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Indoor small mammals in Lithuania: some morphometrical, body condition, and reproductive characteristics

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In 2012–2014, seven species of small mammals were trapped indoor in East and Central Lithuania, *Mus musculus,* and *Apodemus flavicollis* dominating. Population sex and age structure, reproductive aspects, body condition, and morphometry of these species are analyzed in this paper. In the dominant species, the sex ratio did not differed from 1:1. Indoor breeding was analyzed in *M. musculus* (average litter size 5.9 ± 0.6, min. 2, max. 13 juveniles) and *A. flavicollis* (3.7 ± 0.7, 2–6 juveniles). No significant influence of the month on litter size was found in *M. musculus*, winter breeding was registered. Average body condition index of indoor-trapped *A. flavicollis* was $C = 3.17 \pm 0.11$, while that of *M. musculus* was $C = 3.39 \pm 0.05$. The body condition index of *M. musculus* did not depend on gender, animal age, or month of trapping, that is it was very stable. The role of commensal small mammals in the circulation of human pathogens is discussed.

2012–2014 metais rytinėje ir centrinėje Lietuvos dalyse pastatuose buvo sugauti 7 rūšių smulkieji žinduoliai. Dominavo naminės (*Mus musculus*) ir geltonkaklės (*Apodemus flavicollis*) pelės. Straipsnyje analizuojama šių rūšių populiacijų amžiaus ir lyčių proporcijos, veisimasis, įmitimas, kūno, kaukolės ir klubikaulių matmenys. Abiejų rūšių lyčių proporcija statistiškai nesiskyrė nuo 1:1. Pastatuose veisėsi *M. musculus* (vidutinis vados dydis 5.9 ± 0.6; min. 2, max. 13 jauniklių) ir *A. flavicollis* (3.7 ± 0.7; 2–6 jaunikliai). *M. musculus* veisėsi ir žiemą, sezonas vados dydžiui įtakos neturėjo. Vidutinis pastatuose sugautų *A. flavicollis* įmitimo indeksas buvo $C = 3.17 \pm 0.11$, *M. musculus* – $C = 3.39 \pm 0.05$. *M. musculus* įmitimo indeksas buvo stabilus, nepriklausė nei nuo lyties, nei nuo amžiaus, nei nuo sezono. Straipsnio aptarime analizuojama pastatuose gyvenančių smulkiųjų žinduolių reikšmė platinant žmogui pavojingus patogenus.

Keywords: indoor small mammals; body condition; reproduction; age and sex morphometry

Introduction

Some authors propose that our knowledge of urban rodent ecology is rather low (see Garba et al. 2014). Most studies have concentrated on natural or seminatural habitats and even studies in urban areas have focused mostly on the vegetated landscapes of parks and gardens, which have similar small mammal communities to agricultural habitats (Pocock, Searle, and White 2004). However, studies of the ecology of commensal rodents in relation to human habitation have focused mainly on urban habitats (Langton, Cowan, and Meyer 2001). Some authors pose that there is scant information regarding the community composition and habitat distribution of small mammals in dairy and pig production systems (Rosario, Soledad, and Regino 2015). Tattersall (1999) states that wood mice (*Apodemus sylvaticus*) and house mice (*Mus domesticus*) are two of the most common and most intensively studied British mammals, but still little is known for the ecology of either species in and around farm buildings.

In Lithuania, there is only one publication so far about the species composition of small mammals trapped inside farmstead buildings (Atkočaitis 2003). A short communication by the same author (Atkočaitis 2005) summarizes an additional data-set on two-year trapping results from the same place.

Existing publications on the indoor (commensal) populations of small mammals detail mostly house mice (*Mus musculus* and *M. domesticus*) and rats (*Rattus rattus* and *R. norvegicus*) from the USA (Advani 1995), Argentina (Castillo et al. 2003; Gomez et al. 2008; León et al. 2013; Cavia et al. 2015; Rosario, Soledad, and Regino 2015), Mexico (Panti-Maya et al. 2012), Brazil (Masi et al. 2010), Niger (Garba et al. 2014), Pakistan (Mushtaq et al. 2014), UK (Tattersall 1999; Pocock, Searle, and White 2004) and Denmark (Carlsen 1983).

The subjects of research were not only infestation levels (Advani 1995), population control or extermination (Rosario, Soledad, and Regino 2015) and parasites or viral pathogens (Fischer et al. 2000; Castillo et al. 2003; Garba et al. 2014; Fang et al. 2015), but also physiological and ecological perspectives of the reproductive biology (Bronson 1979), comparison of house mice body-weight structures and reproductive traits of the populations in the different habitats (Rowe, Swinney, and Quy 1983; Vadell, Gómez Villafañe, and Cavia 2014), rates of dispersal (Pocock, Hauffe, and Searle 2005), abilities and values of house mice (Witmer and

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Jojola 2006), population size, mortality, a flexible life-history strategy (Pocock, Searle, and White 2004), population growth, population turnover, breeding condition, life expectancy, movements (Rowe, Quy, and Swinney 1987; Gomez et al. 2008), densities, intensive reproduction, age and sexual activity in urban assemblages (Garba et al. 2014), and habitat use and demography (León et al. 2013).

In the research of yellow-necked mice (*Apodemus flavicollis*) and bank voles (*Myodes glareolus*), which are less common indoors, the main accent is put on the maintaining and circulation of a wide range of human pathogens as vectors of some diseases (Fischer et al. 2000; Johansson et al. 2008; Pettersson et al. 2008; Khalil et al. 2014).

We aimed to describe the composition of indoor small mammal species, as well as population and individual parameters (sex and age structure, reproductive aspects, body condition, and morphometry) of the most numerous species, with the intent to contribute to the understanding of small mammal commensalism and management strategies in the middle latitudes.

