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City centre or periphery? Distribution and morphological adaptation of *Apodemus* taxa along an urban gradient

Key words: distribution, morphology, urban gradient, *Apodemus sylvaticus, Apodemus flavicollis, Apodemus uralensis*

Introduction

The city as ecosystem

Cities are an aggregation and combination of different habitat types which are used by a multiplicity of animal species in different ways. An apparently consequence of urbanisation is fragmentation of natural habitats in to a mosaic of small plots of different size and shape (Dickman 1987). From the ecological point of view a city never represents uniformly habitats, but consists of a habitat mosaic of high heterogeneity and space dynamic (Klausnitzer 1993). Besides the sometimes manifold habitat types urban places provide also food resources which are not available in rural areas. Thereby resources are accessible for several animal species which profit from that. Also the milder city micro climate is an advantage. Temperature differences can amount several degrees Celsius and wind is diminished by building complexes (Reiter & Jerabek 2002). Humidity is lower but precipitation often higher. On the other hand emissions can have a more negative effect inside a city compared to rural areas.
In contrast green areas, like public parks and greeneries of different sizes and composition, upgrade climate and conditions for colonization of animals remarkable.

The city as habitat for rodents

Those animal species which survive and persist in urban ecosystems are designated by their high flexibility in behaviour and habitat choice. They cover a diversification of ecological niches and are tolerant against disturbance (Luniak 2004, Adams 2005, Anold et al. 2006). They are often pioneers, which can expand up to the city centres (Klausnitzer 1993, Reiter & Jerabek 2002). Generalists have a crucial advantage, as they are flexible in their lives history strategies. Among mammals the rodents possess advantageous pre-adaptations to colonize such urban ecosystems. Beneath them there are 'classical' commensals like house mouse (*Mus musculus*), brown rat (*Rattus norvegicus*) and black rat (*Rattus rattus*), but also other species especially representatives of the genus *Apodemus* (Frynta et al. 1994, Chernousova 2010).
The urban space is for rodents a heterogeneous environment with many different habitat types possible for niche-building. A problem in this context is the isolation of such suitable habitats by a dense road system, which form an almost insuperable barrier for rodents (Angold et al 2006).
Not only isolation, but also direct influence by humans affects small mammals. On the one

hand it is direct persecution using poison and traps, on the other hand indirect constraints through traffic (Oxley et al. 1974) and environmental pollution. In contrast to natural habitats, degree and intensity of anthropogenic disturbance are essential factors which determine their occurrence. Moreover, frequent and intensive disturbance lead to decreasing species numbers (Dickman 1987, Reiter & Jerabek 2003). Commonly mowing of lawns, utilization of pesticides and planting of exotic plants are some of such anthropogenic disturbances (Dickman & Doncaster 1987). Urban stress seems to have a remarkable higher influence on the structure and dynamic of small mammal populations than other stress factors in forest habitats (Chernousova 2010).
Hence, this could have a potential impact on the morphology of small mammals. Dickman (1987) suppose that in cities, areas with low ground cover are also affected by a higher predation pressure through cats and dogs. Predation pressure in cities is usually lower as in more natural habitats indeed, but natural predators which live in urban habitats can have an influence to a small mammal population as well (e.g., kestrel *Falco tinnunculus* – Sumasgutner et al. 2011, Düesberg 2012; stone marten *Martes foina* – Gamauf 2011).

Rodents in the city of Vienna

Up to now 60 mammal species were detected within the city borders of Vienna (Spitzenberger 2001), among them 22 small mammal species (9 species of insectivores, 13 species of rodents). The highest species numbers were found in semi-natural parts along the periphery (Steiner 1966). But many of these data are rather old. In opposite to several other cities, no systematically investigation on small mammals has been conducted in Vienna until now. Hence it is possible that in the meanwhile new species have immigrated and others have been extinct (Linz: Reiter & Jerabek 2002, Praha: Frynta et al. 1992, 1993, 1994, Oxford: Dickman 1987, Manchester: Yalden 1980). Almost all small mammal records in Vienna were accidently found or were acquired during a few unselected trapping actions (Sieber & Ulbel 1998, specimens held in the Museum of Natural History Vienna). As many small mammals are widely nocturnal, they have to be found and identified by indirect methods (Götz 1991). The only systematic investigation in the city of Vienna was done rather recently by Mitter (2012). During this study in public parks and greeneries the representatives of the genus *Apodemus* were verified disproportional high compared to other small mammal species.
The present study is focused on (1) the distribution and abundance as well as (2) possible morphological differentiation of the *Apodemus* species along the urban gradient in the city of Vienna.

Material and Methods

Study area

With a size of 415 km² and 1.76 million inhabitants Vienna (48° 12′ N, 16° 22′ E) is the largest and highest populated city in Austria. It is situated at the north eastern foothill of the Alps and at the north-western range of the Viennese basin. The high variability of types of landscapes is mirrored by its geographical position. Pannonian influences meet continental climate and both are enriched by the mild city climate (Wichmann et al. 2009). Vienna is a 'green' city. In total less than the half of its area are sealed, the remaining areas are composed by 'green' habitat element (habitat elements: densely sealed 21.1 %, traffic and industrial areas 14.5 %, garden city 10.7 %, parks and cemeteries 12.1 %, agricultural areas 19.2 %, forest 17.6 %, water bodies 4.7 %, fig. 1, 2). Especially big parts at the western periphery (Wienerwald) and the south east (Lobau-riverine forest of Danube, Prater) are covered by forest. Additionally several extensive parks are situated in between the inner city districts. Besides large areas like around the castle Schönbrunn or in the Augarten (50 -> 150 ha) many smaller parks are existing, some only with a size of a few hundred square metres. Green areas have a proportion between 3–13 % in the inner city and up to 70 % in the western districts (http://www.wien.gv.at/umwelt/parks/anlagen/). Vice versa the city centre has the highest sealing proportion. In the course of this investigation we tried to cover a broad spectrum of public parks and greeneries, refer-

