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CRANIAL GROWTH OF CAPTIVE BRED COMMON VOLES (*MICROTUS ARVALIS*)

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Abstract. The cranial growth of the common vole (*Microtus arvalis*) was investigated using 406 captive bred individuals aged from 12 to 724 days. All 17 of the measured skull characters were sex-dependent, with males on average being larger than females. It was found that the steady growth of *M. arvalis* continued for about 10 months, with body weight reaching ca. 45 g and body length nearly 12 cm, while the growth of most skull characters lasted up to 12–14 months and that of some dental characters, i.e., the length of the first upper molar or incisor width, during the whole life of an individual. Correlations of mandibular and maxillary skull characters with body weight and especially body length were quite strong, determining up to 70% of variation in the latter parameters. Animal age was best correlated with dental parameters – the length of molar M_1 and incisor width across both upper incisors.
Key words: captive bred common vole, *Microtus arvalis*, growth, skull

Introduction

It is characteristic that in rodents the process of growth is not inhibited by age, but lasts nearly up to the end of their life. This is undoubtedly due to the short life of these animals, which have no time to attain a period of stabilisation (Haitlinger 1962).

We should not expect a linear growth in most small mammal species. In shrews, seasonal changes in skull morphology are well documented (Pucek 1964; Viktorov 1971; Ivanter 1974); they are followed by changes in other body parameters (Pucek 1965), including tooth wear (Pankakoski 1989).

Data on the growth of the wild bank vole (*Clethrionomys glareolus*) are presented in classical investigations by Zejda (1964, 1971). He found that in central Europe the stagnation of body weight around 20 g and body length around 90 mm is typical of sexually immature individuals of *C. glareolus* older than 2 to 3 months and that body length is more suitable for age definition (Zejda 1971). Different cohorts and sexes of *C. glareolus* show different growth curves of body weight and length. On the other hand, Bujalska and Gliwicz (1968) failed to find any differences in the growth of males and females. For captive bred *C. glareolus*, we found three different growth patterns of skull characters, significant male-female differences in body and skull size, and that measurements of skull characters correlated best with body weight, whereas correlations with body length or individual age were less pronounced (Balčiauskienė 2007).

In a few of publications on the growth of voles of g. *Microtus*, a long period of increase in body parameters was shown (Gebczyńska 1964; Maldžiūnaitė 1976). For the captive grown short-tailed vole (*Microtus agrestis*), the period of intensive growth of condylobasal length of the skull lasts up to the 9th month of life (Gebczyńska 1964). A different growth pattern was shown for seasonal cohorts of the root vole (*Microtus oeconomus*) (Gliwicz 1996). For captive bred common vole (*M. arvalis*), it was shown that animal age has a high influence on the parity (Tkadlec & Krejcova 2001).

M. arvalis is among the main prey species of owls and some raptors. As for *C. glareolus*, the knowledge about body weight and skull growth dynamics may be used in the studies on the feeding ecology of such birds (Balčiauskienė 2007).

The aim of the present publication is to describe the growth dynamics of cranial characters and their correlations with body weight, length and age in the captive bred *M. arvalis*.

Material and methods

The cranial growth of *M. arvalis* was investigated using captive bred individuals. Voles were grown at the Institute of Ecology of Vilnius University (at that time, the Institute of Zoology and Parasitology) in 1972–1977, under the supervision of S. Maldžiūnaitė. Four hundred and six individuals aged from 12 to 724 days were kept in 60 × 120 cm terrariums, with four 20 × 20 × 15 cm houses, 2 motion wheels, and some refuges in each. Temperature was kept in the range of 10–26.5°C in summer and 9–20°C in winter. Food and water were provided *ad libitum*. The only publication from this experiment deals with peculiarities of body weight increase in *M. arvalis* under laboratory conditions (Maldžiūnaitė 1976). The sample of skulls of young voles was collected by killing random specimens of the desired age and that of old voles from naturally dead animals. Skulls were prepared using the boiling procedure and mechanical hand cleaning.

Out of 406 skulls of captive *M. arvalis*, the numbers of available measurements were from 247 for the coronoid height of mandibula (X_5) to 404 for the total length of mandibula at *processus articularis*, excluding incisors (X_1), and the length of mandibular diastema (X_6).

