ON PELVIS MORPHOMETRY OF THE ROOT VOLE *MICROTUS OECONOMUS* (PALLAS, 1776)

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Summary. The aim of this study was to assess pelvis morphometry in the root vole (*Microtus oeconomus*) and to test if pelvis measurements or indices differ depending on vole sex, age and, particularly in females, breeding history. After measuring the length of the ischium (P1), the greatest length of the pubis (P2) and the width of the pubis (P3) in 445 vole individuals strapped in 2004–2008 in Lithuania, it was found that the most significant differences in the pelvis between males and females of *M. oeconomus* were in adult animals. The main sex-related difference in the pelvis of these voles was the width of the pubis. In all age groups of males, index P1/P2 was higher compared to females, while P1/P3 and P2/P3 were statistically significantly lower ($P<0.05$). After puberty, the width of the pubis gained almost 3-fold increase in males, while in females it remained the same. According to parousity, the length of the ischium and the greatest pelvis length were growing in the following order: nulliparous < primigravid < primiparous < multiparous females (differences not significant). The width of the pubis and index P1/P2 did not change. Differences in indices P1/P3 and P2/P3 were statistically significant between nulliparous and primiparous females.

Key words: root vole, *Microtus oeconomus*, pelvis morphometry.

PELKINIO PELĖNO *MICROTUS OECONOMUS* (PALLAS, 1776) KLUBIKAULIŲ MORFOMETRIJA

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Santrauka. Tyrimo tikslas – morfometriškai įvertinti pelkinio pelėno (*Microtus oeconomus*) klubikaulius ir nustatyti, ar yra nuo lyties, amžiaus ir patelių dauginimosi rodiklių priklausančių skirtumų. Išmatavus 2004–2008 metais sugautų 445 individų sėdynkaulio ilgį (P1), didžiausią gaktikaulio ilgį (P2) ir gaktikaulio plotį ploniausiame taške (P3) nustatyta, kad labiausiai skiriasi suaugusių pelėnų patinų ir patelių klubikauliai. Patikimiausiai skyrėsi gaktikaulio plotis (patelių siauresnis). Nepriklausomai nuo amžiaus, patinų P1/P2 indeksas buvo didesnis, o P1/P3 ir P2/P3 indeksas – mažesnis už patelių. Lytiškai subrendusių patinų gaktikaulio plotis padidėjo beveik tris kartus, o patelių nesikeitė. P1 ir P2 matmenys didėjo: suaugusių nesidauginusių < pirmą kartą vaikingų < pirmavedžių < antravedžių (skirtumai nepatikimi); P3 ir P1/P2 nesikeitė. Suaugusių nesidauginusių ir pirmavedžių patelių P1/P3 ir P2/P3 indeksai skyrėsi patikimai.

Raktažodžiai: pelkinis pelėnas, *Microtus oeconomus*, dubens morfometrija.

Introduction. From cranial or mandible dimensions it is possible to estimate the preyed small mammal body mass and age classes (Dickman *et al*., 1991, Blem *et al*., 1993, Zalewski, 1996, Borowski *et al*., 2008). In the field of feeding ecology of owls, birds of prey and other mouse-eating animals, it is highly desirable to identify not only prey species, but also its sex and age (Balčiauskienė, 2006).

The most suitable bony remains for mammalian prey in this respect are pelvic bones. It is known that a mammalian pelvis is sexually dimorphic in both size and shape (Brown & Twigg, 1969, Berdnikovs *et al*., 2006). For example, in the domestic mouse (*Mus musculus domesticus*) the relation between body length and the size and shape of *os coxae* in males and parous and nulliparous females was found (Schutz *et al*., 2009). In another study, pelvic measurements and an index between pubis length and the length of the ischium were used to separate small mammal males from females in the prey of Magellanic horned owls (Trejo & Guthmann, 2003). However, in the most comprehensive study on the pelvis of small mammals, the root vole (*Microtus oeconomus*) was omitted (Brown & Twigg, 1969).