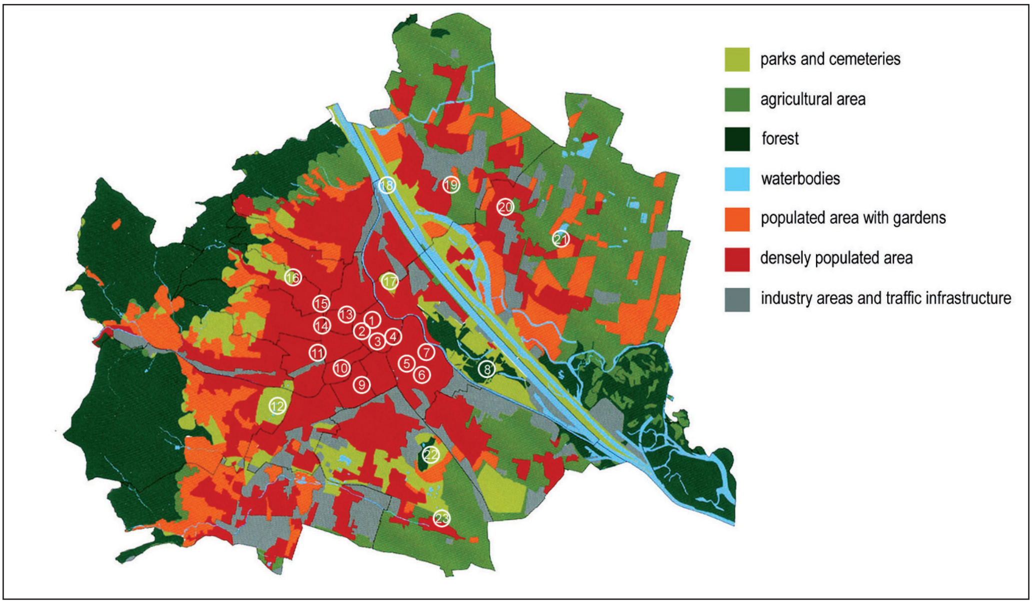

Fig. 1 The city of Vienna and the location of the 23 (1–23) public parks and greeneries investigated. The colour codes designate the different habitat types (modified after Wichmann *et al. 2009).*

Fig. 2 Aerial image of the Viennese city centre (Photo: TU Wien).
Z = city centre, St. Stephen's cathedral, 1 = Volksgarten, 2 = Maria-Theresienpark, 3 = Burggarten, 4 = Stadtpark, 5 = Schlossgarten Belvedere, 17 = Augarten, 18 = Donauinsel

red to its position in between the city border as well as concerning its size and composition (intensively and extensively used) (fig. 3a, b).
Altogether 23 parks were selected randomly (59 different plots) as well as the order of trapping. In the large parks (e.g., Augarten, Stadtpark, Schönbrunn, botanical garden) with diverse habitat types several plots were used. These sites are situated between 0–9 km away from the city centre (St. Stephen´s Cathedral).
Parks east of the Danube have a mean sea level of 155 m a.s.l. In western direction elevation rises up to 270 m a.s.l. According to this precipitation rises from the Pannonian plains in the east with 515 mm to 740 mm in the west of the Wienerwald. Most of the precipitations fall during vegetation period between May–August. Mean temperature varies between 9.6°C in the west and 10.4°C in the east (Wichmann et al. 2009, Berger & Ehrendorfer 2011).

Rodent trapping

The study is based on trapped *Apodemus* individuals caught in life-traps of the Rödl-type (Janova et al. 2010). The traps had dimensions of 24 cm (length) x 6 cm (width) x 6 cm (height). These traps can be efficiently deployed, controlled and afterwards collected. In contrast to pit-falls this kind of traps does not make any damage at the green areas (Götz 1991). Dependent on the habitat type and plot size 10–20 traps were displayed at distances of 10 m each. Distinctive structures like ditches, slopes and markedly trees have been involved as they are good trapping sites for small mammals (Steiner 1966). We used the 'minimum number alive method' (Krebs 1996) to calculate rodent densities. Each site was served for 48 hours and each trap was controlled four times; twice a day, in the morning and evening hours.
This resulted in 2676 trap units, which formed the base for the calculations. The study period extended during reproduction time between May and September. The population bend was relative constant, which made comparisons possible (Steiner 1966, Frynta et al. 1994). Trapping order of parks was chosen randomly to avoid a possible bias. Traps were baited with high-energy peanut butter (78 % fat, 9 % carbohydrates und 13 % proteins). Transporting the equipment in the city was done using an off-road trolley.

Identification

The identification of living *Apodemus* species is not easy (Heinrich 1951, Steiner 1966, Götz 1991, Spitzenberger 2001). Besides classical identification literature, an identification catalogue was prepared using museum study skins. Skins housed in the Museum of Natural History Vienna showed the individual variation in colour and pattern of the taxa in the area around the city. For identification of the specimen especially Steiner (1966) and Jenrich et al. (2010) were useful, as in living animals no teeth formula can be used.

