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Community of small mammals in the urban park revealed in the diet of *Strix aluco* – what changes were noted in recent decades?

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Abstract: The study was conducted between 2016 and 2021 in the urban park of Warsaw agglomeration (Poland). Data on small mammals were obtained from analyses of *Strix aluco* pellets. Long-term changes in species composition and percentage of each species of prey in owls' diet were determined by comparing our data with data published so far for the years 1975–1977 and 2003–2006. In total, owls captured 16 species: 1 – Erinaceomorpha, 2 – Soricomorpha, 8 – Rodentia and 5 – Chiroptera (0, 1, 6 and 4 in the years 2016–2021, respectively). Mammal community of this area was not stable – populations of many species showed remarkable changes in abundance. Decreasing trends were recorded in *Apodemus agrarius*, *Microtus subterraneus*, *Eptesicus serotinus* and *Mus musculus*, while increasing trends – in *Apodemus flavicollis* and *Nyctalus noctula*. In particular, *A. flavicollis* showed rapid population increase – in the recent six years it became a second abundant rodent in this park. These results indicate that urban mammal communities can undergo important changes throughout only one or two decades.

Key words: Mammalia, rodents, bats, urban wooded area, synurbization, owl pellets, Central Europe

INTRODUCTION

Limited wooded area and a high level of its fragmentation within city agglomerations are the most important factors affecting urban communities of small mammals (Gomes et al. 2011). Only few species are well adapted to live in such habitats and tolerate permanent human activity. Apart from synanthropic species like *Mus musculus* Linnaeus, 1758 or *Rattus norvegicus*, some species form urban populations together with those living in the wild. *Apodemus sylvaticus* (Linnaeus, 1758) is a synurbic species in Prague (Mikulová & Frynta 2001) and on British Isles (Wilson et al. 2016). *Apodemus agrarius* lives in some cities in Poland (Andrzejewski et al. 1978, Zalewski 1994, Łopucki & Kitowski 2017) and in Russia (Chernousova 1996, Khlyap et al. 2012) as does *Apodemus flavicollis,* which has recently colonized Warsaw agglomeration (Gortat et al. 2014, Lesiński et al. 2021).

The communities of small mammals can change due to the development of the city structures. Moreover, within-population processes sometimes lead some species to increase their tolerance to urban conditions. The tendency to inhabit cities occurs frequently when suburban populations become extremely abundant and express a high level of dispersal. This phenomenon was described for birds, e.g. *Columba palumbus* Linnaeus, 1758 (Tomiałojć 1976) or mammals, e.g. *A. flavicollis* (Lesiński et al. 2021).

Tracing long-term population changes in many species of mammals is hard and rarely possible, mostly because of their hidden lifestyle and nocturnal activity. The aim of this study was to determine the small mammal community in an urban park by using material from owl pellets, and to find out how stable the populations of each species are throughout a few decades.

STUDY AREA AND METHODS

The study was conducted in Warsaw (ca. two million inhabitants), central Poland. We used material from *Strix aluco* Linnaeus, 1758 pellets to determine small mammal community structure. This avian predator is strictly sedentary (Southern 1954, Sunde & Bølstad 2004) and opportunistic in its predation (Lesiński et al. 2008). It means that many small mammals are usually caught in proportion due to their abundance in a hunting territory.

Pellets were collected between 2016 and 2021 in a city park – Łazienki Royal Gardens situated ca. 7 km from the centre of Warsaw. Sites where pellets were collected were situated in central part (2) and north-west part (1) of the park. In each study year, 2–16 samples were collected and 11–93 mammalian prey items were found. In total, 381 vertebrate prey items were collected, including 61 birds and 315 mammals (Table 1).

Table 1. The number of samples (pellets' collections) and sample sizes (prey items) in the study period

Year	Samples	Prey items	
		Vertebrates	Mammals
2016	2	12	11
2017	3	35	25
2018	2	16	15
2019	16	101	81
2020	13	110	93
2021	9	101	90
Total	45	381	315

Undigested bones, mostly skulls of the owls' prey, were separated from soaked pellets. The key edited by Pucek (1984) and a reference collection were used to determine species of small mammals. The number of individuals was obtained from the maximum number of one of the analysed bone elements (skulls, left and right mandible bones). In a few cases other bones were taken into consideration, e.g. the arms of *Talpa europaea*.

