BIOMETRIC VALUES COMPARISON OF SOMATIC AND CRANIAL FEATURES OF TWO *MICROTUS OECONOMUS* SUBSPECIES

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Abstract: In this paper we evaluate biometry of somatic and cranial features of the root vole *Microtus oeconomus mehelyi* (Éhik, 1928) from Slovakia and *Microtus oeconomus stimmingi* (Nehring, 1899) from Poland. The body length shows the biggest variability and the hind foot length the lowest in all cases. The Polish populations reach higher average values of weight and body length, but lower values of tail length and hind foot length, which all are consistent with both Bergmann's and Allen's rule. Positive correlation has also been proven for both subspecies between the weight and body length. There is a negative correlation among the Polish individuals and positive correlation among the Slovak individuals between the body length and tail length. Similar results have been obtained when the relation between body length and hind foot length was tested. Nineteenth cranial features were also examined. Subspecies *M. e. stimmingi* reached higher average values in all cases except 4 features (LFm, Ia, Io, LOSD). Out of six evaluated features of low jaw, higher average values for *M. e. mehelyi* subspecies were found for 3 features (LMd, LMdD, AMd) and the rest of the features reached lower average values. The rest (Amdm, LOID, ML) reached higher average values for *M. e. stimmingi*.

Key words: root vole, *Microtus oeconomus*, biometry, somatic and cranial features.

INTRODUCTION

The taxonomists' interest about root voles (*Microtus oeconomus* (Pallas, 1776)) and study of its local populations by the end of 19th and beginning of 20th century lead towards various descriptions of this small mammal, but all of its names are synonymic in sense of the zoological nomenclature. Synonyms of *M. oeconomus* (Pallas, 1776): *Microtus oeconomus: Arvicola operarius* Nelson, 1893; *Arvicola ouralensis* Poliakov, 1881; *Arvicola ratticeps* Keyserling et Blasius, 1841; *Lemus medius* Nilsson, 1844; *Microtus koreni* Allen, 1914; *Microtus malcolmi* Thomas, 1911; *Microtus ratticeps* (Keyserling et Blasius, 1841); *Microtus ratticeps altaicus* Ognev, 1944; *Microtus tschuktschorum* Miller, 1899; *Microtus uchidae* Kuroda, 1924; *Mus oeconomus* Pallas, 1776. Pallas described *Microtus oeconomus* in 1776. Commonly known as the tundra or root vole, it is one of only four Holarctic rodents and the only species of the genus *Microtus* that is found on all continents in northern hemisphere. On a basis of mtDNA phylogeographic analysis, the species population dynamics during the Pleistocene

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has been made (Brunhoff et al. 2003). When talking about voles occurrence it is commonly regarded that during the last glacial maximum (17 000 to 21 000 BC) the whole Europe was covered by snow (Flint 1957), and rodents of the genus *Distrostomyx* and *Lemmus* were pushed in to the Central Europe. *Microtus oeconomus* (Jánossy 1986, Chaline 1987, Nadachowski 1989, Kordos 1990) belongs also to such taxa. Fossil findings show that *Microtus oeconomus* had been continuously spreading to Central and Western Europe, where it had survived the inconvenient conditions and then again migrated back to Northern Europe. The spread of root vole was wider after the ice–age than it is nowadays incorporating the North Sea, Germany, Sweden and Great Britain (Tast 1982, Chaline 1987). All of these populations have common phylogeographic origin on a basis of mtDNA variability. *Microtus oeconomus* and *M. agrestis* share the same territories in Central Europe (Jaarola & Searle 2002), which proves their common glacial and postglacial history. European root voles are divided into a Northern and a Central mtDNA phylogroup. Root voles remained north of the classical refugial areas in southern Europe during the last glacial period. The currently fragmented populations in central Europe belong to a single mtDNA phylogroup. Late Quaternary geological and climatic events played a strong role in structuring northern fauna. Central European populations of root vole (including Polish and Slovak) are classified to the same phylogenetic line, which is different from North European, Central Asian and the Beringian lineage. Morphologically defined subspecies do not correspond of the genetic differentiation. Isolated central and western European populations are the glacial relicts.