In our investigation, measurements of skull characters were taken under a binocular with a micrometric eyepiece with an accuracy of up to 0.1 mm. We measured the characters of the right set of skulls; the left set was measured only in a few cases, when skulls were damaged. The following skull (8 mandibular and 9 maxillary) characters of *M. arvalis* were used in our analysis (Fig. 1):

X_1 – total length of mandibula at *processus articularis*, excluding incisors; X_2 – length of mandibula, excluding incisors; X_3 – height of mandibula at, and including, the first molar; X_4 – maximum height of mandibula, excluding coronoid process; X_5 – coronoid height of mandibula; X_6 – length of mandibular diastema; X_7 – length of mandibular tooth row; X_8 – length of molar M_1; X^9 – length of *nasalia*; X^{10} – breadth of braincase measured in the widest part; X^{11} – zygomatic skull width; X^{12} – length of cranial (upper) diastema; X^{13} – zygomatic arc length; X^{14} – length of *foramen incisivum*; X^{15} – length of maxillary tooth row; X^{16} – length of molar M^1; X^{17} – incisor width across both upper incisors.

The lengths of mandibular (X_7) and maxillary (X^{15}) tooth rows were measured as the distance from the anterior edge of the alveolus of the first molar to the posterior edge of the alveolus of the third molar.

A standard statistical approach (mean and standard error, range, Student's *t*-test for comparison of means and Spearman's correlation) was used (StatSoft 2004). To express growth dynamics, smoothed line graphs were drawn (Figs 3–4) using averaged character measurements for age groups arranged in decades (0–9, 10–19 days, etc.). It was previously found (Balčiauskienė 2007) that box and whisker plots are not suitable for this purpose due to excessive extreme values and outliers that overcrowd the graph and make it less expressive.

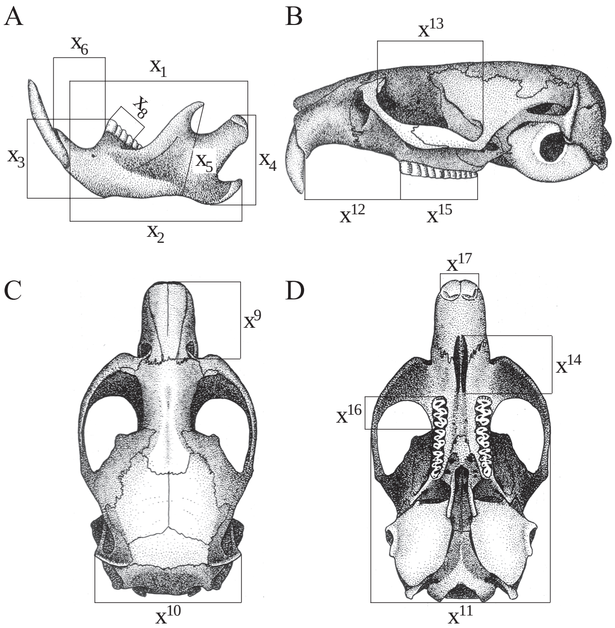

Figure 1. Skull measurements taken in *M. arvalis*: A – mandible, B – lateral view, C – dorsal view, D – ventral view (Lidicker & MacLean 1969; Niethammer & Krapp 1982; Prūsaitė 1988).

Results

The average values of all skull measurements taken are given in Table 1. All measured skull characters were sex-dependent, with males on average being larger than females. For males and females, sample sizes in different age groups were unequal (several groups were represented by one sex only), thus sex-dependent dynamics of skull growth was not analysed.

Cranial characters were strongly correlated with body weight and even stronger with body length, but in most cases they were less correlated with age (Table 2). The highest correlations allow us to conclude that body weight for captive *M. arvalis* may be known from zygomatic skull width (X^{11}) or the length of mandibula, excluding incisors (X_2), with more than 60% of determination, while from the length of cranial (upper) diastema (X^{12}), the total length of mandibula at *processus articularis*, excluding incisors (X_1), the maximum height of mandibula, excluding coronoid process (X_4), or the height of mandibula at, and including, the first molar (X_3) with more than 50% of determination.