Short-term changes in species composition and contribution of each species to small mammal community were analysed within a study period. For long-term comparisons the data published so far (Goszczyński et al. 1993, Gryz et al. 2008) were also used.

RESULTS

Eleven species of small mammals were found in the years 2016–2021 in the study area (Table 2). From among Soricomorpha group, *T. europaea*, with the share slightly exceeding 2% was only found. Chiroptera were represented by four species with the distinct domination of *Nyctalus noctula*. Two species of the genus *Microtus* were found in the group Rodentia with Microtinae. From among Murinae, owls caught: *Rattus norvegicus* (5.4% share since unidentified individuals probably belonged to this species), two species of the genus *Apodemus* being the dominants in samples with a share varying from 26.0% to 34.6%, and *Micromys minutus* (Table 2).

From among species of the genus *Apodemus*, *A. agrarius* had slightly greater share than *A. flavicollis*, and the proportion of both during the three two-years-long periods in the years 2016–2021 showed a declining tendency. Noteworthy, a small sample from the years 2016–2017 contained two times more individuals of *A. agrarius*, while in subsequent years the proportion of the number of individuals of both species approached 1:1 (Table 3). Changes in their share were quite different in the long run. The share of *A. agrarius* increased between the period 1975–1977 and 2003–2006 to reach almost 50%. In the same time *A. flavicollis* was not present in the study area. Till the years 2016–2021, the share of the latter species increased markedly with simultaneous decrease of the share of *A. agrarius*. In the last period, even more impressive decline was noted in *Microtus subterraneus* (Fig. 1).

Table 2. Small mammals captured by tawny owls in the years 2016–2021.

No.	Species	2016	2017	2018	2019	2020	2021	Total N	Total %
1.	*Talpa europaea* Linnaeus, 1758	0	0	0	2	2	3	7	2.2
2.	*Eptesicus serotinus* (Schreber, 1774)	0	0	0	0	2	0	2	0.6
3.	*Nyctalus noctula* (Schreber, 1774)	0	0	1	9	4	2	16	5.1
4.	*Nyctalus leisleri* (Kuhl, 1818)	0	0	0	0	0	1	1	0.3
5.	*Pipistrellus nathusii* (Keyserling et Blasius, 1839)	0	0	0	0	0	1	1	0.3
6.	*Microtus subterraneus* (de Sélys-Longchamps, 1836)	3	1	0	0	1	2	7	2.2
7.	*Microtus oeconomus* (Pallas, 1766)	0	0	0	2	1	0	3	1.0
-.	*Microtus* spp.	0	1	0	1	1	0	3	1.0
8.	*Rattus norvegicus* (Berkenhout, 1769)	0	0	0	0	9	4	13	4.1
-.	*Rattus* spp.	0	0	0	0	0	4	4	1.3
9.	*Apodemus agrarius* (Pallas, 1771)	3	11	7	28	19	41	109	34.6
10.	*Apodemus flavicollis* (Melchior, 1834)	2	4	5	25	32	14	82	26.0
-.	*Apodemus* spp.	3	7	0	13	24	18	65	20.6
11.	*Micromys minutus* (Pallas, 1771)	0	0	2	0	0	0	2	0.6

The differences in shares during the last decades were also found in two species of bats: *Eptesicus serotinus* and *N. noctula*. They were not noted in the years 1975–1977 while in the years 2003–2006 *E. serotinus* was being found more often. In the last period (2016–2021) the proportions reversed and *N. noctula* was recorded more frequently (Fig. 2).

Table 3. Proportion of the individuals of two mice species caught by tawny owls in the study period

Species	2016–2017	2018–2019	2020–2021
Apodemus agrarius	14	35	60
Apodemus flavicollis	6	30	46
Ratio	2.3	1.2	1.3

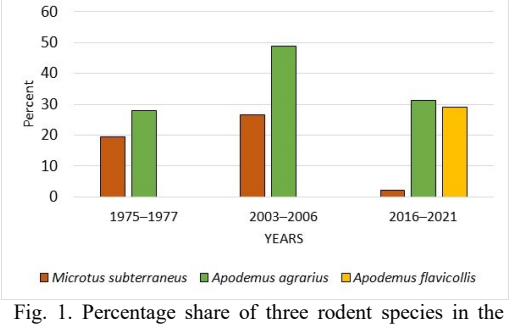

Fig. 1. Percentage share of three rodent species in the tawny owl's diet in three periods of studies in Łazienki Park; data for 1975–1977 and for 2003–2006 from Gryz et al. (2008).

