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The small mammals of Warsaw as inferred from tawny owl (*Strix aluco*) pellet analyses

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In order to estimate small mammal diversity in Warsaw we analysed pellets of tawny owls inhabiting green areas. Altogether we found 21 species of mammals (9 species in the city centre and 19 on the outskirts). In the central zone the largest share was comprised of striped field mouse, house mouse and rats, while species connected to forest and open areas dominated in the outskirts.

Introduction

Where technical problems and the intensive human use of urban green space leave traditional methods of detecting small mammals (like traps and nets) difficult to apply, analyses of owl pellets can offer an alternative source of data on the abundances and local distributions of small mammals (Yalden & Morris 1990, Clark & Bunck 1991, Moreno & Barbosa 1992, Love *et al*. 2000, Balčiauskienė 2005).

The tawny owl is the only member of the *Strigiformes* to nest regularly in the city-centre area of Warsaw (Luniak 1996). It can breed in various habitats, including suburban forests, cemeteries, city parks, roadside alleys and abandoned buildings. The tawny owl is a dietary generalist (Goszczyński 1974, 1981), differing from other owl species in its relatively broad food niche and capacity to hunt prey of sizes ranging from bats *Chiroptera* weighing a few grams (Lesiński 2006) to rabbits *Oryctolagus cuniculus* (Zalewski 1994) and muskrats *Ondatra zibethicus* (Wasilewski 1990). Its diet thus varies, reflecting the availability of prey (Mikkola & Willis 1983), as well as the species composition of small and medium-sized mammals present in a given area.

The tawny owl is a non-migratory, territorial species. Territory sizes relate to the abundance of prey, with this being mediated by habitat fertility and landscape structure. While radio tracking studies on the tawny owl have provided a wealth of data on territory size (Redpath 1995, Sunde *et al*. 2001, Sunde & Bølstad 2004), none of the studies has hitherto been carried out in an urban area. However, our own nocturnal observations and playback surveys suggest a territory size of less than 0.3 km^2 in the city centre (J. Gryz unpubl. data), implying that all prey items found in owl pellets would have been caught within a few hundred meters of the breeding site. Moreover, as the tawny owl is a typically nocturnal species, hunting coincides with the highest levels of activity among most mammals.

The aim of the work described here was thus to assess the diversity of small mammals in

central and outlying areas of Warsaw by verifying a hypothesis that in line with the increasing urbanization within the city limits:

1. the share of insectivores and species connected with forest and open areas will decrease,
2. the share of synantropic species as well as of the striped field mouse *Apodemus agrarius,* regarded by some authors as a synurbic species (i.e. Andrzejewski *et al*. 1978), will increase, and
3. the diversity of the small mammal assemblage will decline towards the city centre.

We were further able to compare the results of these studies with data obtained from the 1970s (Goszczyński *et al*. 1993, J. Goszczyński unpubl. data), to see whether ongoing urbanization of the city has affected small-mammal assemblages.

Study area and methods

We conducted our study in the capital of Poland, between November 2003 and October 2006. Warsaw covers 517.9 km^2 and has more than 1.7 million inhabitants. Built-up areas account for 47% of the area, arable land and orchards for 32.7%, forests for 14.7% and waters for 3.3% of the total area.

To estimate the composition of small-mammal assemblages, we selected 19 territories of tawny owls, from which pellets were collected at least once a month over a 4-year period. Eight of the territories were situated in the central zone (in districts with most inhabitants), and eleven on the outskirts of Warsaw. Tawny owl territories were located in municipal parks, cemeteries and woodlands.

To indicate changes in the small mammal fauna that might have occurred since the 1970s, we selected one site from which sufficient numbers of pellets were collected in both study periods to allow for statistical comparisons. It appeared that the most suitable site for this was Łazienki Park, which is located in the city centre. Its area of ca. 80 ha has not been subject to any major changes, as it has been protected as an item of national heritage. Furthermore, the relative constancy to the distribution of owl territories allowed for the collection of pellets in virtually the same places as in the 1970s.

We analysed pellets collected by following a standard procedure involving the identification of prey species consumed on the basis of the skulls found. Laboratory analyses of the material mainly relied upon the key from Pucek (1981), and other papers (Ruprecht 1979, 1987, Wolf *et al*. 1980, Balčiauskienė *et al*. 2002). However, reference was also made to specimens from skulls held by the Division of Forest Zoology and Wildlife Management of the Warsaw University of Life Sciences.

Altogether we collected 886 pellets, from which the remains of 569 mammals were identified (173 from the central zone and 396 from the outskirts). In total 509 mammals (153 and 356 from the central zone and the outskirts, respectively) were identified to species level. Mammals for which identification to species level proved impossible were not included in calculations of species diversity. However, prey items identified to the level of the order or genus (*Insectivora*, *Microtus* or *Rattus*) were used to test the first and the second hypotheses.

The Shannon-Wiener diversity index was calculated using base 10 (Krebs 1994).

Statistical analyses included a test for the comparison of two percentages (Bailey 1995) and the Mann-Whitney-Wilcoxon test.

Results and discussion

Altogether, the remains of 21 species representing four orders were collected: *Rodentia*, *Insectivora*, *Chiroptera* and *Carnivora* (Table 1). The number of mammal species identified was twice as high in the outskirts of Warsaw as compared with that in the central zone (19 and 9 species, respectively). Rodents were caught most often (accounting for 467 of the prey items), with the greatest shares being accounted for by the striped field mouse and the yellow-necked mouse *Apodemus flavicollis*.