Nowadays, 7 subspecies of *Microtus oeconomus* are recognised (Tast 1982). In this paper we evaluate and compare biometry of somatic and cranial features of *M. o. mehelyi* (Éhik, 1928) from Slovakia and *M. o. stimmingi* (Nehring, 1899) from Poland. *M. o. mehelyi* is found only in western (especially north–western) Hungary, eastern Austria and south–western Slovakia, occupying habitats formed by sediments of freshwater marshes, swamps, floodplains or watersides with dense vegetation. They have a pattern of dark colour on their back. Mehelyi's root vole is the rarest vole subspecies in Central Europe and is considered to be a glacial relict at its current locations, marking the southernmost distribution of this Holarctic species in Europe. Méhelyi's root vole is listed in Appendix III of the Bern Convention and in the IUCN Red List in the category "Least Concern" (2002), and the subspecies *M. o. mehelyi* is listed in the annex of the EU habitats directive as a priority species. History of research, distribution and conservation management of the root vole population along the Danube in Slovakia and Hungary utilized Gubányi et al. (2009). *M. e. stimmingi* is common in eastern part of Germany, Poland, European part of Russia and their back´s colour is brighter.

The aim of this study is to compare the biometric values of somatic and cranial features of two Microtus oeconomus subspecies. Our intention is to point out that the differences of biometric values result from the adaptation of animals to the environmental conditions

MATERIAL AND METHODS

Evaluated *Microtus oeconomus mehelyi* material consists of 32 individuals caught from 25. 4. 1997 to 17. 12. 2005 (Slovak Academy of Sciences' research station at Staré Hory; Protected Landscape Area Ponitrie, State Nature Conservation SR; Department of Ecology and Environmental Sciences, University of Constantine the Philosopher in Nitra). Caught individuals (Table 1) come from 10 localities in south–western Slovakia. *M. o. stimmingi* material comprises of 32 individuals caught from 10. 6. 1992 to 30. 11. 1992 at 3 localities near Baciuty, north–east part of Poland (south–west from the Białystok, material assessed at the University of Białystok). We used classic methods to capture the small mammals according to Pucek & Olszewski (1971) and Morris (1968). Voles were caught by snap traps using a line method (50 trapping points, in 10 m distances). Traps were controlled in 24–hours intervals, exposed for two nights. Part of the material was gained by life catch traps. All animals were surveyed and some groups of ectoparasites described from systematic groups such as: Siphonaptera, Ixodidae and Mesostigmata. Results of ectoparasitological examination were partly published by Bridišová (2008).

To evaluate the biometric features of *M. oeconomus* we determined the sex and split the individuals into two age groups: growing (subadult) individuals and adult individuals. Among the adults we examined whether they are sexually active or inactive. Individuals similar to adults by size but sexually immature and inactive were regarded as subadults.

Following somatic features were monitored: body weight H, in g; body length LC; tail length LCd; hind foot length LTp; all lengths in mm). Following cranial and jaw–bone features were monitored (according to Komosa et al. 2007; Borowski et al. 2008): LCr – total length of skull (Akrokranion – Prosthion), LCB – condylobasal length (condylus occipitalis), LB – total length of the cranial base (Basion – Prosthion), LBP – basal–palatal length (Basion – Staphylion), LPm – median palatal length (Staphylion – Prosthion), LFm – median frontal length (Akrokranion – Nasion), LuV – upper length of the viscerocranium (Nasion – Prosthion), LN – length of the nasals (Nasion – Rhinion), LaZ

Table 1. The material of *Microtus oeconomus* from Slovakia and Poland.

Subspecies	Sex	Adults	Subadults	Together
M. o. mehelyi	Males	12	3	15
	Females	13	4	17
M. o. stimmingi	Males	15	1	16
	Females	14	2	16

Table 2. Comparison of *M. oeconomus* somatic features values from Poland and Slovakia.

	Poland	Slovakia	ANOVA
Weight	46.99	36.11	3.85×10^{-5} **
Body length	119.86	115.02	0.069
Tail length	49.03	50.88	0.308
Hind foot length	17.7	20.38	3.3×10^{-12} **

– zygomatic breadth (Zygion – Zygion), Ia – breadth across the supraorbital processes, Io – postorbital breadth (Frontostenion – Frontostenion), LOSD – length of the tooth row in the maxilla, LD – length of the diastema, LaN – neurocranium breadth (Euryon – Euryon), LM – length of the nuchal crest, LOC – breadth of occipital condyles, IS – breadth of incisive bone, PS – greatest palatal breadth, FI – length of foramen incisivum, LMd – total length of mandible at processus articularis (longitudo mandibulae), AMd – coronoid height of mandibula (altitudo mandibulae), AMdm – maximum height of mandible excluding coronoid process (coronoid process), LOID – length of mandibular tooth row (longitudo ordinis inferioris dentium), ML – mandible length excluding incisors, LMdD – length of mandibular diastema.