Body length may be calculated from zygomatic skull width (X^{11}), the length of mandibula, excluding incisors (X_2), or the length of cranial (upper) diastema

Table 1. Average values (in mm) of mandibular and maxillary characters in captive *M. arvalis* and the significance of male-female differences (M–F).

	Total			Males		Females		M–F, *p*
	Avg ± SE	N	Min–max	Avg ± SE	Min–max	Avg ± SE	Min–max	
X_1	12.74 ± 0.05	404	9.9–14.9	13.06 ± 0.06	9.9–14.9	12.44 ± 0.06	10.1–14.4	<0.001
X_2	12.36 ± 0.05	331	9.5–14.7	12.75 ± 0.07	9.5–14.7	12.00 ± 0.07	9.8–14.1	<0.001
X_3	5.38 ± 0.03	402	3.9–6.9	5.56 ± 0.04	4.1–6.9	5.23 ± 0.03	3.9–6.7	<0.001
X_4	6.78 ± 0.11	379	4.7–8.1	6.91 ± 0.04	4.8–8.1	6.44 ± 0.04	4.7–8.0	<0.002
X_5	7.13 ± 0.04	247	5.5–8.6	7.28 ± 0.05	5.6–8.2	6.97 ± 0.06	5.5–8.6	<0.001
X_6	3.41 ± 0.01	404	2.8–4.0	3.46 ± 0.01	2.8–4.0	3.37 ± 0.01	2.9–4.0	<0.001
X_7	4.90 ± 0.02	402	4.0–6.0	4.96 ± 0.02	4.0–5.7	4.84 ± 0.02	4.0–6.0	<0.001
X_8	2.62 ± 0.01	403	2.0–3.2	2.65 ± 0.01	2.0–3.2	2.59 ± 0.01	2.1–3.2	<0.001
X^9	6.33 ± 0.03	352	4.6–7.6	6.46 ± 0.04	5.0–7.6	6.21 ± 0.04	4.6–7.6	<0.001
X^{10}	10.33 ± 0.02	402	9.2–11.7	10.45 ± 0.03	9.4–11.7	10.22 ± 0.03	9.2–11.3	<0.001
X^{11}	13.10 ± 0.06	382	10.1–16.0	13.51 ± 0.08	10.9–16.0	12.73 ± 0.07	10.1–15.7	<0.001
X^{12}	7.12 ± 0.03	402	5.2–8.5	7.35 ± 0.04	5.2–8.5	6.91 ± 0.04	5.3–7.9	<0.001
X^{13}	7.92 ± 0.03	401	6.4–9.5	8.08 ± 0.04	6.4–9.5	7.78 ± 0.04	6.4–9.2	<0.001
X^{14}	4.41 ± 0.02	323	3.1–5.2	4.53 ± 0.03	3.1–5.2	4.27 ± 0.03	3.4–5.2	<0.001
X^{15}	5.49 ± 0.02	400	4.6–6.6	5.54 ± 0.03	4.6–6.6	5.44 ± 0.02	4.6–6.4	<0.002
X^{16}	1.97 ± 0.01	402	1.6–2.3	2.00 ± 0.01	1.6–2.3	1.93 ± 0.01	1.7–2.3	<0.001
X^{17}	2.62 ± 0.01	400	1.8–3.0	2.66 ± 0.02	2.0–3.0	2.58 ± 0.02	1.8–3.0	<0.003

(X^{12}) with determination coefficient exceeding 70%, whereas from the total length of mandibula at *processus articularis*, excluding incisors (X_1), the height of mandibula at, and including, the first molar (X_3), the maximum height of mandibula, excluding coronoid process (X_4), and the length of *nasalia* (X^9) and *foramen incisivum* (X^{14}) with determination exceeding 60%. Best correlated with animal age were dental characters – the length of molar M_1 (X_8), incisor width across both upper incisors (X^{17}) and length of mandibular tooth row (X_7), all yielding determination over 50% (Table 2).

Table 2. Correlations of cranial characters with body weight, length and age (in days) of captive bred *M. arvalis*; all coefficients are significant at $p < 0.001$.