The composition of the small-mammal assemblages in the central and outlying parts of Warsaw differed markedly (Table 2). In line

with our assumptions, the striped field mouse was caught more often in the central zone. As far as synanthropic species are concerned, we confirmed that rats *Rattus* spp. were more numerous in the central zone. However, in the case of the house mouse *Mus musculus* — also regarded as synathropic — the difference was not significant. Neither forest species like the yellow-necked mouse and the bank vole *Myodes glareolus*, nor species of open areas like the common vole *Microtus arvalis*, the root vole *M. oeconomus* and the field vole *M. agrestis* were collected from the central zone. Insectivores were only represented by the mole *Talpa europaea*, altogether supported our first hypothesis (Table 2). Similar differences (with the exception of *Rattus* spp., where there was no significant difference) between central zone and the outskirts were found when we compared mean percentage shares from separate territories, by means of the Mann-Whitney-Wilcoxon test. Species diversity calculated using the Shannon-Wiener index was higher in the outskirts (1.15) than in the central zone (0.55).

Significant changes in abundance and range size in comparison with the 1970s were found in the striped field mouse, house mouse, mole and bats (Table 3). The percentage of house mice in the diet of tawny owls is currently significantly lower than in the past, probably because this species continues to decrease in abundance in the central zone. Live-trapping studies conducted in Warsaw confirm this view (Andrzejewski *et al*. 1978, Cichocka 2003). We also registered an increase of percentage share of field striped

Table 1. Mammals in the diet of the tawny owl in Warsaw.

Prey	Species number	Species present	
		Central zone	Outskirts
Apodemus agrarius		89	42
Apodemus flavicollis		–	105
Apodemus spp.		12	27
Mus musculus		6	7
Micromys minutus		3	7
Rattus norvegicus		8	10
Rattus spp.		5	–
Microtus arvalis		–	29
Microtus oeconomus		–	8
Microtus subterraneus		25	9
Microtus spp.		–	10
Arvicola terrestris		–	1
Myodes glareolus		–	63
Sciurus vulgaris		1	–
∑ Rodentia	11	149	318
Talpa europaea		7	25
Sorex araneus		–	28
Sorex minutus		–	2
Sorex spp.		–	3
Erinaceus concolor		–	1
Insectivora indet.		3	–
∑ Insectivora	4	10	59
Nyctalus noctula		5	9
Myotis nattereri		–	6
Myotis daubentonii		–	1
Eptesicus serotinus		9	–
∑ Chiroptera	4	14	16
Mustela nivalis		–	2
Mustela vison		–	1
∑ Carnivora	2	0	3
∑ Prey		173	396
∑ Species	21	9	19

Table 2. Small mammal assemblage on the basis of pellet analyses.

Prey	All items			Selected territories	
	Central zone (%)	Outskirts (%)		Central zone (% ± SD)	Outskirts (% ± SD)
Apodemus agrarius	75.4	12.6	$p < 0.001$	82.5 ± 15.1	14.0 ± 8.4
Apodemus flavicollis	0	31.5	$p < 0.001$	0 ± 0	28.2 ± 18.9
Mus musculus	5.1	2.1	$p > 0.05$	3.4 ± 4.2	2.5 ± 2.6
Rattus spp.	11.0	3.0	$p < 0.01$	7.7 ± 6.8	3.5 ± 5.0
Myodes glareolus	0	18.9	$p < 0.001$	0 ± 0	17.4 ± 10.3
Microtus spp.*	0	14.1	$p < 0.001$	0 ± 0	15.8 ± 11.1
Insectivora	8.5	17.3	$p < 0.01$	6.4 ± 7.3	18.5 ± 5.5
Total mammals	118	333		118	329

*without *Microtus subterraneus.*

Table 3. Small mammal assemblage in Łazienki Park (central zone) in the two periods.

Prey	1975–1977*		2003–2006		
	Percentage	*n*	Percentage	*n*	
Apodemus agrarius	27.9	26	48.9	46	$p < 0.01$
Mus musculus	23.7	22	3.2	3	$p < 0.001$
Rattus norvegicus	7.5	7	5.3	5	$p > 0.05$
Microtus subterraneus	19.4	18	26.6	25	$p > 0.05$
Talpa europaea	21.5	20	1.1	1	$p < 0.001$
Chiroptera	0	0	14.9	14	$p < 0.001$
Mammals total		93		94	

*Goszczyński *et al.* 1993, J. Goszczyński unpubl. data.

mouse in the diet of tawny owl. This is in line with the latest live-trapping studies form Warsaw, which showed clear dominance of this species in the small mammal assemblage of city parks in the centre of Warsaw (Cichocka 2003, J. Babińska-Werka pers. comm.). We noticed lower numbers of moles being caught by owls in Łazienki Park, a fact which may readily be ascribed to persecution (the introduction of new methods of eradicating moles and efforts to prevent them from forming molehills on lawns), as well as the likely isolation of the population. In Poland, bats have tended to increase in numbers over the last few decades, so a greater share of this group in the diet of tawny owls is in line with the general trend (Lesiński *et al*. 2008).

As we are aware that seasonal and local differences in the prey composition of the tawny owl could influence our results, to make the material comparable we collected pellets seasonally and at the same time in the two zones (in each of them in many territories located in diverse habitats). Therefore, we believe that our data show a reliable view of the differences between diet composition of the tawny owl population both in the outskirts and in the city centre.

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