The aim of this study was to assess pelvis morphometry in *M. oeconomus* and to test if pelvis measurements or indices differ depending on vole sex, age and, particularly in females, breeding history.

Material and methods. Material was collected by snap-trapping in July-October of 2004 (39 individuals in Rusnė flooded meadows, 9 in Kėdainiai district, Lipliūnai environs), 2006 (195 individuals in Rusnė flooded meadows) and 2008 (106 individuals in Rusnė flooded meadows, 28 in Žagarė regional park, 28 in Kamanos strict nature reserve environs, 39 in Šalčininkai district).

Body mass (Q, g) and body length (L, mm) were recorded before dissection.

Upon dissection trapped *M. oeconomus* were sexed and divided into three age categories: juveniles, subadults and adults, based on their reproductive status (Myllymäki, 1977abc, Gliwicz, 1996, Balčiauskas & Juškaitis, 1997,

Prévot-Julliard *et al*., 1999). All overwintered and breeding individuals, i.e. males with scrotal testes and lactating or pregnant females, were defined as adults. All individuals that remained non-breeding during the year of birth (reproductive organs developed, but inactive – small nipples and closed vagina in females, abdominal testes in males) fell into the category of subadults. All individuals without sex attributes (reproductive organs still developing – threadlike vagina or hardly visible testes) were treated as juveniles. The presence and the status of *glandula thymus* (*gl. thymus* involuted in adults, *gl. thymus* disappearing in subadults, *gl. thymus* functioning in juveniles) as well as animal weight were taken into account.

We analysed the pelvis of 196 males (68 juveniles, 42 subadults and 79 adults) and 240 females (49, 19 and 146, respectively), i. e. 445 individuals in total (9 were not sexed, 33 were not aged). We also checked the breeding condition of adult females and described several groups: 25 individuals were referred to as nulliparous, with no breeding signs present, 40 as gravid with the first litter, irrespective of the length of gravidity, 67 as primiparous, with placental scars and/or *corpora lutea* present from one litter, and 14 as multiparous, with signs of at least two litters (in all cases, placental scars from the first litter and embryos from the second) present.

Pelvic measures were taken according to Dunmire (1955): P1 – length of the ischium (*os ischii*) from the rim of the acetabulum (*margo acetabuli*) to the ischial tuberosity (*tuber ischii*), P2 – greatest length of the pubis from the acetabular rim (*margo acetabuli*), and P3 – width of the pubis (*os pubis*) measured at the thinnest point of *ramus cranialis ossis pubis*. All measurements were taken to the nearest 0.1 mm under a binocular with the measuring scale. Only the right side of the pelvis was measured. We also calculated three indices: P1/P2, P1/P3 and P2/P3.

The standard statistical approach (mean and standard error, range, Student t-test for the comparison of means, correlation matrices) was used. Calculations were done with Statistica for Windows ver. 6.0 software (StatSoft, 2004).

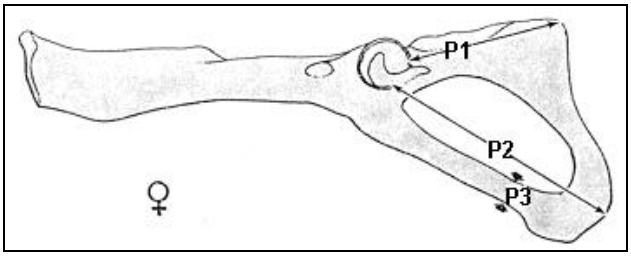


Fig. 1. **Pelvic measures used** (Dunmire, 1955, cf. Brown, Twigg, 1969)

Results. The pelvic measures and indices of *M. oeconomus* males and females of three age groups are presented in Table 1. In adult voles, differences between averages of all three pelvic measures and all three indices were statistically significant. In earlier age, only the greatest pelvis length from the acetabular rim (P2) was significantly bigger in females.

