Does the diet of an opportunistic raptor, the tawny owl *Strix aluco*, reflect long-term changes in bat abundance? A test in central Poland

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Abstract. The hypothesis tested concerned whether the diet of the tawny owl *Strix aluco*, as an opportunistic predator, does reflect increases in the density of bat populations in the owl's hunting areas. In our study area, there was a mass use of toxic pesticides during which numbers of bats declined drastically, after which recoveries in the populations of most European species occurred. Thus, in Poland, numbers of bats reached their lowest levels in the 1980s. We examined the diets of tawny owls in Warsaw and the adjacent Kampinos Forest of central Poland, based on the remains of 9142 prey items. Bat specimens were found to comprise the following percentages of all vertebrate prey items: 1976–1989: 0.03–0.14%, 1990–1999: 0.32–0.40%, and 2000–2007: 0.54–1.71%. If the share taken by bats among mammalian prey is in turn considered, the analogous figures are 0.09–0.17%, 0.45–0.99% and 0.92–3.26%. Patterns in owl diets were consistent with trends in bat numbers at 15 large winter roosts located some 10–50 km from the study area in 1989–2006.

Key words: Chiroptera pellets, populations trends, city, winter roosts

Introduction

The long-term tracking of changes in bat populations is difficult, as accurate methods for evaluating the density of populations are lacking, and methods available are very labour-intensive (Thomas & LaVal 1988). However, one of the indicators of bat population abundance could be the proportion of Chiroptera accounted for in the diet of opportunistic predators. The validity of this pattern is based on the assumption that such predators take incidental prey items at a frequency correlated (within certain limits) with that prey's availability in their hunting area.

Most owls are dietary generalists, tending not to restrict themselves to a single species or narrow range of prey (Anderson & Erlinge 1977). Furthermore, the tawny owl *Strix aluco* has been found to show dietary adaptability, dependent on the availability of prey (Goszczyński 1981, Balčiauskienė & Naruševičius 2006). Additionally, Jędrzejewski at al. (1994) emphasize the marked dependence of forest-dwelling tawny owls on small rodents, the supplementation of this diet with other animal groups only occurring when rodent populations are at a low density. Bats occur relatively rarely in the diet of tawny owls, normally accounting for less than 1% of prey items (Southern 1954, Southern & Lowe 1968, Ruprecht 1979, Mikkola

1983, Yalden 1985, Goszczyński et al. 1993, Obuch 1998, Kowalski & Lesiński 2002, Obuch 2003). Nevertheless, an opportunistic element to the hunting and consumption of bats by tawny owls is evidenced by several examples. Specifically, (1) in Germany, in the vicinity of a large winter colony of the greater mouse-eared bat *Myotis myotis*, remains of six individuals were among specimens of 16 prey items present in more than a dozen tawny owl pellets (Gauckler & Kraus 1963); (2) in Poland, the presence of a large (over 1500 bats) winter colony of bats apparently caused owls to hunt for them frequently, such that Chiroptera made 21.9% of the overall vertebrate prey items (n = 425) (Kowalski & Lesiński 1990); (3) in England, where bats comprised 7.5% of captured vertebrates (n = 1052), for one owl that likely found large maternity colonies of bats (Julian & Altringham 1994); (4) in Slovakia, where some sub-fossil or recent pellet samples collected near cave entrances suggested a high proportion of bats in the diet (Obuch 1998).

The accepted method of estimating long-term changes in bat populations involves an annual census performed in large underground winter roosts. In our study area, the bat populations have been influenced by the use of highly-toxic pesticides with the sharp decline that had taken place in the 1970s. Studies carried out in caves in southern Poland from the 1950s through to the present day confirmed that bat populations were lower in the 1980s than at any other time (Węgiel et al. 2001). The results of censuses at the end of the 20^{th} century show a clear rebound in the populations of many species in Poland (Kowalski & Lesiński 1991, Fuszara & Jurczyszyn 2002, Lesiński et al. 2005), as well as in many other countries of Central and Eastern Europe (Zima et al. 1994, Řehák & Gaisler 1999, Lutsar et al. 2000, Gaisler & Chytil 2002). Because all bat species residing in Poland are insectivorous, the upward trend is most likely due to reduced contamination of the environment, this applying, not only to species recorded in winter roosts but also to entire bat assemblages.

Therefore, we propose that the tawny owl‘s status as an opportunistic predator should result in bats caught in proportion to their abundance in the hunting area used by owls. Specifically, we predict increases in bats in the diets of owls during recent decades. Were this to be the case, the corollary might also apply, inasmuch as that analyses of the diets of tawny owls could be employed as an alternative method of monitoring long-term changes in bat numbers.