	Body weight	Body length	Age
X_1	0.751 (N = 404)	0.824 (N = 390)	0.659 (N = 404)
X_2	0.792 (N = 331)	0.864 (N = 318)	0.561 (N = 331)
X_3	0.723 (N = 402)	0.790 (N = 389)	0.668 (N = 402)
X_4	0.737 (N = 379)	0.807 (N = 365)	0.602 (N = 379)
X_5	0.634 (N = 247)	0.735 (N = 236)	0.594 (N = 247)
X_6	0.538 (N = 404)	0.562 (N = 389)	0.375 (N = 404)
X_7	0.609 (N = 402)	0.705 (N = 388)	0.709 (N = 402)
X_8	0.629 (N = 403)	0.743 (N = 389)	0.775 (N = 403)
X^9	0.665 (N = 352)	0.780 (N = 338)	0.670 (N = 352)
X^{10}	0.650 (N = 402)	0.678 (N = 388)	0.444 (N = 402)
X^{11}	0.799 (N = 382)	0.871 (N = 369)	0.691 (N = 382)
X^{12}	0.752 (N = 402)	0.859 (N = 388)	0.645 (N = 402)
X^{13}	0.668 (N = 401)	0.756 (N = 388)	0.566 (N = 401)
X^{14}	0.652 (N = 323)	0.773 (N = 312)	0.622 (N = 323)
X^{15}	0.648 (N = 400)	0.719 (N = 388)	0.679 (N = 400)
X^{16}	0.602 (N = 402)	0.672 (N = 389)	0.647 (N = 402)
X^{17}	0.624 (N = 400)	0.756 (N = 386)	0.743 (N = 400)

The best correlations of two cranial and two mandibular characters with body weight, as well as linear regressions, are shown in the graphical form (Fig. 2). Quite a steady growth of *M. arvalis* continued for about 10 months, with body weight reaching ca. 45 g and body length nearly 12 cm (Fig. 3). Ca. a 2 month long depression in the growth of body parameters was observed at 11–12 months of age, then the growth renewed again.
A similar growth pattern was characteristic of most of the skull characters involved in the study – they kept growing for about 10 months of age; then fluctuations did not allow to define a clear growth pattern. The only individual of 155 days was excluded from the sample. The most intensive growth of mandibular characters, such as the total length of mandibula at *processus articularis*, excluding incisors (Fig. 4 A), the length of mandibula, excluding incisors, the height of mandibula at, and including, the first molar, the maximum height of mandibula, excluding coronoid process, the coronoid height of mandibula and the length of mandibular tooth row, takes the first 70–80 days of age, then slows down, but still continues. The growth curves of the other mandibular characters – the length of mandibular diastema and molar M_1 – are more sloping.
The growth curves of maxillary characters were somewhat different. The period of initial growth was shorter (50–60 days) and of different intensity. The growth curves of the length of *nasalia*, zygomatic skull width, the length of cranial (upper) diastema and incisor width across both upper incisors were steeper (Fig. 4 B), whereas those of the length of molar M^1, the length of maxillary tooth row and the length of *foramen incisivum*, the breadth of braincase measured in the widest part (Fig. 4 C). The growth itself was long (about 12 months) and it lasted even longer with respect to the breadth of braincase or the length of maxillary tooth row.