Fig. 3a, b Examples of intensively (left) and extensively (right) used parks in the city of Vienna. (Photo: G. Mitter)

Morphology

Trapping

Each trapped mouse was identified, measured and subsequently released at the same place. The whole procedure persisted about 3–5 minutes. Before measuring, each animal was put from the trap into a large plastic bag and from there into a small one litre transparent plastic bag (Toppits, Zipper Gefrierbeutel 1l). Then handling was relatively easy and every mouse was treated with consideration (fig. 4). Weight was determined by a digital scale (Soehnle 8027 ultra) and morphometric measurements were taken by using a fiberglass caliper (dial-Max, Wiha company). Definition of measurements (KRL – body length, SL – tail length, OL – ear length and HFL – length of hindfoot) followed Jenrich et al. (2010). Based on Steiner (1966) the *Apodemus* species were divided into two age categories based on their body weight. Sexual maturity in *Apodemus* is reached only after passing a certain body weight. The limiting value for the three *Apodemus* species found were as follows: yellow-necked mouse *Apodemus flavicollis* < 16 g, wood mouse *Apodemus sylvaticus* < 18 g und ural field mouse *Apodemus uralensis* < 16 g. Lighter animals were categorized as subadult, heavier ones as adult and sexual mature.

KRL and SL were measured with an accurateness of 1mm, and SL and HFL with 0.5 mm. During measuring process the mouse body was always held in the same position.

Museum study skins

Identification was ensured comparing body measurements of living animals with those of museum specimens (Museum of Natural History Museum Vienna). Of *A. flavicollis* and *A. sylvaticus* 20 study skins (adult females: adult males 50:50) were used and of *A. uralensis* 22 specimens. We tried to use only animals of the same time period (May–September) as well as from Vienna and its surrounding. When the material from that region was not sufficient, as

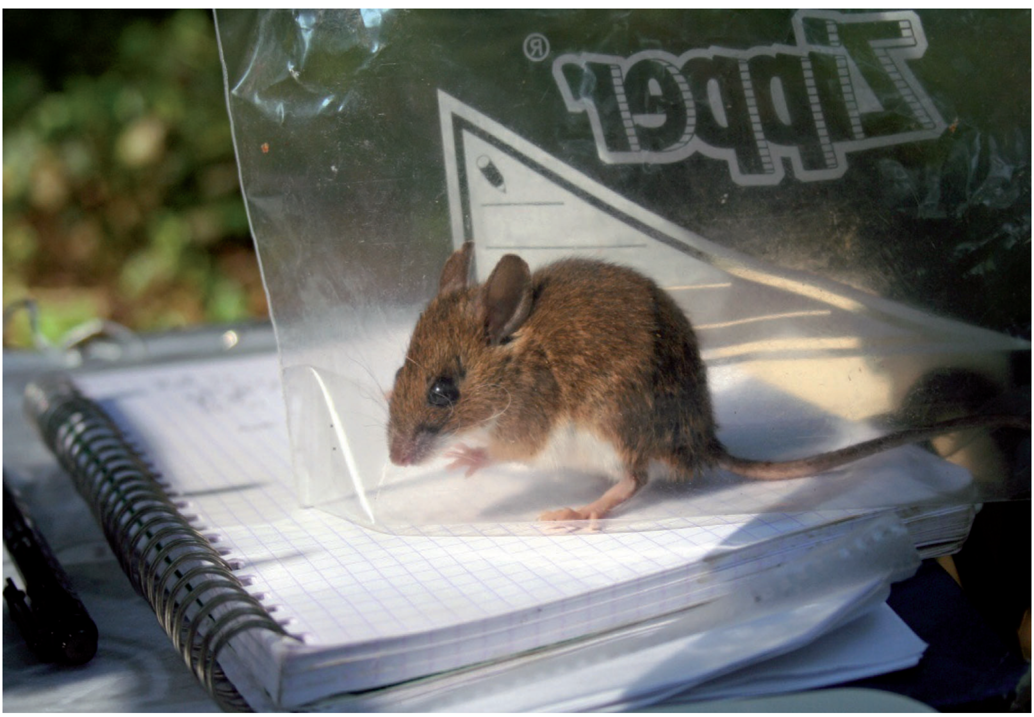

Fig. 4 Yellow-necked mouse (A. flavicollis) in a plastic bag ready to be measured. (Photo: G. Mitter)

happened in *A. uralensis*, skins from adjacent Lower Austria and Burgenland were added. The measurements at the skins were taken in the same manner as in the living mice. Body weight was inherited from the labels.

Weather condition

From other investigations it is known that capture rate is lowest at hot and rainy days, respectively (Gentry et al. 1966, Götz 1991, Vickery & Bider 1981). Therefore, on days with such extreme weather conditions no trapping occurred. Weather data (temperature, precipitation) were received from Zentralanstalt für Meteorologie und Geodynamik (ZAMG – Hohe Warte) in Vienna.

Statistical analysis

As the bigger part of the available habitat data of the parks were not normally distributed, analyses were undertaken by non-parametric Spearman correlations. Morphological characters of living animals and study skins were tested about their significance by ANOVA within and among the species groups. The single characters were tested using Mann-Whitney U-test. Fisher´s Discriminant function was used to answer the question whether the three *Apodemus* species could be differentiated and be assigned to the right species group by their morphology respectively. This function enables by using the morphological data to determine species affiliation. Possible relationships between trapping success and weather conditions and morphological characters and habitat data were calculated with regression analyses. All calculations were carried out using SPSS 17.0.

Results

Trapping success and dispersal

During the study period six small mammal species were determined. All of them belonged to the rodent group – 3 species of the genus *Apodemus* (wood mouse, yellow-necked mouse, ural field mouse) as well as house mouse, brown rat and the bank vole (*Cletrionomys glareolus*). The majority, 127 (98.4 %) of 129 captures, belonged to the genus *Apodemus*. The most common species was *A. sylvaticus* with 48.7 % (n = 55), followed by *A. flavicollis* with 43.3 % (n = 49) and ural field mouse with 8 % (n = 9) as the rarest one. 14 specimens could not be identified unambiguously due to their subadult age and early escape.