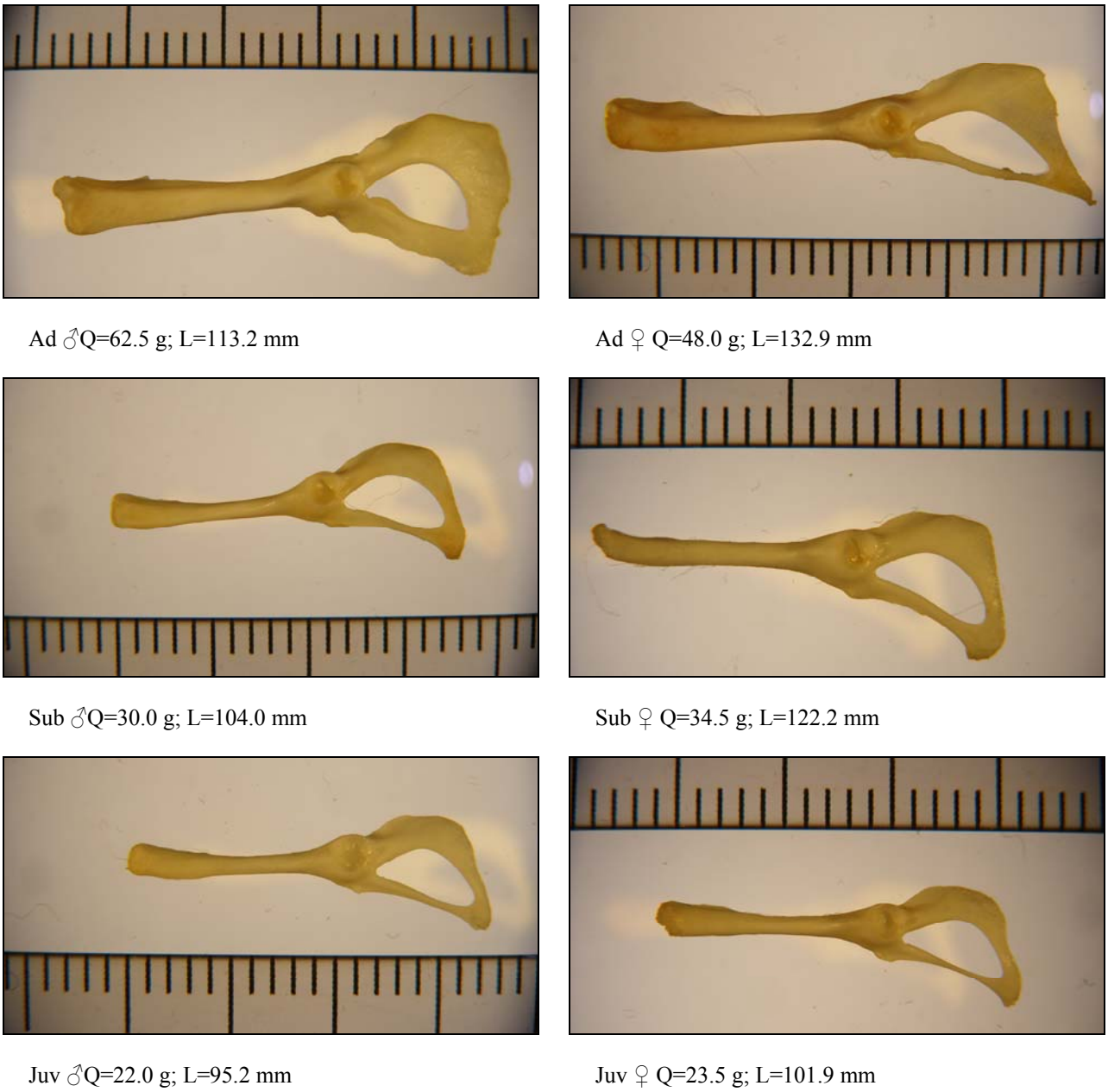
Table 1. **Pelvis measurements** (in mm) **and indices of *M. oeconomus* depending on sex and age** (avg±SE, min–max in parentheses)