Materials and methods

Our sample consists of 145 individuals (5 rodent and 2 insectivore species) trapped in buildings, cellars and storehouses located in villages about 10 km from Vilnius (4° 48′ 40.86″, 25° 9′ 54.66″; 54° 34′ 30.99″, 25° 9′ 59.92″; 54° 34′ 41.88″, 25° 5′ 47.51″) and in Pašiliai homestead (125 km from Vilnius, Central Lithuania, 55° 33′ 27.92″, 24° 13′ 4.16″).

Commensal small mammals were trapped indoor in 2012–2014: shrews were trapped in winter and spring (February–April), while rodents in autumn, winter, and spring (September–April). Reproduction data were obtained from 26 animals.

Trapped mice, voles, and shrews were identified to species, then weighed to an accuracy of 0.1 g (body weight, *Q*). Body length (*L*), tail length (*C*), hind foot length (*P*), and ear length (*A*) were measured using sliding calipers (to an accuracy of 0.1 mm). Animal age and gender were recorded under dissection, and were judged based on the status of sex organs and atrophy of the thymus, as this decreases with the animal's age (Balčiauskas, Balčiauskienė, and Janonytė 2012a). We used three age categories: adults (females with visible placental scars and corpora lutea, or pregnant or lactating, males with scrotal testes, and full cauda epididymis), subadults (females with inactive reproductive organs, small nipples, and closed vagina, males with developed abdominal testes) and juveniles (females with thread-like vagina, males with hardly visible testes), according to Prévot-Julliard et al. (1999). The skulls were cleaned by *Dermestes* beetle larvae. Craniometric measurements were taken under a binocular microscope with a micrometric eyepiece or digital caliper, both graduated to 0.1 mm. Skull characters *X*1–*X*17 (Figure 1) were measured following Lidicker and MacLean (1969) and Niethammer and Krapp (1982), and *X*18–*X*23 following Kryštufek and Vohralik (2005). Only the characters of the right side of the skull were used. Pelvic measurements were taken according to Brown and Twigg (1969).

Body condition was evaluated as an index based on the ratio of body weight and body length (Drouhot et al. 2014; Balčiauskas, Balčiauskienė, and Jasiulionis 2015). Such indexes are used as indicators of animal health (Peig and Green 2009). We used the body condition index:

$C = (Q/L^3) \times 10^5$ (Moors 1985), where *Q* is body weight in g, and *L* is the body length in mm.

We used basic statistics such as mean and standard error (SE) for body and cranial measurements, and Student's *t* and ANOVA for comparisons (StatSoft. Inc 2010). The age and sex proportions of *M. musculus* and *A. flavicollis* were compared using χ^2 statistics. All calculations were done in Statistica ver. 6.0.

Results

Species composition

Seven species of small mammals were trapped indoor in 2012–2014. The most numerous were *M. musculus* (107 individuals) and *A. flavicollis* (22 individuals). Other species were less common: common shrew (*Sorex araneus*) – 8 individuals, brown rat (*Rattus norvegicus*) – 3 individuals, striped field mouse (*Apodemus agrarius*) and *M. glareolus* – 2 individuals each, pygmy shrew (*Sorex minutus*) – a single specimen. Species diversity was low, Shannon's $H = 1.30$, domination quite high, Simpson's $c = 0.57$.

Sex and age structure of most numerous species

The sex ratio in the two dominant indoor small mammal species, *M. musculus* and *A. flavicollis*, did not differ from 1:1 ($\chi^2 = 1.20$, df = 1, $p = 0.27$ and $\chi^2 = 0.83$, $p = 0.37$, respectively, Table 1). Significant differences in sex ratio were also not observed in other small mammal species.

The prevalence of juveniles in the indoor-trapped *M. musculus* was not significant ($\chi^2 = 3.20$, df = 2, $p = 0.20$), while in *A. flavicollis* adult individuals prevailed ($\chi^2 = 9.70$, df = 2, $p = 0.008$). Among *A. agrarius* and *M. glareolus*, adult animals were not trapped.

Reproductive aspects

Indoor breeding was registered in *M. musculus* and *A. flavicollis*. Based on placental scar count, the litter size of indoor-trapped *A. flavicollis* was 3.7 ± 0.7 (2–6) juveniles. However, the small number trapped young individuals of this species indicate that indoor breeding in *A. flavicollis* is not frequent and that juveniles are not entering buildings.