Biometric data were processed by descriptive statistics. We were looking for differences of arithmetic mean values of observed features between the Polish and Slovak voles. ANOVA variance analysis was used to test hypothesis and for validation of statistical significance of variability between individual features (H_0 = Deviations of mid biometric values from the average values are dependent on each other). Relation of variables was tested by F–test (F. critical value). Also P value is a relevant part of the test's outcome. By t test the divergence (consistency) of mid values was tested. We set up minimal level of relevance $p_\alpha = 0.05$, where $p > 0.05$ we approve H_0 on a level of statistical significance 0.05. The importance of differences was levelled up to: significant difference (p_α = 0.05 – 0.01, marked „*“), highly significant difference (p_α = < 0.01, „**“). We also examined correlation between lengths of measured body parts, especially for Polish and Slovak root voles populations

RESULTS

Evaluation of sexually mature adult individual's somatic features of *Microtus oeconomus* males and females showed, as expected, that the body length reveals the biggest variability in all cases. Hind foot length values shows the lowest variability. The longest hind foot length had an individual caught in southern Slovakia during summer season. Big differences of tail length between adult males and females were also observed.

The average values of weight and body length of adult individuals of the subspecies *M. o. stimmingi* are higher (statistically highly significant in case of weight), but the subspecies *M. o. mehelyi* have bigger average values of tail length and hind foot length (differences highly significant in case of hind foot length, Table 2). Presented somatic features were analysed on mid values variance among observed subspecies (H_0 = mid values are equal to each other). Level of statistical significance was set up to $\alpha = 0.05$. We can see that the Polish populations of *M. o. stimmingi* reach higher average values of body weight and body length, but lower values of tail length and hind foot length in comparison to Slovak populations of *M. o. mehelyi.*

In case of weight, its decrease is highly significant for Slovak populations compare to Polish (23 %) and the hind foot growth in case of Slovak populations is about 13 % (also highly significant). The least change has been observed in case of tail length, and there is also no significance in case of body length (difference only 4 %).

We have examined relation between individual somatic features for both sexes according to regression and correlation. Positive correlation has been proven for both subspecies between weigh and body length, but more significant relation has been observed for the subspecies *M. o. mehelyi*

(Significance of F regression analysis = 2.233×10^{-5}, correlation = 0.7745). For the subspecies *M. o. stimmingi*, the F significance of regression analysis is 0.01756, correlation equals to 0.4377 (Fig. 1, 2).

The relation between the tail length and body length is negative among the Polish individuals (F significance of regression analysis = 0.8309, correlation = –0.04145) and positive correlation among the Slovak individuals (F significance of regression analysis = 1.1115×10^{-5}, correlation = 0.7586, Fig. 3, 4). Similar results were obtained in case of body length and hind foot length observations. The relation among Polish population is negative (F significance of regression analysis = 0.8456, correlation = –0.0378) and among the Slovak individuals is positive (F significance of regression analysis = 0.0795, correlation = 0.5183, Fig. 5, 6).

Evaluation of cranial and jaw–bone features

We measured and evaluated 19 different features of *Microtus oeconomus* cranial (Table 3). Using classical methods of descriptive statistics we evaluated variability of selected neurocrania of sexually mature adult males and females. We realised testing of cranial measures average values between Polish and Slovak individuals (*M. o. stimmingi* and *M. o. mehelyi*) to evaluate statistically significant differences or of non–significant differences. We have found out higher average values of cranial features common for subspecies *M. o. stimmingi*, except 4 features. Average values of cranial features LFm, Ia, Io, LOSD were higher among *M. o. mehelyi* (in case of Io significantly and LOSD highly significant, Table 3).

Testing variability of six jaw–bone features of adult and mature *M. oeconomus* males and females we have found out that the length of wishbone shows biggest variability in all cases. The most stable feature of jaw–bone is diastema (Table 4).