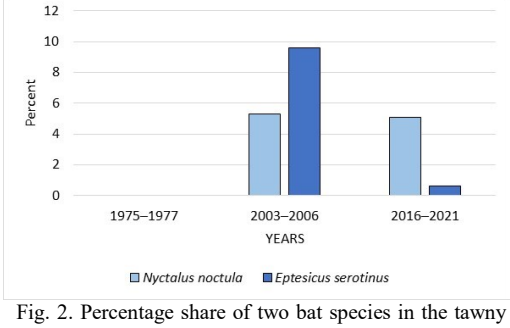

Fig. 2. Percentage share of two bat species in the tawny owl's diet in three study periods in Łazienki Park; data for 1975–1977 from Goszczyński et al. (1993), and for 2003–2006 from Gryz et al. (2008).

DISCUSSION

The analysis of the share of small mammals in the diet of opportunistic predators like owls is a good method to assess the structure of prey communities (McDonald et al. 2013, Heisler et al. 2016). The method may be particularly adequate and useful when comparing the shares of species and proportions between species in different habitats and in long-term cycles.

Wooded areas in Warsaw agglomeration are important refuges for small mammals both terrestrial (Gryz et al. 2017) and bats (Lesiński et al. 2000). Studies on communities of small

mammals in the study park were already carried out with the use of the same method. The presence of the following species: *T. europaea*, *Sorex araneus* Linnaeus, 1758, *E. serotinus*, *N. noctula, M. subterraneus*, *M. musculus*, *R. norvegicus*, *A. agrarius, A. flavicollis, M. minutus* and *Sciurus vulgaris* Linnaeus, 1758 was noted so far (Goszczyński et al. 1993, Gryz et al. 2008, Lesiński et al. 2021, J. Goszczyński unpubl. data). Studies in the years 2016–2021 supplemented the list of local species with the three next ones: *Nyctalus leisleri*, *Pipistrellus nathusii* and *Microtus oeconomus*. Taking into account unpublished data (*Myotis daubentonii* (Kuhl, 1819) caught by *S. aluco* in 1977) and observation of a hedgehog *Erinaceus* sp., one may summarise the presence in the area of 16 species belonging to: Erinaceomorpha (1), Soricomorpha (2), Chiroptera (5) and Rodentia (8).

Urban communities of rodents in Europe are variable (Chernousova 1996, Klimant et al. 2017, Łopucki & Kitowski 2017). Noteworthy, the formation of urban population of *A. flavicollis* in Warsaw, mainly in Łazienki Royal Gardens is an exceptional phenomenon. In European cities, closely related species *A. sylvaticus* is observed more frequently (Mikulová & Frynta 2001, Wilson et al. 2016).

Changes that had taken place in communities of small mammals in the study park were rapid and remarkable. The changes were mostly affected by the colonisation of Warsaw agglomeration by *A. flavicollis* (Lesiński et al. 2021). As a more effective competitor, this species led to decreasing the number of *A. agrarius*, which had much earlier become synurbic species there represented by numerous urban population in the 1970's (Andrzejewski et al. 1978). One should not exclude the negative effect of *A. flavicollis* on *M. subterraneus.* Before colonisation of the park by the first species, the second one constituted up to ¼ mammalian prey of *S. aluco* (Fig. 1). *M. subterraneus* was also characterised by declining numbers in periurban forests of Warsaw from 10.5–18.0% in the years 1976–1984 to 1.6–1.9% in the years 2005–2009. In the same time span, *A. flavicollis* markedly increased its share from 13.2–21.0% to 41.3–49.2% (Lesiński & Gryz 2012).

Observed long-time decline of the numbers of *M. musculus* in the study park is surprising. In the years 1975–1977, the species was one of the most numerous rodents (23.7% mammalian prey), while in the years 2003–2006 its share was only 3.2% (Gryz et al. 2008). In the years 2016–2021 it was not found in pellets of the tawny owl in the area (Table 2), which may suggest the proceeding decline of its numbers.