	Adultus		Subadultus		Juveniles	
	Males	Females	Males	Females	Males	Females
P1	5.8±0.08 (3.6–7.0)	5.1±0.05*** (3.6–6.6)	4.0±0.07 (3.2–5.2)	4.1±0.12 (3.3–5.1)	3.7±0.05 (2.7–4.5)	3.6±0.05 (2.9–4.4)
P2	7.4±0.08 (5.8–9.9)	8.3±0.08*** (5.5–10.3)	6.0±0.10 (5.1–8.8)	6.5±0.18** (5.2–8.1)	5.5±0.06 (4.0–6.3)	5.8±0.10** (4.3–7.7)
P3	1.1±0.03 (0.3–1.7)	0.4±0.01*** (0.3–0.6)	0.4±0.02 (0.3–0.7)	0.4±0.02 (0.3–0.6)	0.5±0.01 (0.3–0.6)	0.3±0.01*** (0.2–0.6)
P1/P2	0.8±0.01 (0.4–0.9)	0.6±0.00*** (0.5–0.7)	0.7±0.01 (0.6–0.8)	0.6±0.01** (0.5–0.8)	0.7±0.01 (0.5–0.8)	0.6±0.01*** (0.5–0.9)
P1/P3	5.6±0.27 (2.1–16.3)	12.3±0.24*** (6.7–22.0)	9.6±0.40 (4.6–19.0)	11.0±0.67 (5.1–16.3)	8.4±0.28 (4.3–15.3)	12.2±0.55*** (5.2–21.5)
P2/P3	7.5±0.53 (4.6–27.7)	20.1±0.39*** (10.6–35.7)	14.5±0.69 (7.0–32.0)	17.6±0.95* (9.0–24.7)	12.5±0.42 (6.6–22.0)	19.8±0.86*** (7.8–33.5)

Note: male-female differences, based on Student's *t* are: * – $p<0.05$; ** – $p<0.01$; *** – $p<0.001$

With age, the length of the ischium (P1) gained more increase in males, but male-female differences were significant in adult voles only. The greatest pubis length from the acetabular rim (P2) was significantly bigger in females irrespective of age (juvenile, subadult, or adult). The biggest gain in pelvis length was characteristic of females after puberty (Table 1). On the contrary, the width of the pubis (P3) gained almost threefold increase in males after puberty, while in females it remained the same. This measure was significantly bigger in young males.

Index P1/P2 was significantly bigger in males of all age groups, while indices based on P3 (P1/P3 and P2/P3) were always bigger in females, and most of these differences were significant (Table 1). Indices clearly reflect changes in pelvis shape, which are most noticeable in adult voles (Fig. 2).



Ad ♂Q=62.5 g; L=113.2 mm

Ad ♀ Q=48.0 g; L=132.9 mm

Sub ♂Q=30.0 g; L=104.0 mm

Sub ♀ Q=34.5 g; L=122.2 mm

Juv ♂Q=22.0 g; L=95.2 mm

Juv ♀ Q=23.5 g; L=101.9 mm

Fig. 2. **Pelvis shape in males and females of *M. oeconomus* of three age groups**

In both males and females of *M. oeconomus* the length of the ischium (P1) and the greatest pubis length from the acetabular rim (P2) were highly correlated to both body mass and body length (Table 2). The width of the pubis (P3) was also correlated to both body mass and body length in males; correlation in females was weak, though significant. Thus, the width of the pubis is the main sex-related pelvis difference in *M. oeconomus*.