53 % of the total captures have been males. This happened especially in the most numerous trapped *A. sylvaticus* (58.2 %) and *A. flavicollis* (59.2 %). Only in *A. uralensis* a surplus of females was found (males 47 %). Half of the females were pregnant.

The highest capture rates were recorded in May and June and became lower in the following months.

Positively affected were the trapping numbers by the amount of precipitation ($r_s = 0.771$, $P < 0.036$). Extreme data were omitted from the calculations to avoid biases. In contrast, no influence was found regarding temperature ($r_s = 0.860$, $P < 0.436$, N.S.).

Abundance of *Apodemus* species along the urban gradient

Not only within the study period, also within the study area the three *Apodemus* taxa showed conspicuous differences in the distribution and frequency pattern. Remarkable was the frequency along the urban gradient (fig. 5). The range varied between 0 and 55 individuals / 100 trap units.

Three peaks were visible: the first peak was found in the intensively anthropogenic influenced parks close to the city centre (Volksgarten, Belvedere)(distance 1–1.3 km). The second one with the highest numbers, was in the seminatural parks of Botanischen Garten and Augarten (distance 1.7–1.9 km), and the third peak in the big area of Schönbrunner Schloßpark (distance 5–6 km) with intensive and extensive habitat elements.

Noticeably, the capture rate declined towards the periphery in *A. sylvaticus* ($r_s = -0.789$, $P < 0.01$) and was more or less constant in the other two species (*A. flavicollis*: $r_s = 0.277$, N.S: *A. uralensis*: $r_s = 0.540$, N.S.). Both species, *A. sylvaticus* and *A. flavicollis*, were found broadly overlapping. But close to the centre *A. sylva-*

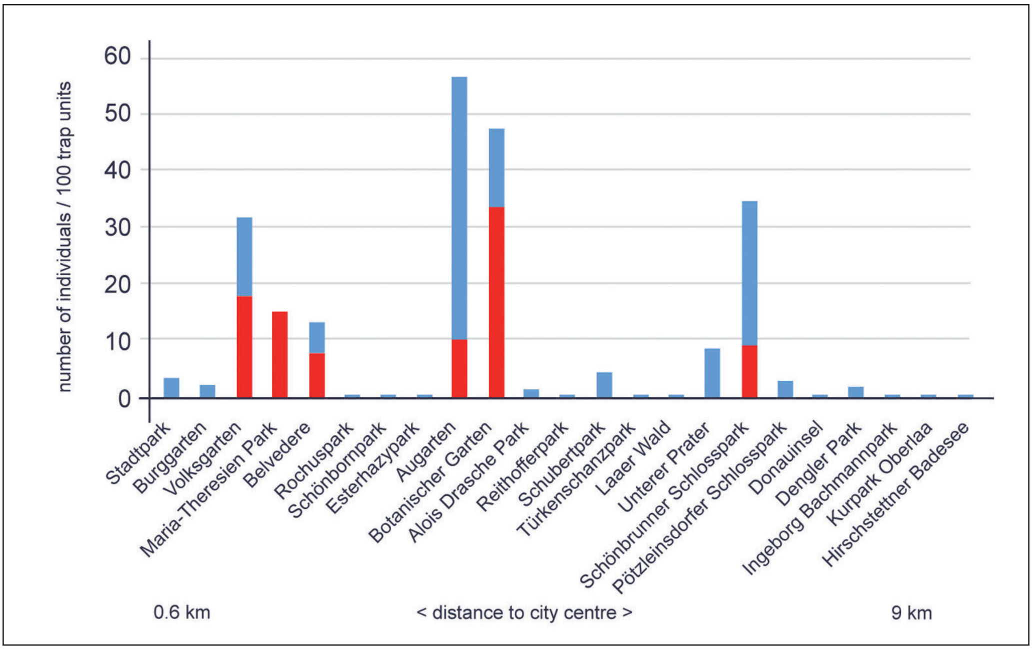

Fig. 5 Distribution and frequency of trapped Apodemus specimens / 100 trap units along the urban gradient between the city centre (St. Stephen's Cathedral) and the periphery (n=113). Red columns = A. sylvaticus, blue columns = A. flavicollis.

ticus was dominating (65–100 %) and towards the periphery *A. flavicollis* (74–100 %). Distinctive differences were even noted between parks at close quarters, like between Burggarten and the Volksgarten (fig. 5).
However, *A. uralensis* was proven only for the south eastern parts of the city (Mitter 2012). Whether this is a relict source or if these animals immigrated into the city in more recent times cannot be said at the moment. Anyway, *A. uralensis* occurs sympatrically with both other *Apodemus* species.

Abundance of *Apodemus* species in relation to park size

Both common *Apodemus* species were also unevenly distributed in relation to size of the parks and greeneries (fig. 6). Medium-sized (> 3.5 ha) and large parks (> 50 ha) were preferred against small ones (< 3.5 ha). In *A. sylvaticus* a correlation between trapped individuals and park size was confirmed (r_s = -0.869, P < 0.01), in *A. uralensis* a trend for preference of larger parks was found (r_s = 0.512, P < 0.08) whereas no such context was observed in *A. flavicollis* (r_s = 0.304, N.S.). Generally, in medium-sized park categories *A. sylvaticus* was dominating and in the large ones *A. flavicollis* (Mann-Withney U-Test = 4.6, P < 0.05).