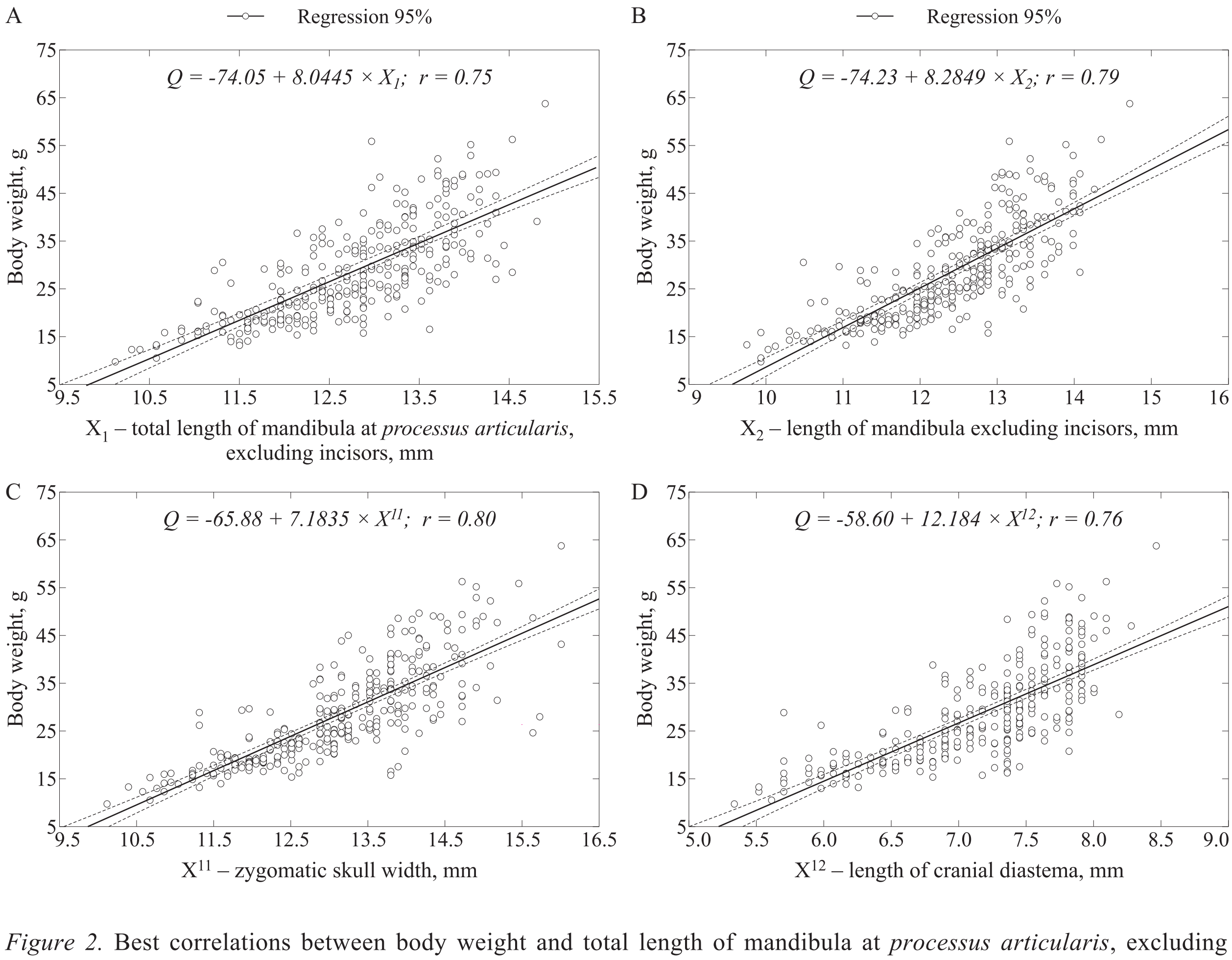

Figure 2. Best correlations between body weight and total length of mandibula at *processus articularis*, excluding incisors (A), length of mandibula, excluding incisors (B), zygomatic skull width (C) and length of cranial diastema (D) in captive bred *M. arvalis*.