Table 2. **Correlation of pelvis measurements, body mass and body length in males and females of *M. oeconomus*** (all correlation coefficients significant at $p<0.001$)

	Males (N=177–184)			Females (N= 196–212)		
	P1	P2	P3	P1	P2	P3
Q	0.92	0.90	0.86	0.87	0.87	0.37
L	0.86	0.88	0.73	0.81	0.80	0.23

Table 3 presents the dynamics of pelvis growth in males and females. As a relative age dimension, we used body mass groups defined in decigrams. In males, steady growth was found in the length of the ischium and the

greatest pubis length from the acetabular rim, while pubis width exhibited a decline in the group of body mass of 20.0–29.9 g. In males, the length of the ischium of voles with body mass over 30 g was bigger than that in females. On the contrary, the greatest pubis length from the acetabular rim was bigger in females of all body mass groups. The width of the pubis was bigger in males despite the above-mentioned decline (which was also observed in females in the group of body mass of 20.0–29.9 g). Most of male-female pelvis measurement differences are highly significant in adult animals (body weight over 30 g); in young voles (body weight up to 20 g) pelvis measures are similar, with the exception of P3 (Table 3).

Table 3. **Pelvis measurements** (in mm) **of *M. oeconomus* depending on body mass** (g). Data presented as avg±SE (N)

Body mass	P1		P2		P3	
	Males	Females	Males	Females	Males	Females
0-9.9	2.94 (1)					
10.0–19.9	3.29± 0.10 (19)	3.45± 0.08 (15)	5.00± 0.13 (19)	5.37± 0.14 (11)	0.50± 0.02 (19) **	0.38± 0.03 (17)
20.0–29.9	3.94± 0.04 (84)	3.97± 0.05 (63)	5.82± 0.04 (84) ***	6.38± 0.09 (63)	0.46± 0.01 (85) ***	0.35± 0.01 (65)
30.0–39.9	4.91± 0.18 (15)	4.86± 0.06 (51)	6.72± 0.16 (15) ***	7.95± 0.11 (49)	0.83± 0.08 (16) ***	0.43± 0.01 (51)
40.0–49.9	5.73± 0.07 (25) ***	5.32± 0.06 (61)	7.31± 0.13 (23) ***	8.75± 0.09 (60)	1.05± 0.04 (25) ***	0.43± 0.01 (61)
50.0–59.9	6.08± 0.08 (32) ***	5.59± 0.09 (16)	7.64± 0.11 (30) ***	9.09± 0.11 (14)	1.18± 0.04 (33) ***	0.48± 0.02 (17)
60.0–69.9	6.16± 0.52 (6)		7.97± 0.08 (6)		1.52± 0.06 (6)	0.37 (1)

Note: male-female differences, based on Student's *t* are: * – $p<0.05$; ** – $p<0.01$; *** – $p<0.001$

It was found that average pelvis indices of males and females differed in most body mass groups, with the exception of index P1/P2 in voles with body mass up to 20 g, which did not differ. P1/P3 in males and females with body mass up to 20 g differed at $p<0.01$. All other shown differences in pelvis indices between males and females were highly significant ($p<0.001$, Fig. 3).

We also analysed data on pelvis measurements and indices in adult females depending on their reproductive status. The length of the ischium (P1) and the greatest pubis length from the acetabular rim (P2) were bigger depending on parousity in the following order: nulliparous < primigravid < primiparous < multiparous females, though no significant differences between groups were observed (Table 4). The width of the pubis (P3) did not change in adult females. So did index P1/P2, showing that both P1 and P2 changed in the same manner. The only significant differences were found in indices P1/P3 and P2/P3 between nulliparous and primiparous females (both $P<0.05$).

Discussion. The size and shape of pelvic bones in different animal taxa are of great importance in various fields: ecology (Trejo & Guthmann, 2003), morphology (West, 1990, Morris, 2008) and paleontology (Ratnikov, 2001).

For the small mammal species other than *M. oeconomus* it was shown that intraspecific variations in pelvic bones (*os coxae*) may be non-sex-dependent (related to muscular development and locomotor function), or sex-dependent (Brown & Twigg, 1969, Schilling, 2005). In the latter case, the authors highlight three sources of differences: (1) sexual dimorphism established in the early post-natal period, (2) male pubertal changes, and (3) female parturition changes. They point out that multiparous females may get extreme elongation of the pubis, accompanied by complete symphysis resorbtion (Brown & Twigg, 1969).