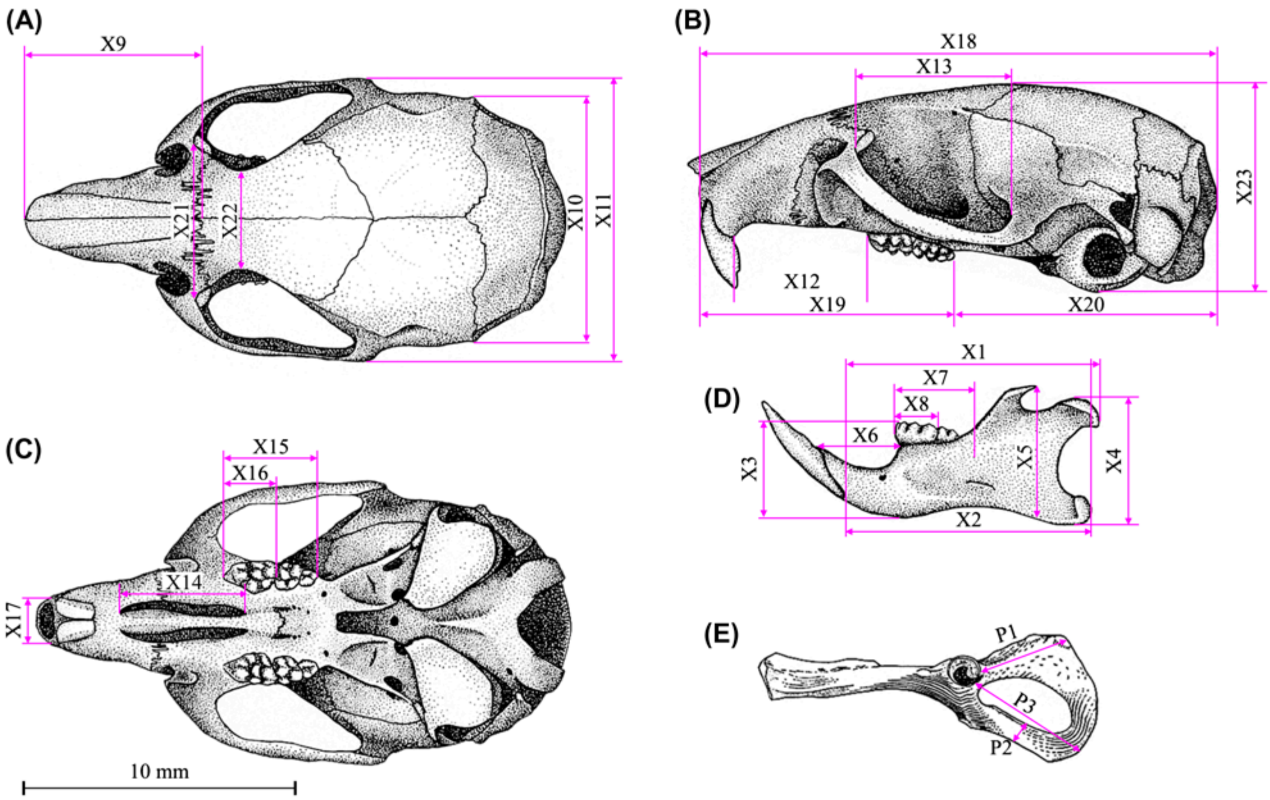

Figure 1. Skull and pelvic measurements taken: (A) – dorsal view, (B) – lateral view, (C) – ventral view, (D) – mandible, and (E) – pelvis.
Notes: *X*1 – total length of mandibula at processus articularis, excluding incisors; *X*2 – length of mandibula excluding incisors; *X*3 – height of mandibula at, and including, 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 lower molar M1; *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 toothrow; *X*16 – length of molar M1; *X*17 – incisor width across both upper incisors; *X*18 – condylobasal length; *X*19 – length of rostrum; *X*20 – length of the braincase; *X*21 – interorbital constriction; *X*22 – postorbital constriction; *X*23 – height of the braincase; *P*1 – length of the ischium (*os ischii*); *P*2 – *X*25 – greatest length of the pubis from the acetabular rim (*margo acetabuli*); *P*3 – width of the pubis (*os pubis*) measured at the thinnest point of *ramus cranialis ossis pubis*.
Source: Modified according Prūsaitė (1988) and Brown and Twigg (1969).

Table 1. Age and sex structure of house mice (*M. musculus*) and yellow-necked mice (*A. flavicollis*) trapped indoors in Lithuania, 2012–2014.

Species	Males	Females	Adults	Subadults	Juveniles
M. musculus	62	45	35	28	44
A. flavicollis	8	14	15	4	3

The average litter size in indoor-trapped *M. musculus* was 5.9 ± 0.6 (2–13) juveniles. The average number of registered embryo was 6.8 ± 0.7 (4–9), while the number of placental scars was 6.7 ± 1.1 (2–13), and that of corpora lutea – 7.0 ± 1.1 (4–10). Winter breeding was registered through December–April (Figure 2), and there was no significant influence of the month on litter size (ANOVA, $F_{4,8} = 3.04$, $p = 0.084$).

Breeding disturbances, expressed as non-implantation (the difference between the number of *corpora lutea* and

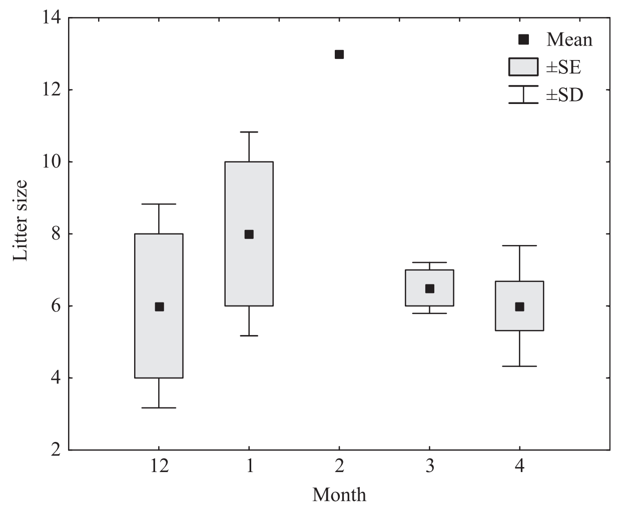

Figure 2. Litter size changes in the winter months of indoor-trapped *Mus musculus*.

number of embryo or placental scars), were registered in *M. musculus*. In January, a female was recorded with two non-implanted embryos and eight resorted embryos (in total, the number of *corpora lutea* was 10 and the number of embryo 8). One case of non-implantation and another case of resorption were also registered in April.

Morphometrics: body, skull, and pelvis

Statistics on body, skull, and pelvis measurements of *M. musculus* (Table 2) and *A. flavicollis* (Table 3) are presented by age groups.