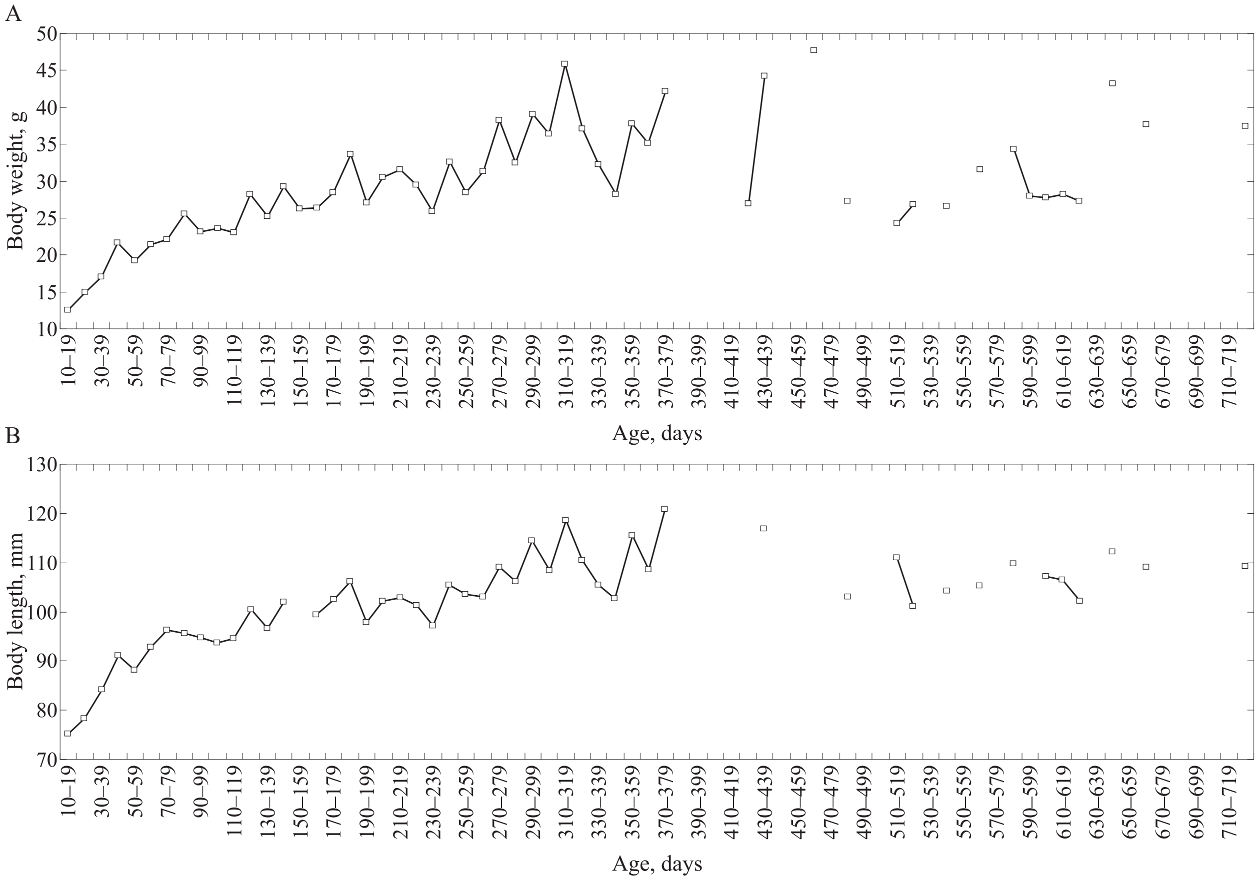

Figure 3. Dynamics of body weight (A) and body length (B) in captive bred *M. arvalis*.

Discussion

In *C. glareolus*, a very high variability in body weight (with an amplitude of up to 240% in adult captive bred animals and up to 200% in animals living in the wild) was found by Bashenina (1981). She also stated that the growth dynamics of body weight was the same both in captive and wild voles. Bashenina's data differ from other authors' reports (Zejda 1971; Balčiauskienė 2006, 2007).

From captive grown *M. agrestis*, it was concluded that a rapid increase in body length takes place up to the 9th month of life. Then the growth rate significantly decreases and remains stable at nearly the same level up to the 20th month of life (Gebczyńska 1964). The period of intensive growth in condylobasal length of the skull lasts up to the 9th month of life. The growth of the other skull measurements agrees with that of condylobasal length.

We used the skull collection from the experiment, of which only the first year results on the intensity of body weight gain have been published (Maldžiūnaitė 1976). From only 75 individuals of *M. arvalis*, it was concluded that the period of intensive growth was 90, 230 and 170 days long for individuals born in spring, summer and autumn, respectively. Sexual maturity was recorded for individuals with body weight about 35 g; then, according to the author, the growth stopped for 20–150 days (Maldžiūnaitė 1976).