We found the elongation of the pelvis (P2) in *M. oeconomus*, too. This measure in females significantly exceeds that in males starting from juveniles at the body mass of ca. 20 g. The width of the pubis (P3) in males is significantly bigger starting from early juvenile age at the body mass of 10 g. We had no possibility to test the pelvis of voles of up to 10 g body mass.

In rats (*Rattus norvegicus*), changes in pelvis shapes of both sexes were found to be parallel until puberty. Before puberty, sexes became different with respect to pelvic shape earlier than the onset of size dimorphism. Before reproductive maturity, specific changes in female pelvic shape occur possibly due to the influence of estrogens (Berdnikovs *et al*., 2006).

In *M. oeconomus,* age-related changes in the shape of pelvis are significant and well reflected by pelvis indices. All differences of indices P1/P2, P1/P3 and P2/P3 between males and females were significant in all body weight groups, with one exception – index P1/P2 in voles with body mass up to 20 g did not differ. The significance of these differences point out to a possibility of animal sex and body weight estimation from pelvis bones.

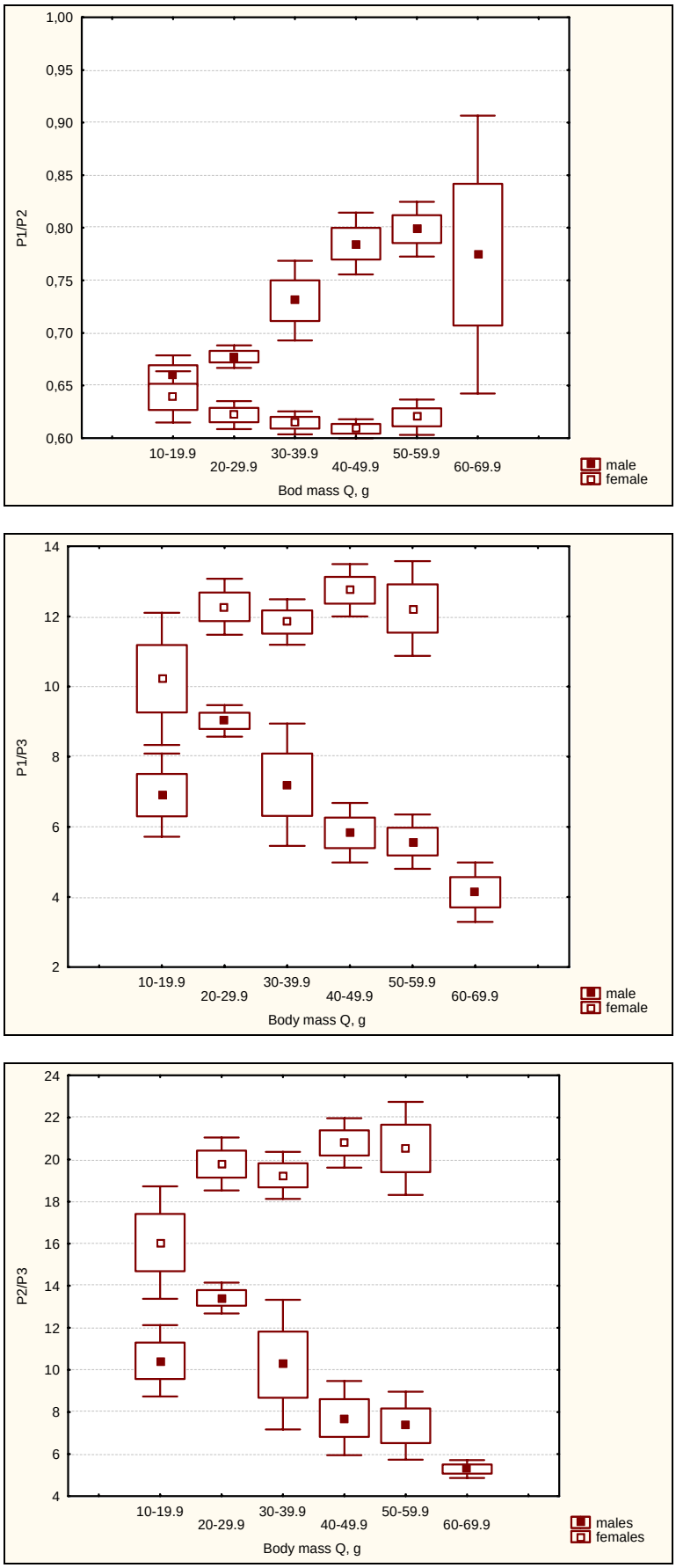


Fig. 3. **Pelvis indices of *M. oeconomus* depending on body mass. Data presented as mean, SE and 1.96×SE**

Table 4. **Pelvis measurements** (in mm) **and indices of adult *M. oeconomus* females depending on parousity** (avg±SE, min–max in parentheses)

	Nulliparous	Primigravid	Primiparous	Multiparous
P1	4.98±0.13 (3.59–6.07)	5.02±0.08 (4.23–6.07)	5.14±0.06 (4.05–6.62)	5.23±0.16 (3.77–6.16)
P2	8.19±0.23 (5.52–10.3)	8.22±0.15) (6.35–9.8)	8.41±0.10 (6.53–9.8)	8.46±0.30 (6.26–9.8)
P3	0.45±0.02 (0.28–0.55)	0.43±0.01 (0.28–0.64)	0.42±0.01 (0.28–0.64)	0.45±0.03 (0.28–0.64)
P1/P2	0.61±0.01 (0.54–0.72)	0.61±0.01 (0.55–0.67)	0.61±0.00 (0.51–0.71)	0.62±0.01 (0.58–0.69)
P1/P3	11.3±0.49 (7.33–19.0)	12.2±0.48 (7.83–22.0)	12.7±0.33 (6.71–20.0)	12.3±1.02 (8.29–21.3)
P2/P3	18.6±0.84 (12.2–31.7)	20.0±0.82 (12.7–33.3)	20.7±0.51 (10.6–31.7)	20.2±1.88 (13.7–35.7)