In *M. musculus*, body size (weight and length) highly overlaps between age groups (Table 2), despite averages differing significantly (ANOVA, body weight $F_{2,103} = 52.53$, $p < 0.0001$, body length $F_{2,100} = 38.23$, $p < 0.0001$). Differences in tail length, length of the hind foot, and ear length are also highly significant between age groups ($p < 0.002$–0.0001).

Out of 23 skull measurements, significant differences between *M. musculus* age groups were not found in the length of mandibular tooth row, *X*7 or the length of lower molar M1, *X*8 (ANOVA, $F_{2,90} = 0.45$, $p = 0.62$ and $F_{2,90} = 0.04$, $p = 0.96$, respectively). Differences in all other skull measures between age groups were significant ($p < 0.04$–0.0001).

The combined influence of individual age and gender in *M. musculus* was significant on all pelvis measures: *P*1 ($F_{3,35} = 12.91$, $p < 0.0001$) explained 48.5% of size variance, *P*2 ($F_{3,35} = 16.09$, $p < 0.0001$) explained 58.0% of size variance, and *P*3 ($F_{3,35} = 14.39$, $p < 0.0001$) explained 51.4% of size variance. The influence of age (Wilks $\lambda = 0.29$, $p < 0.0001$, Table 3) was stronger than that of gender (Wilks $\lambda = 0.68$, $p < 0.005$).

In contrast, there were significant differences in body size in *A. flavicollis*. Body weight did not overlap between age groups (ANOVA, $F_{2,19} = 16.36$, $p < 0.0001$, Table 3). As for body length ($F_{2,19} = 22.09$, $p < 0.0001$) and tail length ($F_{2,7} = 5.53$, $p < 0.05$), despite significant differences in average, overlap was found. Accordingly, some cranial measures (*X*1–*X*6, *X*9, *X*11, *X*12, *X*17–*X*19, *X*23) had significant differences between age groups ($p < 0.02$–0.001), while others (*X*7, *X*8, *X*10, *X*13–*X*16, *X*20–*X*22) highly overlapped and did not differ. Differences in measurements of pelvic characters were significant in *P*1 and *P*2 ($p < 0.001$), and near significant in *P*3 ($p = 0.054$).

Table 2. Morphometric data of indoor *M. musculus* adults, subadults, and juveniles, trapped in 2012–2014.

	Adults (*n* = 16–35)		Subadults (*n* = 9–27)		Juveniles (*n* = 13–44)	
Character[a]	Avg. ± SE	Min–Max	Avg. ± SE	Min–Max	Avg. ± SE	Min–Max
Q	18.4 ± 0.70	12.1–30.3	15.2 ± 0.39	11.0–20.5	11.1 ± 0.43	5.5–16.5
L	81.1 ± 1.07	70.6–97.2	77.6 ± 0.78	70.6–88.0	68.8 ± 1.16	51.8–82.0
C	66.8 ± 1.09	51.3–83.5	65.1 ± 0.97	58.2–83.0	58.9 ± 0.91	44.1–72.1
P	16.3 ± 0.09	14.9–17.3	16.0 ± 0.12	14.7–17.1	15.8 ± 0.12	13.7–17.2
A	11.3 ± 0.16	8.9–13.6	10.9 ± 0.17	8.9–13.0	10.0 ± 0.18	7.0–12.0
*X*1	9.4 ± 0.05	8.8–10.1	9.0 ± 0.05	8.5–9.5	8.6 ± 0.08	7.1–9.5
*X*2	9.2 ± 0.06	8.6–9.9	8.8 ± 0.07	8.2–9.3	8.3 ± 0.09	6.7–9.4
*X*3	3.2 ± 0.03	2.9–3.6	3.1 ± 0.03	2.9–3.3	2.9 ± 0.03	2.5–3.3
*X*4	5.1 ± 0.04	4.7–5.6	4.8 ± 0.05	4.3–5.2	4.6 ± 0.05	3.8–5.2
*X*5	5.3 ± 0.04	4.8–5.8	5.0 ± 0.04	4.7–5.2	4.7 ± 0.05	4.1–5.4
*X*6	2.9 ± 0.02	2.7–3.0	2.8 ± 0.02	2.6–2.9	2.7 ± 0.02	2.3–2.9
*X*7	2.5 ± 0.02	2.4–2.9	2.5 ± 0.01	2.4–2.7	2.5 ± 0.02	2.3–2.7
*X*8	1.0 ± 0.01	0.9–1.2	1.0 ± 0.01	1.0–1.1	1.0 ± 0.01	0.9–1.2
*X*9	7.0 ± 0.07	6.3–7.7	6.7 ± 0.08	5.8–7.3	6.4 ± 0.07	5.2–7.3
*X*10	9.4 ± 0.05	8.9–9.8	9.3 ± 0.07	8.7–9.8	9.1 ± 0.05	8.6–9.6
*X*11	10.6 ± 0.09	9.7–11.7	10.1 ± 0.10	9.4–11.1	9.6 ± 0.13	8.1–10.8
*X*12	4.9 ± 0.05	4.5–5.4	4.7 ± 0.04	4.4–5.2	4.4 ± 0.06	3.7–5.1
*X*13	5.9 ± 0.05	5.4–6.3	5.5 ± 0.05	5.1–5.9	5.4 ± 0.07	4.4–6.1
*X*14	4.6 ± 0.04	4.2–5.1	4.4 ± 0.04	4.0–4.7	4.2 ± 0.05	3.7–4.9
*X*15	3.5 ± 0.02	3.3–3.9	3.4 ± 0.02	3.3–3.6	3.3 ± 0.02	3.0–3.6
*X*16	1.1 ± 0.01	1.0–1.4	1.1 ± 0.01	1.0–1.2	1.1 ± 0.01	1.0–1.2
*X*17	1.5 ± 0.01	1.4–1.7	1.4 ± 0.02	1.3–1.6	1.3 ± 0.02	1.0–1.5
*X*18	21.4 ± 0.12	20.6–22.3	20.0 ± 0.77	10.9–21.5	20.1 ± 0.20	17.9–21.6
*X*19	9.9 ± 0.07	9.3–10.5	9.5 ± 0.05	9.1–9.9	9.1 ± 0.10	7.8–10.2
*X*20	10.2 ± 0.07	9.7–10.7	10.1 ± 0.08	9.6–10.4	9.6 ± 0.10	8.6–10.4
*X*21	3.5 ± 0.03	3.2–3.9	3.4 ± 0.04	2.9–3.8	3.3 ± 0.03	3.1–3.7
*X*22	3.3 ± 0.01	3.1–3.5	3.3 ± 0.02	3.1–3.5	3.3 ± 0.02	3.0–3.6
*X*23	7.4 ± 0.07	7.0–7.7	7.4 ± 0.06	6.9–7.7	7.2 ± 0.05	6.8–7.6
*P*1	4.1 ± 0.09	3.3–5.0	3.6 ± 0.09	2.9–4.0	3.3 ± 0.12	2.2–4.4
*P*2	6.1 ± 0.17	5.1–7.5	5.6 ± 0.13	5.2–6.5	4.8 ± 0.18	3.9–6.0
*P*3	0.7 ± 0.03	0.5–0.9	0.7 ± 0.02	0.6–0.8	0.5 ± 0.01	0.5–0.6