Out of 6 evaluated jaw–bone features, 3 features (LMd, LMdD, AMd) reach higher average values among subspecies *M. o. mehelyi* and the rest of features (Amdm, LOID, ML) reached higher average values among stimmingi subspecies. By testing (ANOVA) statistically highly significant difference has been proven ($P < 0.01$) among surveyed subspecies in case of AMd and ML features (Table 4).

We examined the relation between somatic features and cranial features among both subspecies of *Microtus oeconomus*. We have found out some differences of observed features between Polish and Slovak individuals in results of regression analysis. In all cases there has been positive correlation, but more significant among the subspecies *M. o. mehelyi* (significance, F = 0.00814, correlation 0.675, Fig. 8; F = 8.17×10^{-5}, correlation 0.706, Fig. 10) than among the subspecies *M. o. stimmingi* (not significant, F = 0.6738, correlation 0.0816, Fig. 7; F = 0.9254, correlation 0.018, Fig. 9)

DISCUSSION

Microtus oeconomus mehelyi belongs to more robust subspecies of root voles within Europe, so it belongs to the biggest voles in Slovak territory. Its habitus, population dynamics and bionomics of subspecies from Slovakia were surveyed in details by Kratochvíl & Rosický (1955). They present following biometric measures: body length among adult individuals (from last year litters) in summer period varies from 116 to 142 mm (129.7 mm in average), tail length among adult individuals varies from 42 to 73 mm. Tails of the most robust individuals are longer than half of their body length, hind foot length varies according to above mentioned authors in interval from 18.5 to 22.6 mm with most common values among adult population from 19.5 to 22.4 mm. The eye diameter is regarded as stable recognition feature (the adult individuals most common value of eye diameter is interval from 3.3 to 3.7 mm.) Other measures were realised on individuals of *M. o. mehelyi* populations in other parts of Europe: Neusiedler See (Bauer 1953) and Balaton (Éhik 1953). The adult individuals reach higher values of body length, which has been proven by Kratochvíl & Rosický (1955) and that is a result of female´s earlier sexual maturity. The tail length is considered as one of the recognition features among *M. o. mehelyi* subspecies belongs to long tailed subspecies. Taxonomic value of this feature depends on a knowledge of tail length relation to the body length of individuals when theirs body size is about 100 mm. The hind foot length is one of the recognition features and varies the least. Our measures varied from 18.5 mm to 23 mm. The body weight is determined by many objective factors such as season, daytime, weather, trophical and topical conditions etc. Bauer (1953) and Éhik (1953) presented following measures for the subspecies *M. o. mehelyi*: LCB from 26 to 30 mm (average 27.9 mm). Rácz et al. (2005) analysed the historical relationship between Hungarian populations by analyzing morphological skull similarities (mandibles and skulls) and they found out that root vole populations form four regional clusters in Hungary.

Wasilewski (1956) presents following values of somatic features for adult of the subspecies *M. o. stimmingi* after hibernation from Bialowieza: weight from 32 to 53 g, body length from 107 to 132 mm, tail length from 41 to 51 mm, hind foot length from 16.7 to 18.5 mm. Craniological features: LCB from 25.9 to 27.5 mm, LD from 7.56 to 8.05 mm, LN from 7.25 to 7.9 mm, LaZ from 14.5 to 15.5 mm, Io from 3.45 to 3.75. Ognew (1950) in Wasilewski (1956) presents for stimmingi in western part of Russia

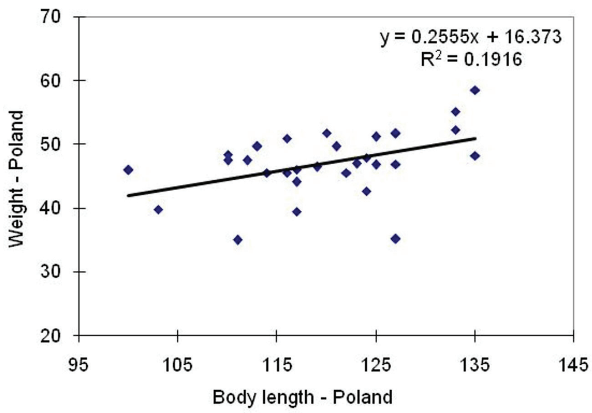

Figure 1. The relation between weight and body length of *Microtus oeconomus stimmingi*.