Relatively little is known regarding the effects of partuitive events on the magnitude of sexual pelvis dimorphism in small mammals (Schutz *et al*., 2009). In domestic mouse it was found that females had the largest *os coxae*, with parous females having the largest and males the smallest. *Os coxae* shape was also significantly different between groups and more divergent between parous females and males than between nulliparous females and males.

In adult females of *M. oeconomus* we found that P1 and P2 get longer depending on the reproductive status from nulliparous to multiparous, and P3 do not change, but the significance of these differences did not reach statistical reliability. The only significant differences were found in the indices P1/P3 and P2/P3 between nulliparous and primiparous females (both $p<0.05$).

Generalizing our findings, sexual and age related pelvis differences are characteristic of *M. oeconomus*, though at the moment we cannot present guides how to distinguish between sexes, as Trejo & Guthmann (2003) did for other small mammal species.

We suppose the future analysis scheme can be as follows: first, sex assessed from the shape of the pelvis (more elongated in females) and P3 (generally, less than 0.5 mm in females), and then body mass and age prognosticated according to P2 and indices. A very high correlation of pelvis measures and body mass shows a near-functional dependence. A possibility to find parousity in females of this species is limited.

Conclusions

1. The most significant differences in the pelvis between males and females of *M. oeconomus* were found in adult animals.

2. The main sex-related difference in the pelvis of *M. oeconomus* was the width of the pubis.

3. In all age groups of *M. oeconomus* males, index P1/P2 was higher compared to females, while P1/P3 and P2/P3 were significantly lower ($P<0.05$). After puberty, the width of the pubis gained almost 3-fold increase, while in females it remained the same.

4. Depending on parousity, the length of the ischium and the greatest pubis length were growing in the following order: nulliparous < primigravid < primiparous < multiparous females (differences not significant). The width of the pubis and index P1/P2 did not change. Differences in P1/P3 and P2/P3 were statistically significant between nulliparous and primiparous females.

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