hansson 1966, Clough 1967, Frafjord 1992, Frafjord et al. 1993). In south Norway the common shrew is sympatric with the pygmy shrew and the water shrew *Neomys fodiens*. In Finnmark, the masked shrew *S. caecutiens* is also found in small numbers and probably in a few sites only, among these are Pasvikdalen (Clough 1967, Frafjord et al. 1993). In Norway, only a very few *S. minutissimus* and *S. isodon* have been reported (Heggberget 1990).

Small and large scale geographical variation have been found in the common shrew, both in genetic heterogeneity (Heikkilä 1989), in skull dimensions (Skarén 1964, Sulkava et al. 1985), and in body size (Frafjord 1992). Such variation may be related to phylogenetic divergence or to short-term fluctuations related to for example, peaks in density, food availability or interspecific interactions. Our results did not support the conclusion of Sulkava et al. (1985, see also Skarén 1964) that the snout of the common shrew is proportionately longer in the north. We found a reduction of the mandible in shrews from Finnmark, while local differences in Hordaland were small. Andersson & Hansson (1966) reported a body weight of subadult common shrews from Nordland county (68°20' N) of 7.3 g, which is intermediate between the shrews from Hordaland and Finnmark of our study. Hanski (1989) indicated a decrease in the size of the skull of *S. caecutiens* with increasing latitude in Siberia, as well as geographic variation in the litter size of this species. Further studies may possibly reveal whether the apparent northward reduction in the size of the common shrew is real, or merely results from differences in the quality of the habitat (food availability, shelter from predators, climate, interspecific or intraspecific competition) that can also be found along local gradients (for example along altitudinal gradients).

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Sammendrag

Geografisk variasjon i størrelse hos vanlig spissmus i Norge.

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Vanlig spissmus har vid utbredelse i Norge og finnes i mange typer miljøer fra kyst til høyfjell. Samtidig er det en art med kort liv-

slengde og liten evne til individuell spredning. Derfor kan det være interessant å undersøke om det finnes lokale tilpasninger hos denne arten. Vi undersøkte dette ved åmåle kjevelengde hos spissmus fra Hordaland og fra Finnmark (Pasvik-området), samt ved å måle halelengde og vekt hos endel dyr. Vanlig spissmus fra Finnmark hadde ca. 3% mindre kjeve enn spissmus fra Hordaland, og forskjellen i vekt var enda større. Forskjellen mellom spissmus fra to forskjellige daler i Hordaland (Tysse og Eksingedalen) var minimal. Vi undersøkte også aldersrelaterte forskjeller i størrelse og fant at voksne spissmus som hadde overvintret var 2-3 % større enn spissmus av året. Kjønnsforskjeller var derimot små, men unge hunner var signifikant tyngre enn hanner. Det er vanskelig å si hvor store deler av de ulikhetene som ble funnet som er genetisk fastlagt eller hvor store deler som er et direkte resultat av miljøet og næringstilgangen.

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