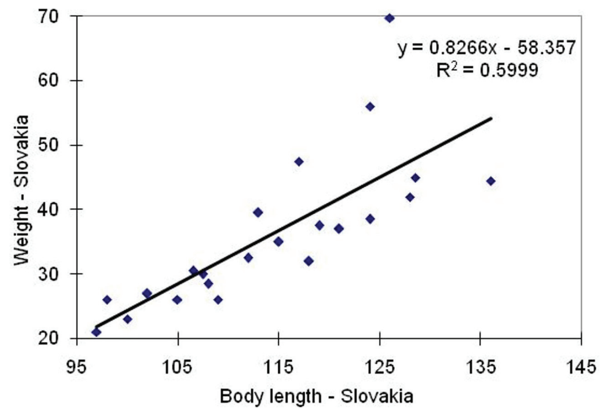

Figure 2. The relation between weight and body length of *Microtus oeconomus mehelyi*.

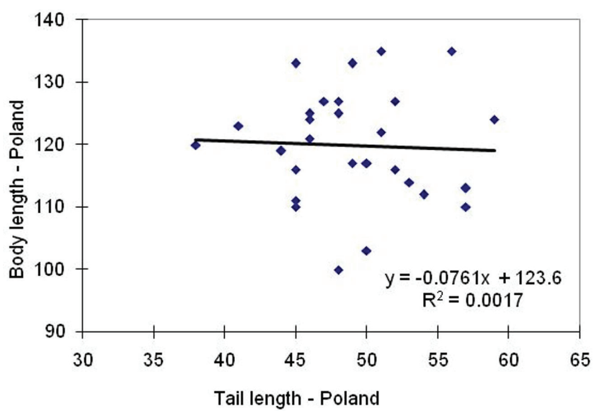

Figure 3. The relation between tail length and body length of *Microtus oeconomus stimmingi*.

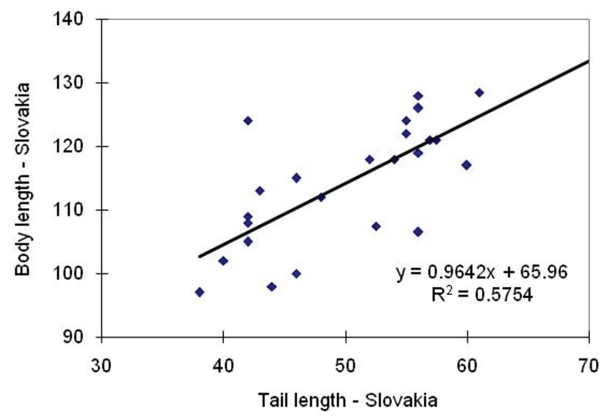

Figure 4. The relation between tail length and body length of *Microtus oeconomus mehelyi*.

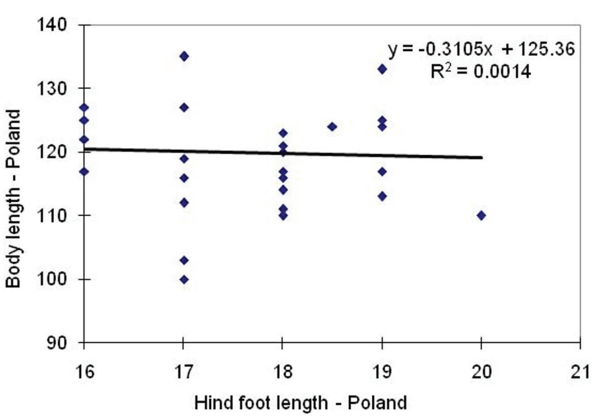

Figure 5. The relation between hind foot length and body length of *Microtus oeconomus stimmingi*.

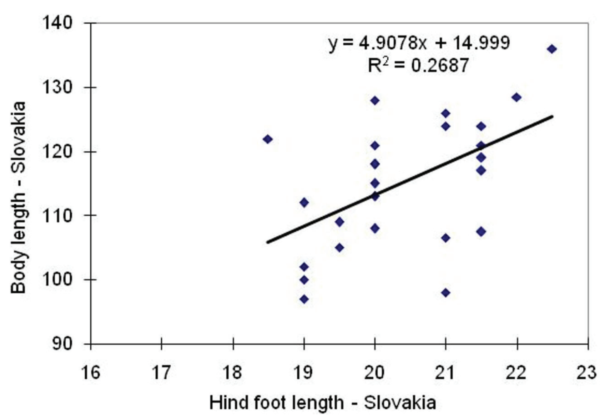

Figure 6. The relation between hind foot length and body length of *Microtus oeconomus mehelyi*.