Material and Methods

The work entailed an analysis of the diets of tawny owls in central Poland. Material for this was collected in Warsaw (in parks and peripheral forests within the city limits, including an area of approximately 500 km^2), as well as in the adjacent Kampinos Forest (ca. 400 km^2). Specifically, use was made of data published by Goszczyński et al. (1993) collected between 1976 and 1984 at 11 sites in Warsaw and 13 sites in the Kampinos Forest. Reference was made to a total of 4694 items of vertebrate prey (all sites combined). Additionally, pellets collected at 15 sites across Warsaw in the period 1985–2007 yielded 2130 vertebrate prey items (bats were found at 7 sites: 14 per 244 vertebrate items, 7/224, 7/430, 1/161, 1/166, 1/281, 1/386 and 8 sites without bats) while 27 sites in the Kampinos Forest gave 2318 items of prey for analysis (bats were found at 3 sites: 9 per 1178 vertebrate items, 1/138, 1/117 and 24 sites without bats. The overall sample comprised remains from 9142 preys taken by tawny owls.

Our data were compared with long-term census data obtained from bats' winter roosts. The current studies also drew on work done between 1989 and 2006 in a complex of 15 large underground roosts at the Modlin Fortress some 10–50 km from the study area (Fuszara & Fuszara 2002, Fuszara E. & Fuszara M., pers. comm.). Bats were counted in February, with no removal from shelter walls taking place. These winter habitats attract bats from over a large area, including part of the study area, as was demonstrated by the presence of a ringed representative of a relatively sedentary species, i.e. a brown long-eared bat *Plecotus auritus* previously present in nesting boxes in the Kampinos Forest some 26 km away (Kowalski et al. 2002).

To estimate the statistical significance of differences between numbers of bats and of other kinds of prey taken, the χ^2 test was used, applying a significance level of $P = 0.05$.

Results

Only small numbers of bats (46 of 9142 preys) were present in the diets of tawny owls living within the study area. At most, bats represented 1.71% of the individual items of vertebrate prey for tawny owls (up to 3.26% of the mammalian prey). However, in the cases of both Warsaw and the study area as a whole, significant differences were noted when data from different years were compared. There were clearly higher frequencies of bats in the diets of tawny owls in the years 1990–2007. These differences were statistically significant in relation to owls of the Kampinos Forest where the share of all mammalian prey accounted for by bats was considered, though in the case of vertebrate prey the trend to changes was similar (Table 1).

An upward trend for the numbers of bats wintering at the Modlin Forts was also noted, there being a several-fold increase overall in the study period. Thus, there was an association between the numbers of hibernating bats and the frequency of bats found in the owl diets (Fig. 1).

Discussion

Data from the literature indicate that the tawny owl is a dietary generalist whose diet has a composition related to the densities of potential prey items available at a given time (Goszczyński 1981). This is also seen in large differences in dietary composition between owls inhabiting diametrically different environments. Thus, in urban areas, there is a greater share of birds in the owl diet (Goszczyński et al. 1993), while in agricultural areas it is the role played in the diet by the common vole *Microtus arvalis* that is greater (Goszczyński 1981).

Our data confirms opportunistic predation behaviour of the tawny owl in regard to bats also, the availability of prey in hunting areas being reacted to, in respect, not only of large concentrations (Gauckler & Kraus 1963, Kowalski & Lesiński 1990, Julian & Altringham 1994), but also of changes in the density of entire assemblages. Tawny owl pellets collected in the Toruń area between 1988 and 1990 revealed that only 0.16% of the vertebrate animals preyed upon were bats (Zalewski 1994). This result coincides with one obtained for a similar period and similar environments in and around Warsaw (Table 1), providing further support for the hypothesis being tested here.

Likewise capable of being interpreted in such a light are the results of studies on the dietary composition of barn owls *Tyto alba,* based on studies carried out 20 years apart

Table 1. Comparison of the share of bats in the tawny owl diet during three study periods n – total number of prey items, n_b – number of bats.

Prey items	Warsaw									
	1976–1989			1990–1999			2000–2007			Difference d.f. = 2
	n	n_b	%	n	n_b	%	n	n_b	%	
Vertebrates	3253	1	0.03	315	1	0.32	1814	31	1.71	$\chi^2 = 54.3$, $P < 0.001$
Mammals	1142	1	0.09	224	1	0.45	951	31	3.26	$\chi^2 = 38.9$, $P < 0.001$
	Kampinos Forest									
	1976–1989			1990–1999			2000–2007			Difference d.f. = 2
	n	n_b	%	n	n_b	%	n	n_b	%	
Vertebrates	1477	2	0.14	997	4	0.40	1286	7	0.54	$\chi^2 = 3.5$, NS, $P = 0.178$
Mammals	1191	2	0.17	404	4	0.99	761	7	0.92	$\chi^2 = 6.5$, $P < 0.05$
	Total									
	1976–1989			1990–1999			2000–2007			Difference d.f. = 2
	n	n_b	%	n	n_b	%	n	n_b	%	
Vertebrates	4730	3	0.06	1312	5	0.38	3100	38	1.23	$\chi^2 = 51.0$, $P < 0.001$
Mammals	2333	3	0.13	628	5	0.80	1712	38	2.22	$\chi^2 = 47.9$, $P < 0.001$