Morphology

Although all three *Apodemus* species are phenologically similar, almost all adult individuals were clearly identifiable due to five morphological characters. Using a Fisher's discriminant analysis 89.3 % of all individuals were correctly assigned to their specific groups. This function allows by inserting the measured data to test the species assignment to the specific groups. As expected, the museum study skins provided the highest acceptance; 96.8 % of the study skin were correctly assigned and 84.2 % of the live-trap captures. The combined data set had 89.3 % correct classifications. Highest proportion of overlapping was recorded between *A. sylvaticus* and *A. flavicollis*. We assume that the living *Apodemus* individuals were assigned correctly as those which died in the traps were identified properly (subsequently skull check). The graph of that data combination was done using cannonical discriminant analysis (fig. 7). At DF1-axis size-related general characters were present, and at DF2-axis especially ear length (OL). For calculating inter-specific morphological differences among the three *Apodemus* species, body weight and morphometric data of the trapped males and females were pooled, as there were no significant differences between the sexes. Also pregnant females remained as they showed no significant differences from other females. As weight and the morphometric data (SL, KRL, HFL, OL) were almost normally distributed, parametric analyses could be used.

Comparing the particular morphometric data, it could be shown that although the three species overlap, in the arithmetic means they differed very well. Matching the most similar species *A. flavicollis* and *A. sylvaticus*, the former one is heavier, has the longest SL, HFL and OL. Only in the character KRL they are comparable, but this is maybe due to the hamper handling with the living animals.

For all three taxa SL and HFL are the most important and diagnostic characters. SL was clearly longer than KRL in *A. flavicollis*, both characters had the same dimensions in *A. sylvaticus*, and in *A. uralensis* SL was shorter than KRL (Mann-Whitney U-Test, $P < 0.05$). This was already true in young animals. In all characters the data of *A. uralensis* were the smallest (table 1).

A statistical matching by one-way ANOVA underlined the significant differences of all characters among the three species (table 2). The differences in the museum study skins were a bit larger because they were easier to measure. However, the measuring procedure was more difficult in the living animals, the differences were significant as well.

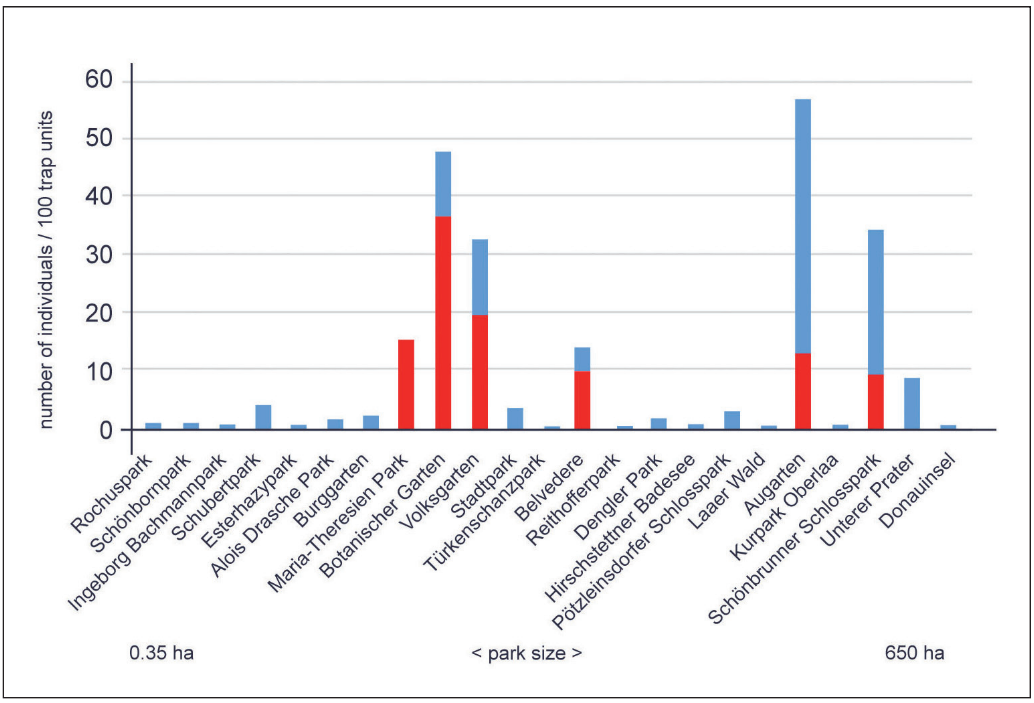

Fig. 6 Frequency of Apodemus trapping numbers / 100 trap units in relation to park size (n = 113). Red columns = A. sylvaticus, blue columns = A. flavicollis.