higher values: LCB (from 26 to 28.2 mm, average 27.4 mm). Another values: LN from 8 to 8.7 mm, tail length from 115 to 134 mm (average 120 mm), tail length from 35 to 59 mm (average 45 mm), hind foot length from 16 to 21.5 mm (average 19 mm). Zimmermann (1950) found following biometric values for stimmingi species: body length from 95 to 137 mm (average 112.8 mm), tail length from 30 to 61 mm, LCB from 23.1 to 29 (average 25.5 mm). Frank & Zimmermann (1956) present following values from the subspecies *M. o. stimmingi* from northeast Germany: body length from 101 to 133 mm (average 111.6 mm), tail length from 37 to 67 mm (average 48.9 mm), hind foot length from 17 to 21 mm (average 19.6 mm), LCB from 25 to 29 mm (average 27 mm). Jorga (1971) recorded following values for German individuals of the subspecies *M. o. stimmingi*: tail length from 38 to 55 mm (average 42.9

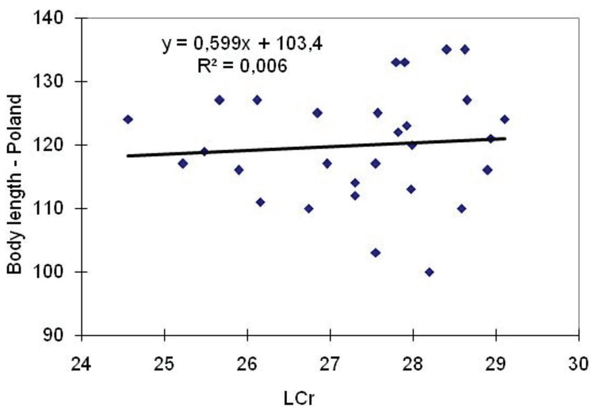

Figure 7. The relation between body length and LCr of *Microtus oeconomus stimmingi*.

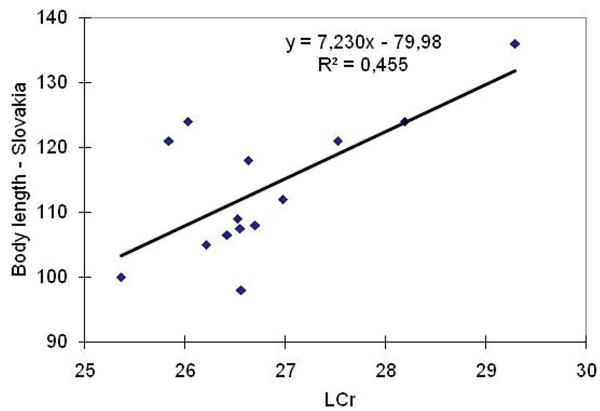

Figure 8. The relation between body length and LCr of *Microtus oeconomus mehelyi*.

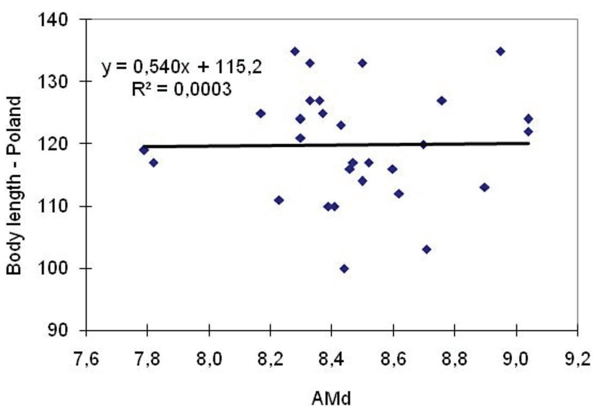

Figure 9. The relation between body length and AMd of *Microtus oeconomus stimmingi*.