From a larger sample of the same experiment (406 instead of 75 animals, with the maximum age of 724 instead of 364 days) we conclude that the growth period in captive *M. arvalis* is much longer – about 10 months. Moreover, we suppose that the only individual, which lived 155 days and was much smaller than the individuals of similar age, was included in analysis and distorted the growth curve. We excluded it from our dataset at the suggestion of Lidicker and MacLean (1969).

We do not present analysis of sex-dependent differences in body and skull growth as the sample across age groups and sexes was not equal. In literature, data on sex-dependent growth of *M. arvalis* are absent, but no sex-dependent differences were found in all skull measurements in wild as well as in captive *M. agrestis* (Gebczyńska 1964).

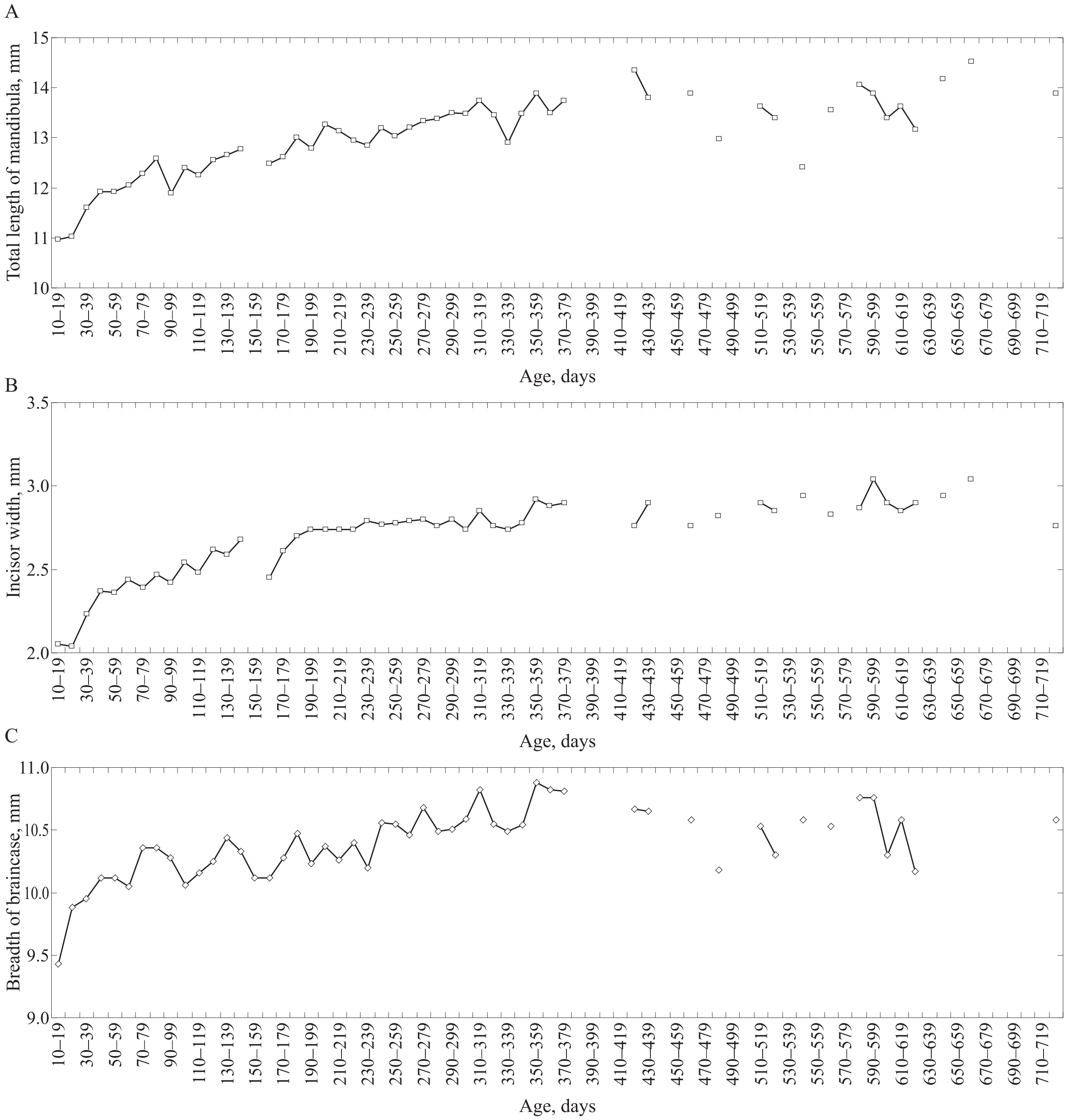

Figure 4. Dynamics of the total length of mandibula at *processus articularis*, excluding incisors (A), incisor width across both upper incisors (B) and the breadth of braincase measured in the widest part (C) in captive bred *M. arvalis*.