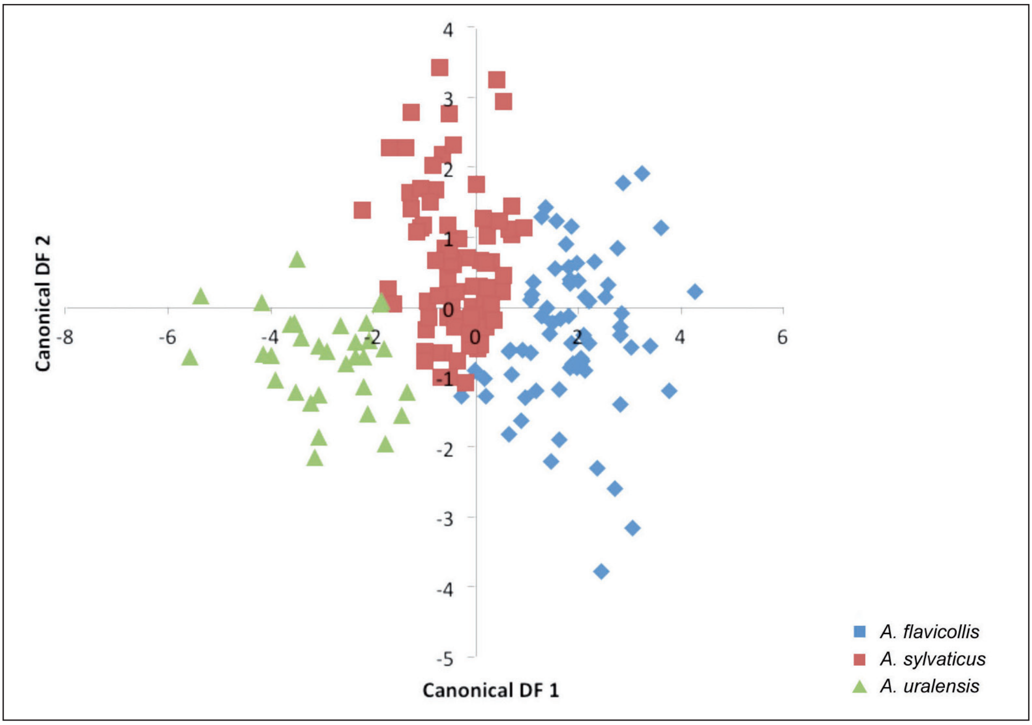

Fig. 7 Canonical Discriminant Function Analysis of morphological characters of all three Apodemus species (trapped specimens and study skins together; n=176). Blue (diamond) = A. flavicollis, red (squarae) = A. sylvaticus, green (triangle) = A. uralensis

Table 1 Adult body weights and morphometric measurements of three Apodemus species trapped in the city of Vienna

	Weight (g)	**SL (mm)**	**KRL (mm)**	**HFL (mm)**	**OL (mm)**
Apodemus flavicollis (n = 49)					
mean	33.4	95.4	88.5	21.1	13.6
SD	4.5	5.0	6.6	0.8	0.6
Apodemus sylvaticus (n = 55)					
mean	28.4	84.4	88.8	19.8	12.8
SD	2.5	3.8	3.4	1.2	0.6
Apodemus uralensis (n = 9)					
mean	20.5	69.8	73.3	16.7	10.9
SD	2.2	6.1	4.5	1.0	1.0

Table 2 One-way ANOVA of morphological characters of the three Apodemus species

	Living animals (n = 113)		Study skins (n = 62)		Living animals + Study skins (n = 176)	
	***F*-value**	***P***	***F*-value**	***P***	***F*-value**	***P***
Weight	18.392	**< 0.0001**	49.834	**< 0.0001**	81,024	**< 0.0001**
SL	39.035	**< 0.0001**	96.246	**< 0.0001**	89,009	**< 0.0001**
KRL	11.586	**< 0.0001**	46.233	**< 0.0001**	26,284	**< 0.0001**
HFL	16.544	**< 0.0001**	238.244	**< 0.0001**	72,994	**< 0.0001**
OL	10.180	**< 0.0001**	35.041	**< 0.0001**	39,336	**< 0.0001**

Influence of habitat on morphology

Body weight and park size

Public parks and greeneries can have a different importance in size and habitat composition (as food resource) for small mammals. We predicted that in good quality habitats body weight is higher than in poor quality habitats. Here body weight was taken as indirect predictor for fitness. Therefore, we tested whether park size has an influence to body weight for *Apodemus* mice. Because of inappropriate relation between capture numbers and park numbers, the latter ones were divided into 5 size categories. In *A. flavicollis* (r_s = 0,516, P < 0,029) as well as in *A. sylvaticus* (r_s = 0,633, P < 0,034) a significant relationship between body weight and park size was found. In smaller parks (< 50 ha) mean body weight was lower than in more extensive greeneries, especially in category > 100 ha. Including all parks (also those with 0 values) for the calculations, then only a trend was found (*A. flavicollis:* r_s = 0.700, P < 0.094, N.S.; *A. sylvaticus:* r_s = 0.400, P < 0.3, N.S.). In *A. uralensis* presumably sample size was too small to show any relationship in both cases (r_s = 0.200, P < 0.4, N.S.).

Body weight and urban gradient

We also tested a possible relationship between body weight and the relationship to the park locality along the urban gradient. The range (as distance to the city centre) varied between 0.6 km and 9 km. None of that three *Apodemus* taxa showed a significant relationship (*A. flavicollis:* r_s = 0.16, P < 0.29, N.S.; *A. sylvaticus:* r_s = 0.27, P <0.3, N.S.; *A. uralensis* r_s = -0.394, P < 0.303, N.S.). It is very likely that the different park sizes, which are variable in the different zones, are responsible that for. In none of the morphometric characters any differences along the urban gradient or park size related were found.

Discussion

City centre or periphery? – Species composition and distribution of *Apodemus* mice in urban habitats

Evolutionary success of a species or the individual success of survival depends on the successful adaptation to varying environmental conditions (Scharfe & Schlund 1992). In the city of Vienna a high variety of habitats is existing offering a high number and quality of ecological niches. Under such conditions wild animals can reach high abundances. Opportunistic commensals have the best preconditions to use such biotic and abiotic advantages of artificial developed habitats (Glitzner et al. 1999, Pattisiall & Cundall 2009). This is true also for different kind of rodents, inclusive *Apodemus* mice.