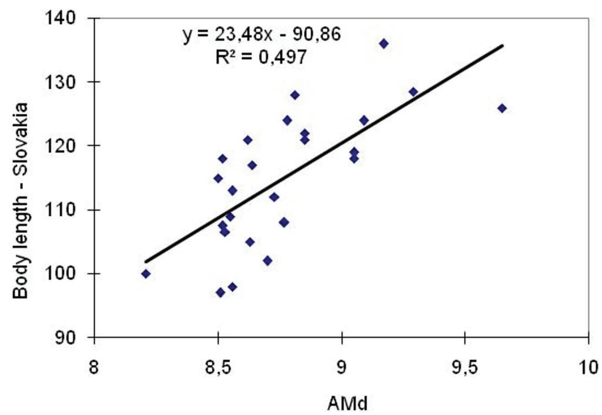

Figure 10. The relation between body length and AMd of *Microtus oeconomus mehelyi*.

mm). According to Wasilewski (1956) and Van Wijngaarden & Zimmermann (1965) the subspecies *M. o. stimmingi* reach lower values of LCB than the subspecies *M. o. mehelyi*, which is inconsistent with our measures. According to above mentioned authors, the subspecies *M. o. stimmingi* is situated somewhere between *M. o. mehelyi* and *M. arenicola* according to LCB size. Average values of LCB of individuals from surroundings of Baciuty (Poland) are higher than values from south Slovakia.

Presented differences are consistent with two ecological rules, Bergmann's and Allen's. The Polish populations from higher altitudes have adapted on lower average year temperatures. They have bigger body size and weigh more, but have smaller tails and hind feet. The decrease of hind foot length and increase of body weight in colder regions seems to be the main decisive mechanism for adaptation of species on environment. When considering the body measures of the subspecies *M. o. mehelyi*, we would have expected lower weight values and higher hind foot length values of stimmingi subspecies. So we can see the stimmingi subspecies´ adaptation on their environment and the relevance of ecological rules.

Bergmann's rule states in its original version that warm–blooded vertebrate species from cooler climates tend to be larger than congeners from warmer climates and is a valid ecological generalization for birds and mammals (Meiri & Dayan 2003). It was found out that over 72 % of the birds and 65 % of the mammal species follow Bergmann's rule.

The results could be totalled as follows:

1. The body length shows the biggest variability of somatic features in all cases for *Microtus oeconomus mehelyi* and *M. o. stimmingi* subspecies; the lowest variability is common for hind foot length values. Polish populations reach higher average values of body weight and body length, but lower values of tail length and hind foot length.

2. Presented differences prove the relevance of both, the Bergmann's and the Allen's rule.

3. Positive correlation has been proven for both subspecies between the weight and body length. The relation between body length and tail length is negative among Polish individuals and positive among Slovak individuals. Similar results were gained in case of relation testing between body length and hind foot length.

Table 3. Comparison of *M. oeconomus* cranial features values from Poland and Slovakia.

	Poland	Slovakia	ANOVA
LCr	27.37	26.77	0.116
LCB	26.89	26.28	0.147
LB	25.78	25.29	0.272
LBP	4.78	4.68	0.383
LPm	20.99	20.68	0.333
LFm	19.69	19.81	0.717
LuV	8.74	8.66	0.542
LN	7.87	7.47	0.0009**
LaZ	15.38	14.48	$4.21 \times 10^{-5**}$
Ia	3.11	3.21	0.108
Io	3.65	3.76	0.012*
LOSD	6.73	6.9	0.009**
LD	8.41	8.14	0.02*
LaN	12.65	12.37	0.064
LM	12.13	11.49	6.75×10^{-5}**
LOC	8.77	8.46	0.007*
IS	3.38	3.37	0.825
PS	5.22	5.08	0.0005**
FI	5.14	4.68	0.008**

Table 4. Comparison of *M. oeconomus* jaw–bone features values from Poland and Slovakia.

	Poland	Slovakia	ANOVA
LMd	14.95	15.11	0.307
LMdD	4.31	4.41	0.127
AMd	8.47	8.77	0.0009
Amdm	8.58	8.5	0.43
LOID	6.7	6.59	0.189
ML	15.61	14.89	6.69×10^{-5}

4. Nineteenth cranial features have been observed. Higher average values were common for *stimmingi* subspecies except 4 features (LFm, Ia, Io, LOSD).

5. Out of six examined features of jaw–bone, higher average values were observed for 3 features (LMd, LMdD, AMd) of the subspecies *M. o. mehelyi* and the rest (Amdm, LOID, ML) reached higher values of the subspecies *M. o. stimmingi*.

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