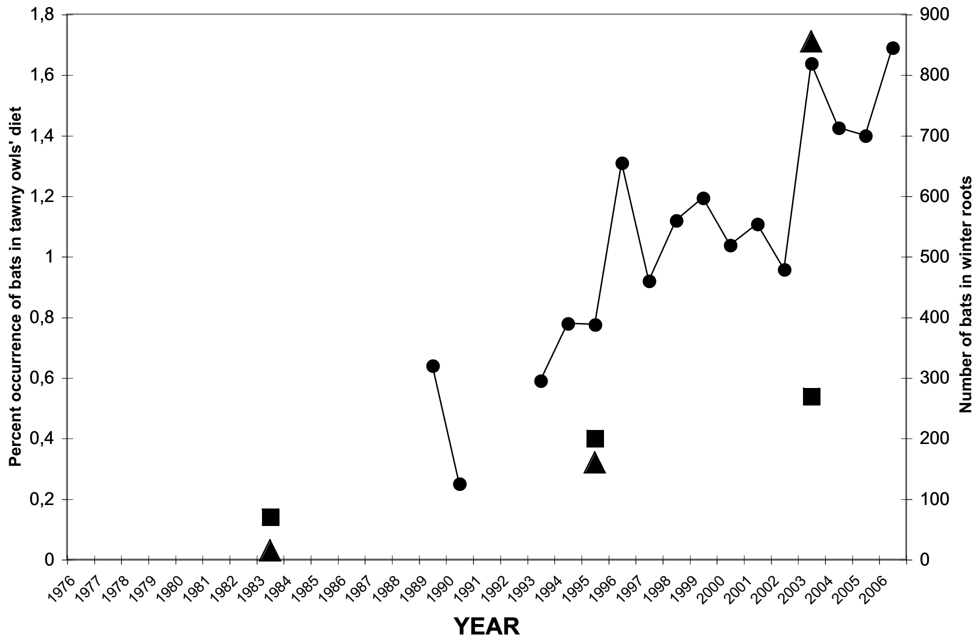

Fig. 1. Changes in the percentage share of bats among vertebrates in the tawny owl diet (triangles - Warsaw, squares - Kampinos Forest, the values are marked in the middle of each study period) in comparison with changes in bat numbers (circles) in the winter roosts located in the vicinity of the study area (Modlin Forts – Fuszara & Fuszara 2002, and unpublished data).

at a site in western Poland (B e k a s i ń s k i et al. 1996). Material sampled in the 1960s (i.e. before bat numbers declined so drastically) revealed that 0.59% of all the individual vertebrate animals captured (n = 2212) were bats. In contrast, the sample of consumed prey from the early 1990s (just after bat populations had crashed; W ę g i e l et al. 2001) only had 0.07% of bats (n = 2787). Data from P é r e z - B a r b e r í a (1991) also indicated that barn owls react to the density of bat populations and the availability of bats on a wider scale. Extending considerations to Spain and Western Europe, the same author found that bats accounted for ever lower shares of the diet among owls living at higher and higher latitudes, an observation explicable in relation to declining population densities, and successively shorter periods of the year in which bats are active.

The results presented support the contention that bats taken in the diets of tawny owls (and most likely also individuals of other owl species, e.g. the barn owl) are of auxiliary value when it comes to evaluating changes in abundance within local bat assemblages. A limitation to the approach obviously concerns the need for rather extensive and reliable material to be collected. Repetition at similar locations plus comparisons with the results of previous analyses in turn allow an approximate picture of general trends in bat populations to be gained.

We cannot predict whether or for how long the abundance of bats in the study area will continue to increase. If the present trend is maintained, the share of bats in the diet of tawny owls seems likely to increase further. Samples from southern Poland obtained in the 1950s and 60s (i.e. clearly before the onset of massive declines in bat numbers) indicated that 2.0–3.7% of all vertebrates taken were bats (C a i s 1963, K u l c z y c k i 1964). These might be the highest achievable frequencies of bats in tawny owl diets, bearing in mind the unlikely circumstance of bat populations rebounding fully to the level existing 50 years ago. Furthermore, the capture of bats is more demanding than that of other types of prey, such that rodents will likely always represent the primary component in the diets of the tawny owl.

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