In the course of the this paper we investigated distribution, density and morphological adaptations of small mammals under environmental conditions of an extended city like Vienna. In total 6 species were recorded, which were found also in the 'Atlas of Mammals in Austria' as the most common in and around Vienna (Spitzen-

BERGER 2001). In comparison to investigations of two cities not too far away from Vienna (Linz: REITER & JERABEK 2002; Praha: FRYNTA et al. 1994) the diversity of small mammals is markedly lower in Vienna. This can have several reasons: different trapping duration, different trapping methods and that in Vienna only public parks and greeneries were selected and not specific high quality habitats like fallow land, wetlands etc. Studies conducted during the last decades in Vienna or in its surrounding found a high diversity as well (STEINER 1966: Donau-Auen, STEINER & SPITZENBERGER 1967: Donau-Auen, Wienerwald, CSAIKL 1980: Steinfeld, GÖTZ 1991: Marchfeld). Besides the trapping methods (GÖTZ 1991, JANOVA et al. 2010, TORRE et al. 2010) anthropogenic factors could be relevant as well. During this investigation 28.1 % (n = 29) of the traps 'got lost' and in 21.41 % (n = 573) of the trap units the traps were opened or at least manipulated, presumably to 'save' the animals. These factors certainly had a negative impact to the data, especially in the inner city districts.

The species in question have a different potential by their biological peculiarities and demands for settling in big cities. The most common trapped species was *Apodemus sylvaticus. A. sylvaticus* counts as a pioneer species, which is able to colonize 'artificial' habitats even within a year. In this short time after re-cultivation it can establish viable populations (HALLE 1993). The same pattern was found in Vienna where it has its widest distribution also in the highest sealed city zone. Especially this species is prone to settle in urban key areas up to the Viennese city centre which was already documented by SPITZENBERGER (2001). FRYNTA et al. (1994), FRYNTA & VOHRALÍK (1994) and REITER & JERABEK (2002) confirmed this also for other European cities. A. *flavicollis* was found to be the second most common species. It was recorded in inner city districts in small numbers, but it was dominating in more natural habitats at the city periphery. *A. flavicollis* is very mobile, but during its dispersal it prefers forested habitats (MONTGOMERY 1989 a,b, VUKICEVIC et al. 2006), and refuses open habitats. Hence, in Vienna this species was found more often in peripheral areas. The same pattern was recognized also in SPITZENBERGER (2001).

At the third position, with the lowest numbers trapped, *A. uralensis* followed. This species reaches in eastern Austria, inclusive the south eastern parts of Vienna, its westernmost limit of distribution. For the first time single individuals of *A. uralensis* even were caught close to the city centre. This is remarkable as in literature it is called as 'steppe' species (JENRICH et al. 2010) and in Austria it is documented for 'dry' habitats (BAUER 1960), wet fields and meadows (STEINER 1966) and humid riverine forests (SPITZENBERGER & STEINER 1967).

After DICKMAN & DONCASTER (1987) and FRYNTA et al. (1994), several reasons are responsible for the dominance of *A. sylvaticus*: the high flexibility in habitat use, its unspecific feeding ecology, the wide dispersal distances, high population density which causes in low local extinction rates and the widely absence of potential competitors like *A. flavicollis*. It was remarkable that no uniform population dynamic for the whole city area was recognizable. Along the urban gradient in three regions locally high abundances were found. This could indicate that either independent isolated subpopulations or different population cycles occur in the city area.

In *Apodemus* species population cycles of 3–4 year intervals are known also from urban habitats (CHERNUSOVA 2010). Similar observations were made in relation to park size and habitat quality (BARKO et al. 2003). In general capture rate was low in semi-natural forest habitats. One possibility could be that a latency period is responsible for that pattern or that in the high quality forest habitats the bait of the traps was less attractive.

Both most common species showed a definitely male disproportion. Comparable results were found in southern Moravia (PELIKAN 1969) and outside of Vienna as well (STEINER 1966). This phenomenon is interpreted with reproductive behaviour during which males use larger home ranges and explore very intensively (MONTGOMERY 1989a, FRYNTA 1992, FRYNTA & VORHALIK 1994).

Urbanisation and morphology

A. flavicollis and *A. sylvaticus* are very common and widely distributed in Europe. Identification of the three *Apodemus* species by phenotypic characters only may pose some problems and was seen critically or even almost impossible in the past (HEINRICH1951, STEINER 1966, GÖTZ 1991, SPITZENBERGER 2001), which antagonize clarification of several questions (KUNCOVÁ & FRYNTA 2009).

If this would be true, an investigation based on living trapped *Apodemus* mice would be impossible. But using newly published identification keys this should allow an almost boundless identification of at least adult animals (CSAIKL 1980, FEILER & TEGEGN 1998, FRYNTA et al. 2001, JENRICH et al. 2010). The combination of morphological and phenological characters was tested in the presented paper and was clearly confirmed. Therefore the results are considered as realistic.

We found that body weight positively correlated with park size. Presumably larger greeneries harbour more and higher qualitative food than small ones. Particularly in intensively used, almost sterile parks, food supply sinks and becomes monotone. Pesticides foster such food decline.

Additionally, a negative correlation was found between number of trapped individuals and park size. The higher the mice density, the lower was their body weight. This phenomenon was seen repeatedly in small mammals and is interpreted as physiological interference because of excessive stress (KREBS 1996, MIKULOVÁ & FYNTA 2001). High densities in city centres were recorded also in New York (EKERNAS & MERTES 2006), in Illinois (BARKO 2003) and in Praha (FRYNTA 1992, 1993, FRYNTE et al. 1994, MIKULOVÁ & FRYNTA 2001). Reasons are reduced emigration possibilities because of lining and barriers like roads around the parks, which isolate the populations (BARKO et al. 2003, EKERNAS & MERTES 2006). Morphologically even in Praha differences were found along the urban gradient. Although these differences were small, they were highly significant. Skull and teeth measures were smaller in the city centre (MIKULOVÁ & FRYNTA 2001). In Praha, FRYNTA (1993) found also differences in body weight along the urban gradient. This could not be observed in Vienna; here park size was more relevant. But maybe sample size was only too small in the present case.