Note: *Q* – g, all other characters – in mm.
[a]Abbreviations – as in Materials and methods.

Table 3. Morphometric data of indoor *A. flavicollis* adults, subadults, and juveniles, trapped in 2012–2014.

	Adults (n = 4–15)		Subadults (n = 3–4)		Juveniles (n = 1–3)	
Character[a]	Avg. ± SE	Min–Max	Avg. ± SE	Min–Max	Avg. ± SE	Min–Max
Q	41.4 ± 1.67	33.4–53.8	30.9 ± 0.52	30.2–32.4	21.4 ± 3.88	17.0–29.1
L	109.1 ± 1.54	98.2–117.0	103.5 ± 0.68	102.5–105.5	83.9 ± 5.56	77.9–95.0
C	115.9 ± 2.93	109.2–123.5	102.9 ± 2.56	97.8–105.8	100.4 ± 5.35	94.9–111.1
P	24.4 ± 0.18	24.0–24.8	24.2 ± 0.57	23.1–25.0	23.1 ± 0.58	22.2–24.2
A	16.4 ± 0.86	14.0–18.0	14.8 ± 0.90	13.0–15.9	14.0 ± 0.81	12.6–15.4
*X*1	13.6 ± 0.10	13.0–14.2	13.1 ± 0.32	12.5–13.6	12.2 ± 0.23	12.0–12.7
*X*2	12.7 ± 0.12	12.1–13.9	11.8 ± 0.32	10.9–12.3	11.1 ± 0.30	10.7–11.7
*X*3	4.8 ± 0.06	4.3–5.2	4.4 ± 0.12	4.2–4.8	4.0 ± 0.23	3.8–4.5
*X*4	6.9 ± 0.08	6.3–7.5	6.4 ± 0.23	6.2–6.9	5.8 ± 0.41	5.2–6.6
*X*5	7.2 ± 0.10	6.7–8.1	7.1 ± 0.28	6.8–7.6	6.2 ± 0.38	5.8–7.0
*X*6	4.0 ± 0.04	3.9–4.2	3.9 ± 0.07	3.8–4.0	3.7 ± 0.08	3.6–3.9
*X*7	3.6 ± 0.03	3.4–3.8	3.6 ± 0.07	3.4–3.7	3.6 ± 0.05	3.5–3.7
*X*8	1.4 ± 0.02	1.2–1.5	1.4 ± 0.06	1.2–1.5	1.3 ± 0.03	1.3–1.4
*X*9	9.6 ± 0.12	8.6–10.4	8.9 ± 0.33	8.3–9.8	8.5 ± 0.17	8.2–8.7
*X*10	11.9 ± 0.11	11.2–12.5	12.0 ± 0.22	11.7–12.4	12.1	12.1–12.1
*X*11	14.0 ± 0.15	13.1–14.6	14.0 ± 0.11	13.9–14.3	12.0 ± 1.00	10.9–14.0
*X*12	7.5 ± 0.09	7.1–8.3	7.1 ± 0.12	6.9–7.3	6.5 ± 0.32	6.0–7.1
*X*13	8.7 ± 0.09	8.4–9.3	8.4 ± 0.12	8.3–8.6	8.0	8.0–8.0
*X*14	5.4 ± 0.07	4.8–5.7	5.2 ± 0.08	5.1–5.3	5.0 ± 0.15	4.7–5.2
*X*15	4.4 ± 0.05	4.1–4.8	4.3 ± 0.15	3.9–4.6	4.1 ± 0.05	4.0–4.2
*X*16	1.5 ± 0.03	1.3–1.7	1.4 ± 0.08	1.2–1.6	1.4 ± 0.06	1.3–1.5
*X*17	2.3 ± 0.03	2.1–2.6	2.1 ± 0.10	1.9–2.4	1.8 ± 0.09	1.7–2.0
*X*18	29.7 ± 0.26	28.2–31.2	28.0 ± 0.53	27.0–28.8	27.9	27.9–27.9
*X*19	14.7 ± 0.13	14.0–15.5	13.8 ± 0.27	13.2–14.2	13.1 ± 0.53	12.1–14.0
*X*20	12.6 ± 0.15	12.0–13.6	12.2 ± 0.35	11.5–12.6	12.4	12.4–12.4
*X*21	4.6 ± 0.06	4.2–5.0	4.4 ± 0.08	4.2–4.5	4.3 ± 0.09	4.2–4.4
*X*22	4.1 ± 0.03	3.9–4.2	4.2 ± 0.09	4.0–4.3	4.0 ± 0.23	3.8–4.2
*X*23	10.3 ± 0.10	9.9–10.8	9.9 ± 0.17	9.7–10.2	10.1	10.1–10.1
*P*1	5.9 ± 0.10	5.2–6.7	5.1 ± 0.11	4.9–5.4	4.3 ± 0.97	3.3–5.2
*P*2	7.8 ± 0.13	6.8–8.4	7.1 ± 0.12	7.0–7.4	5.8 ± 1.01	4.8–6.8
*P*3	1.0 ± 0.07	0.6–1.3	0.8 ± 0.04	0.6–0.8	0.7 ± 0.03	0.6–0.7