Recently, bats have been relatively often caught by *S. aluco* in urban parks (Lesiński et al. 2009). In the park under study they constituted more than 6% of mammalian prey. Noteworthy, three (*N. noctula, N. leisleri, P. nathusii*) out of four bat species noted in the years 2016–2021 belong to long-distance migrants (Hutterer et al. 2005). Two species dominating in the park (*N. noctula* and *E. serotinus*), are of similar size and often hunt in open areas (Pucek 1984). Therefore, they may compete with each other. An increase of the share of *N. noctula* in the diet of *S. aluco* noted in the last decades may reflect its increasing numbers in the whole city. Mild winters, which have been more and more frequent recently in this part of Europe make this bat species overwinter in the city built-up areas even in places poorly isolated thermally (Lesiński & Janus 2019). More common sedentary behaviour of *N. noctula* increases its survival which may manifest itself in increasing number of its urban populations. A lack of bats in samples from the years 1975–1977 probably results from the fact that mid-European bat populations showed extremely low densities in this time period (Lesiński 2010, Węgiel et al. 2021). This in turn was most probably caused by intensive use of highly toxic pesticides. It is hard to interpret the presence of *M. oeconomus* – a species associated with wetlands (Tast 1966). In the study area, the species was not noted before (Goszczyński et al. 1993, Gryz et al. 2008). Possibly, a small population (1% of mammals in the diet of *S. aluco* – Table 2) reached the park from the valley of the Vistula River (the distance of about 1 km). There are linear water bodies between the park

and the river, which might act as migration corridors for *M. oeconomus*. The species does not find appropriate habitats in the park and that is why it will probably die out.

The rate and intensity of changes in communities of small mammals in the city park suggest the necessity of long-term monitoring studies in such man-made ecosystems. Numerically dominating species of small mammals or bats may already change during one or two decades.

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STRESZCZENIE

[**Zgrupowanie małych ssaków w parku miejskim określone na podstawie diety puszczyka *Strix aluco* – jakie zmiany zanotowano w ostatnich dekadach?**]

Badania nad zgrupowaniem małych ssaków w dużym, miejskim parku Warszawy – "Łazienki Królewskie" prowadzono w latach 2016–2021. Wykorzystano metodę analizy wypluwek *Strix aluco*. Puszczyk to osiadły gatunek sowy, wykazujący cechy generalisty pokarmowego, który wyławia ofiary drobnych ssaków w proporcjach zbliżonych do ich zagęszczeń w areałach łowieckich. Z wypluwek wypreparowano 315 osobników drobnych ssaków (Tab. 1). Poza tym, wykorzystano dane publikowane z tego terenu z lat 1975–1977 oraz 2003–2006, by ocenić wieloletnie zmiany w składzie gatunkowym i udziale poszczególnych gatunków w lokalnym zgrupowaniu. Ogółem stwierdzono na tym terenie przedstawicieli 16 gatunków: jeden gatunek – Erinaceomorpha, 2 – Soricomorpha, 8 – Rodentia, 5 – Chiroptera (a w latach 2016–2021 odpowiednio 0, 1, 6 i 4 – Tab. 2). Gatunkami dominującymi były: *Apodemus agrarius* i *A. flavicollis* (pierwszy nieco licznejszy – Tab. 3). W ostatnich latach badań w parku zanotowano obecność rzadkich w mieście gatunków, jak: *Nyctalus leisleri* czy *Microtus oeconomus* (Tab. 2). W całym okresie, obejmującym ponad cztery dekady, w zgrupowaniu drobnych ssaków nastąpiły bardzo wyraźne zmiany. Trend spadkowy zanotowano w przypadku takich gatunków, jak: *A. agrarius*, *Microtus subterraneus*, *Eptesicus serotinus* i *Mus musculus*, podczas gdy dla *A. flavicollis* i *Nyctalus noctula* stwierdzono wyraźny wzrost liczebności (Ryc. 1 i 2). Szczególnie szybkie zmiany wykazano dla *A. flavicollis*, który w ostatnich latach badań stał się drugim pod względem zagęszczenia gatunkiem gryzonia w parku. Wyniki przeprowadzonych badań wskazują, że miejskie zgrupowania drobnych ssaków mogą być bardzo niestabilne, a znaczne zmiany w zagęszczeniach gatunków dominujących liczebnie mogą się dokonywać w okresie kilku dekad.

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