From the pooled male-female sample, we found that in captive bred *M. arvalis* older than one year variations in body parameters were irregular; individuals were smaller – their weight and length decreased (Fig. 3). The growth of the skull continued at least until 12–14 months of age (Fig. 4) and then also became irregular. Some dental characters, e.g. the length of molar M^1 (X^{16}) and incisor width across both upper incisors (X^{17}), seemed to be growing during the whole lifespan of species in captivity. However, life of wild voles is much shorter and individuals of such an old age (more than 1.5 years) should be very rare among free-living *M. arvalis* (Maldžiūnaitė 1976). On average, the lifespan of *M. arvalis* is only 9 months (Niethammer & Krapp 1982).

The same situation was in captive grown *C. glareolus*, where variations in body parameters and skull measurements in older individuals aged one year and over were quite uneven. Three growth patterns of skull characters in *C. glareolus* were found: (1) a rapid growth in the first decade of age followed by a very slow change or stabilisation (width of molar M_1 and length of maxillary tooth row), (2) long period of flat growth (length of mandibular tooth row and mandibular diastema) and (3) a long period of initial growth followed by the plateau phase (length of *nasalia* and *foramen incisivum*) (Balčiauskienė 2007). Such a manner of growth clearly differs from the growth of *M. arvalis*, where growth is shallow, steady and takes longer.

Though correlations between body weight and skull measurements in *M. arvalis* were quite strong (stronger than in *C. glareolus*, see Balčiauskienė 2007), we still doubt that in the case of captive specimens of *M. arvalis* body measurements can constitute the basis for age determination. In this we agree with Gebczyńska (1964). On the other hand, our data serve as methodological frame for searching the best predictors of body weight in wild voles from their skulls.

Conclusions

The growth of body weight and length of captive bred *M. arvalis* was quite steady and continued about 10 months, while that of most skull characters lasted up to 12–14 months and of some dental characters, i.e., the length of the first upper molar or incisor width, during the whole life of an individual.

Growth peculiarities were different from those of captive bred *C. glareolus*, in which three different growth patterns with a fast initial phase were determined. The cranial growth of *M. arvalis* was shallow, steady and took longer.

Correlations of mandibular and maxillary skull characters with body weight and especially body length were quite strong, determining up to 70% of variation in the latter parameters. Animal age was best correlated with dental parameters – the length of molar M_1 and incisor width across both upper incisors.

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Nelaisvėje augintų paprastųjų pelėnų (*Microtus arvalis*) kaukolės augimas

L. Balčiauskienė

Santrauka

Kraniometriniam paprastųjų pelėnų (*Microtus arvalis*) tyrimui panaudota 406 nelaisvėje užaugintų individų (12–724 dienų amžiaus) kaukolių kolekcija, kurią 1971–1974 metais surinko S. Maldžiūnaitė. Visiems 17 tirtų kaukolės matmenų buvo būdingas lytinis dimorfizmas (patinai didesni už pateles). Nustatyta, kad tolygus *M. arvalis* augimas truko apie 10 mėnesių – kol kūno svoris pasiekė apie 45 g, o kūno ilgis – apie 12 cm. Dauguma kaukolės matmenų didėjo iki 12–14 mėnesių amžiaus, o pirmasis viršutinis krūminis dantis ir viršutinių kandžių plotis – visą gyvenimą. Kaukolės matmenys su pelėnų kūno svoriu, o ypač su kūno ilgiu koreliavo pakankami stipriai (determinacijos koeficientas siekė iki 70%). Su amžiumi stipriausiai koreliavo dantų matmenys – krūminio M_1 danties ilgis bei viršutinių kandžių plotis.

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