Conclusions

Because of their adaptability representatives of the genus *Apodemus* are widely distributed in public parks and greeneries in Vienna and locally even common. But it is in question, if this capability is enough to settle permanent in smaller parks or resettle such ones after populations went extinct. Increasing sealing of urban habitats, intensive car traffic, frequent cutting of green areas, pesticide use and growing exotic plants are anthropogenic factors which should not be undervalued. In long-term time periods this can substantially reduce urban small mammal fauna. We could show that in urban Vienna small mammal diversity is already smaller today than some decades ago. Planting autochthonous plants and reducing chemicals for pest control would have positive effects not only to small mammals, but also for whole urban wildlife.

Summary

In the city of Vienna, Austria (1.76 million inhabitats), investigations in public parks and greeneries on three representatives of the genus *Apodemus* (Wood Mouse *Apodemus sylvaticus*, Yellow-necked Mouse *A. flavicollis*, Herb Field Mouse *A. uralensis*) was conducted. The study was focused on distribution and morphological adaptations of these species along the urban gradient. Between mid May and end of September 2010 in 23 parks at 59 different patches small mammals were systematically trapped with living-traps (4 controls during 48 hours). The 2676 trap-units adduced 129 rodents (4.8 % success rate; *A. sylvaticus* 48.7 %, *A. flavicollis* 43.3 %, *A. uralensis* 8 %). With 98.4 % the three *Apodemus* taxa were the most abundent small mammals. The trapped individuals were uneven distributed along the urban gradient. The number varied between 0–55 individuals/100 trap-units. Medium-sized (>3.5 ha) and larger parks (>100 ha) were preferred against smaller ones. There was a broad overlap between the two most common species *A. sylvaticus* and *A. flvicollis*. But in urban areas *A. sylvaticus* was dominant, whereas in suburban habitats *A. flavicollis* was more common. *A. uralensis* was trapped in small numbers between periphery and almost city centre. For identification reasons besides colour pattern five morphological characters were measured. Although there was some overlap, 84.2 % of all live-trapped individuals were correctly assigned in a multivariate comparison to their specific groups (museum study skins 96.8 %). The most important diagnostic and significant characters among the species were the tail-length in relation to body length and hindfoot length. In trapped *A. sylvaticus* and *A. flavicollis* body weight correlated well with park size. In small and medium sized parks (< 50 ha) body weight was smaller than in larger green areas (> 100 ha). No such correlation was found of body weight along the urban gradient.

Zusammenfassung

Stadtzentrum oder Peripherie? Verbreitung und morphologische Adaptation der *Apodemus*-Arten entlang des urbanen Gradienten

In der Stadt Wien, Österreich (1.76 Mill. Einwohner), wurden Untersuchungen an den drei *Apodemus* Arten (Waldmaus *Apodemus sylvaticus*, Gelbhalsmaus *A. flavicollis*, Zwergwaldmaus *A. uralensis*) in öffentlichen Parks und Grünanlagen durchgeführt, mit dem Ziel Verbreitung und Häufigkeit sowie etwaige morphologische Anpassungen entlang des urbanen Gradienten zu eruieren. Zwischen Mitte Mai und Ende September 2010 wurden dazu 23 Parks mit 59 verschiedenen Standorten zufällig ausgewählt. Diese Standorte wurden mit Lebendfallen systematisch befangen (4-malige Kontrollen während 48 Stunden). Während der 2676 Falleneinheiten wurden 129 Individuen gefangen (Erfolgsrate 4.8 %; *A. sylvaticus* 48.7 %, *A. flavicollis* 43.3 %, *A. uralensis* 8 %). Mit 98,4 % dominierten die drei Arten der Gattung *Apodemus*. Die Fänglinge waren unregelmäßig in 3 Peaks entlang des urbanen Gradienten verbreitet. Die Schwankungsbreite lag zwischen 0–55 Fänglingen /100 Fallen. Mittelgroße (> 3.5 ha) und größere Parks (> 100 ha) wurden zugunsten kleinerer Grünflächen bevorzugt. Die beiden häufigsten Arten *A. sylvaticus* und *A. flavicollis* zeigten eine breite Überlappung, jedoch dominierte *A. sylvaticus* im urbanen zentrumsnahen Raum, während im peripheren suburbanen Raum *A. flavicollis* häufiger anzutreffen war. *A. uralensis* wurde nur in geringer Anzahl, jedoch zwischen der Peripherie und dem Stadtzentrum festgestellt. Um die Identifikation zu erleichtern wurden neben der Fellfarbe und -zeichnung auch fünf morphologische Merkmale erfasst. Obwohl es ein gewisses Maß an Überlappung gab, wurden mindestens 84.2 % der Lebendfänge richtig identifiziert und im multivariaten Vergleich den richtigen Gruppen zugeordnet (im Vergleich Museumsbälge zu 96.8 %). Das beste diagnostische Merkmal war die Schwanzlänge in Relation zur Körperlänge und die Hinterfußlänge. Eine Verschneidung der Körpergewichte (Maß für Fitness) bei *A. sylvaticus* und *A. flavicollis* erbrachte einen signifikannten Zusammehang mit der absoluten Parkgröße. Demnach waren in kleinen und mittelgroßen Parks (< 50 ha) die Körpergewichte geringer als in ausgedehnten Grünanlagen (> 100 ha). Es wurde jedoch kein Zusammenhang zwischen dem Körpergewicht der Apodemen entlang des urbanen Gradienten gefunden.

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