Note: *Q* – g, all other characters – in mm.
[a]Abbreviations – as in Materials and methods.

Body condition dynamics of M. musculus and A. flavicollis

The average body condition index of indoor-trapped *A. flavicollis* was 3.17 ± 0.11, with no significant differences between months (ANOVA, $F_{6,15} = 1.62$, $p = 0.21$). The best body condition was observed in March–May, and the worst in December–February (Figure 3(A)).

In indoor-trapped *M. musculus*, the average body condition index was 3.39 ± 0.05, thus, insignificantly higher than in *A. flavicollis* ($t = 1.81$, df = 123, $p = 0.07$). The body condition index of *M. musculus* did not depend on gender (ANOVA, $F_{1,127} = 0.37$, $p = 0.54$), animal age ($F_{2,126} = 2.20$, $p = 0.11$), or month of trapping ($F_{8,120} = 1.61$, $p = 0.13$), that is it was very stable (Figure 3(B)). Simultaneously, these three factors (gender, age, and month) explained just 3.6% of the body condition index variance (main effects ANOVA, $F_{9,93} = 1.42$, $p = 0.19$, $r^2 = 0.036$).

Discussion

Small mammals indoors

Small mammals that live in buildings, livestock farms, and living houses permanently (all year round) are referred as eusynanthropic, including such species as black rat (*Rattus rattus*) and brown rats (*R. norvegicus*) rats and *M. musculus*. Even if emigrating to fields for summer, *M. musculus* migrate back to buildings after other rodent numbers increase from August to November (Carlsen 1983). Species which use human-related shelter temporarily, mostly in the cold period, are referred as hemisynanthropic. These may be *A. sylvaticus* and *A. flavicollis* mice (Fischer et al. 2000). At high abundances and in warm, rainy winters, *M. glareolus* is also reported to use buildings (Johansson et al. 2008; Pettersson et al. 2008; Khalil et al. 2014). In Poland, *A. agrarius* was reported to colonize urban environment (Luniak 2004) and also settle in houses in China along with *M. musculus* and rats (Zhu et al. 1986).

Representatives of all these species were also trapped indoors in Lithuania; however, data on commensal and hemisynantropic small mammals in Lithuania are very scarce. In south-west Lithuania during six autumn–winter seasons in farmstead buildings situated in nearest proximity to forest, 827 small mammals (10 species) were trapped. *M. musculus* comprised 32.4%, *A. flavicollis* 28.1%, and *A. agrarius* 16.2%. This latter species was the most numerous only in 2004–2005, comprising

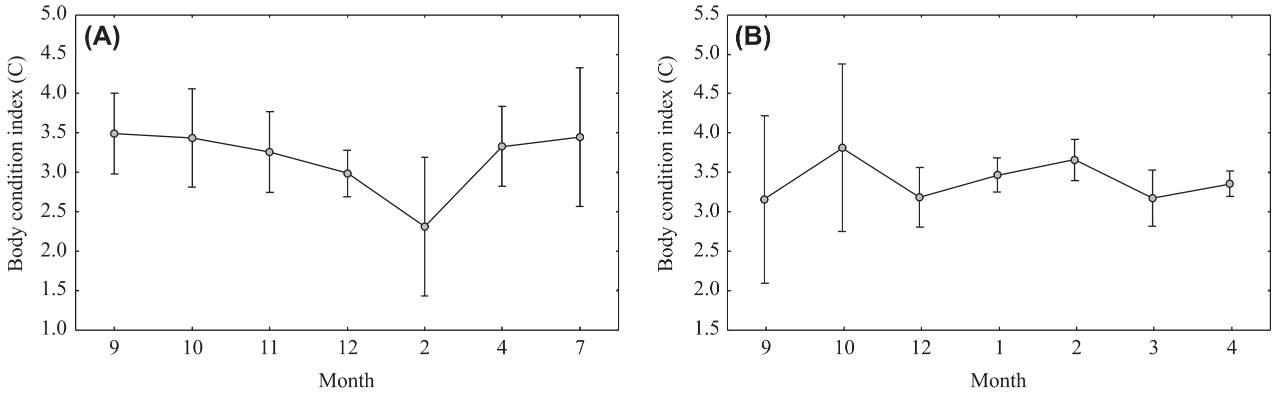

Figure 3. Monthly dynamics of body condition in indoor-trapped *A. flavicollis* (A) and *M. musculus* (B). Vertical bars – 0.95 CI.

29.1% (Atkočaitis 2003, 2005). Such fluctuation of abundance is in accordance with wild populations of *A. agrarius*, as we observed a one-year long abundance of numbers during a 10-year period in East Lithuania (Balciauskas and Angelstam 1993). In specific habitats, such as flooded meadows, *A. agrarius* may maintain high abundance for longer periods (Balčiauskas, Balčiauskienė, and Janonytė 2012b).

Life in commensal habitats (in and abound dwellings, farms, buildings, and stores) requires small mammals to have a specific lifestyle. Despite environmental conditions being stable and food supply abundant, both these features may be instantly changed by humans, thus commensal habitats have their benefits and costs (Pocock, Searle, and White 2004). *M. musculus* mitigate changes by being able to feed on "virtually anything" and using "almost anything" for shelter and bedding (Witmer and Jojola 2006).

Reproduction aspects

Reproduction of *M. musculus* is not related to seasonality (induced by photoperiod), they may breed in complete darkness (Bronson 1979). In many situations, mice breed continuously, with 6–8 litters per year with 4–7 young; these young individuals mature within 3 weeks (Rowe, Swinney, and Quy 1983; Witmer and Jojola 2006). In dense populations, even if food is abundant, regulation of the population density of *M. musculus* occurs through physiological and behavioral factors, such as lowered fecundity, reduced litter size, and embryonic resorption (Rowe, Taylor, and Chudley 1964). Both non-implantation and embryo resorbing cases were also registered in our sample of *M. musculus.*

When breeding of commensal *M. musculus* stops or decreases in autumn and winter (Rowe, Quy, and Swinney 1987), it is mainly a result of the combined effects of a marginal diet and a low ambient temperature (Pryor and Bronson 1981; Pocock, Searle, and White 2004). Dry seasons also influence population structure and abundance (Panti-Maya et al. 2012).

M. musculus did not show differences in litter size resulting from any environmental characteristics. If animals are more exposed to seasonal changes in weather conditions, changes in reproductive investment are more evident (Vadell, Gómez Villafañe, and Cavia 2014). We also found that litter size in the indoor *M. musculus* was quite stable in autumn and winter period. Our sample of indoor *M. musculus* was dominated by males, and such finding corresponds to other authors (León et al. 2013; Mushtaq et al. 2014).

Indoor-trapped *A. flavicollis* had a somewhat similar age structure of population as it was registered in the non-vegetative period in the wild in Lithuania: main proportion of the population were adult individuals (over 50% in field conditions, 68% indoor), with juveniles accounting for 25 and 14%, respectively. In nature, the proportion of subadult individuals rose towards spring, accounting for up to 80% of individuals in April. Breeding of *A. flavicollis* in non-vegetative period was rarely observed in nature (Balčiauskienė, Balčiauskas, and Čepukienė 2009). Even in the sample size of indoor *A. flavicollis,* however, we have evidence of winter breeding.

Morphometrics: body, skull, and pelvis

Data on *M. musculus*, presented in *Fauna of Lithuania. Mammals* (Prūsaitė 1988), mainly refer to an unpublished source from 1959 (Ph.D. thesis of N. Likevičienė), while data on its parasites from 1974 and 1979. It was maintained that for this species year-round breeding is characteristic in heated buildings, but there is no breeding in the autumn–winter period in non-heated ones. In dwelling houses up to 10 litters (5–13 young, average 7.2) per year are registered. Maturation occurs at the body weight of 10–11 g (Prūsaitė 1988) or is closely related to body-weight increase in the 10–14 g range (Rowe, Swinney, and Quy 1983). In our sample, the minimum body weight of breeding male was 12.1 g, and that of females 14.0 g.

Body size parameters of adult *M. musculus*, presented in *Fauna*, and most possibly referring to wild-trapped individuals, are in correspondence with our data. The body mass of adult males was on average 17.5

(12.4–27) g, that of females 23.1 (12.8–33.1) g, and body length 80 (69.4–95.5) mm and 84.8 (68.5–96.8) mm, respectively (Prūsaitė 1988). Our data enhance knowledge of the species morphometry with body and skull measurements of subadult individuals and juveniles, and pelvic measurements for all age groups (see Table 3).

Not all cranial measures of adult *M. musculus*, presented in *Fauna*, are compatible with our data, *X*11, *X*19, and *X*22 being up to 10% smaller in our sample of indoor-trapped individuals. However, the description in *Fauna* is based on a very small sample (9–12 individuals), and, according to Macholán (1996), there is a chance that the measurements were author-dependent. Moreover, morphological characters are likely to be affected by ecological (food) and seasonal factors (Macholán 1996).

Pelvic measurements of indoor *M. musculus* in Lithuania were similar to these presented by Brown and Twigg (1969) for mice, inhabiting the British mainland. Age and gender-based differences in the indoor-trapped *M. musculus* populations in Lithuania were significant. In wild *A. agrarius,* age and sex-based differences of pelvic measurements overlap (Balčiauskienė and Balčiauskas 2015), yet this species was not trapped in numbers indoors.

There are no data on body condition of *M. musculus* in Lithuania, so we may compare only *A. flavicollis* in this respect between wild population in the non-vegetative period (October–April, recalculated after Balčiauskienė, Balčiauskas, and Čepukienė 2009), wild populations in low-quality habitat in late summer and autumn (Balčiauskas, Balčiauskienė, and Jasiulionis 2015) and those trapped indoors (see above). Accordingly, in the non-vegetative period, the average body condition index in wild-trapped *A. flavicollis* was $C = 3.29 \pm 0.03$, significantly higher than in the indoor mice (Student's $t = 3.24$, $p < 0.005$). Changes in the body condition index in wild *A. flavicollis* (Figure 4) followed the same pattern as indoor-trapped mice (see Figure 3(A)): from similar values in autumn, body condition constantly became worse in winter, with minimum values observed in March (0.73 ± 0.37) and February (2.31 ± 0.41), respectively.

Compared to the body condition index of *A. flavicollis* from a non-productive habitat, situated in the territory of a colony of great cormorants (*Phalacrocorax carbo sinensis*), trapped in summer and autumn ($n = 404$, Balčiauskas, Balčiauskienė, and Jasiulionis 2015), indoor-trapped animals were in worse condition ($t = 8.45$, $p < 0.0001$). Thus, indoor-trapped *A. flavicollis* in winter do not gain significant bonuses from the shelter and/or food supply in unheated buildings.

Disease transmission: threat to humans

Commensal rodents, being near to human activities, pose potential threats to both public, and animal health

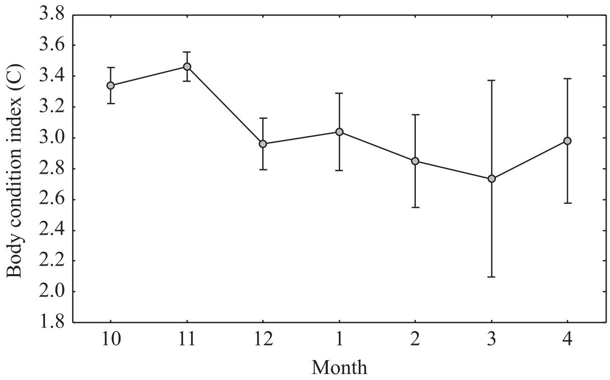

Figure 4. Monthly dynamics of body condition in the wild-trapped *A. flavicollis* in the non-vegetative period (recalculated after Balčiauskienė, Balčiauskas, and Čepukienė 2009). $N = 213$, vertical bars – 0.95 CI.

through transmission of a variety of diseases (Gratz 1994). Farm buildings and their surroundings are particularly important for *M. musculus* (a major pest of stored products) (Rowe and Swinney 1977). They are also found in suburban and rural habitats (Langton, Cowan, and Meyer 2001).

Eusynanthropic species, *M. musculus* and *R. norvegicus,* are most important in disease transmission, less important are non-synantropic species such as *M. glareolus*, *A. flavicollis*, *A. agrarius and A. sylvaticus*, as well as the common vole (*Microtus arvalis*), short-tailed vole (*Microtus agrestis*), water vole (*Arvicola terrestris*), and others (Skoric et al. 2007).

In Finland, *A. flavicollis* and *M. musculus* from a cattle farm had antibodies to lymphocytic choriomeningitis virus (Laakkonen et al. 2007). From several Central European countries, it is known that Dobrava virus is transmitted by *A. flavicollis* and *A. agrarius*, while Puumala virus by *M. glareolus* (Klempa et al. 2005; Laakkonen et al. 2007; Johansson et al. 2008; Kraigher et al. 2012; Khalil et al. 2014). Dobrava virus is a hantavirus that causes hemorrhagic fever with renal syndrome (HFRS) in Europe. In China, which accounts for 90% of HFRS cases worldwide, the disease is caused by two viruses. Of these, Hantaan virus is associated with *A. agrarius*, while Seoul virus with *R. norvegicus* and *R. rattus*. 25.3% of trapped *M. musculus* were seropositive to hantavirus (Fang et al. 2015).

In the years of high population density, small mammals may aggregate indoor, thus increasing the probability of disease transmission to humans (Khalil et al. 2014). For *M. glareolus*, the main factor leading to gathering in buildings are mild and rainy winters with less snow cover (Pettersson et al. 2008).

Small mammals are also infected by tick-borne zoonotic bacteria (*Borrelia* spp., *Anaplasma phagocytophilum*, *Coxiella burnetii,* and others), thus being reservoirs for them. In Spain, *A. flavicollis*, *A. sylvaticus*, *M. domesticus*, *M. glareolus,* and a few shrew species were infected by these bacteria (Barandika et al. 2007). In Lithuania, *A. flavicollis*, *M. glareolus,* and *M. arvalis* were shown carrying ticks and their larvae infected with *Borrelia burgdorferi sensu lato* and *B. afzelii* (Radzijevskaja et al. 2013), however, investigated small mammals were not trapped indoors.

Mycobacteria were found in the organs of the common shrew (*Sorex araneus*) and organs of *A. flavicollis* and *M. musculus* (Fischer et al. 2000). All these species were trapped indoors in Lithuania. As mycobacteria pass through digestive tract unaffected, small mammals may spread them with droppings and pass them to their predators (Fischer et al. 2000). Of fungal organisms, *Pneumocystis* sp. and *Emmonsia parvum* were found in the lung tissue of the house mouse (Laakkonen et al. 2007).

In Lithuania, several helmint species, which are dangerous to humans, were registered in small mammals. *Hymenolepis diminuta* was found in *M. musculus*, *A. agrarius*, *R. norvegicus* and *M. glareolus*, *Rodentolepis straminea* in *M. musculu*s, *R. norvegicus* and *M. glareolus*, *Hydatigera taeniaformis* in *A. flavicollis*, *R. norvegicus* and *M. glareolus*, *Syphacia obvellata* in *M. musculus* and *A. flavicollis*, and *Trichinella spiralis* in *M. musculus* (Prūsaitė 1988). In non-synantropic species, *M. glareolus* and *A. flavicollis*, inhabiting forested (Scandola et al. 2013), rural and urbanized (Reperant and Deplazes 2005) areas of Switzerland and France, zoonotic nematode *Capillaria hepatica* was found.

Thus, eusynanthropic and non-synantropic species of small mammals have high significance in maintaining various pathogens in nature and their transmission to humans. Along with climate change and accompanying changes in species ranges, indoor small mammals may pose a higher threat level in disease transmission.

Disclosure statement

No potential conflict of interest was reported by the authors.

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