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Feeding ecology of Long-eared Owls in winter: an urban perspective

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Suggested short title: **Diet of urban Long-eared Owl**

Capsule. Although considered as a specialist predator of *Microtus* voles, the Long-eared Owl *Asio otus* may adapt its diet according to the local prey availability. We reviewed the diet of this nocturnal raptor in urban environments during the winter, using studies which reported the ingested biomass relating to different prey categories and so energy intake could be considered. The species was confirmed to feed mainly on *Microtus*, but in some area rats dominated the ingested biomass.

KEYWORDS: *Asio otus*, cities, diet, biomass, *Microtus*, rats

Urban areas are exponentially expanding throughout the world (McDonald 2008; Ferenc *et al.* 2014) and buildings are progressively replacing and fragmenting natural habitats (Turner *et al.* 2004; Marzluff *et al.* 2008). Urban parks and green patches may constitute the only natural remnants providing refuges for wildlife within anthropogenic habitats (Cornelis & Hermý 2004; Grimm *et al.* 2008). Herbivorous, scavenging and omnivorous synanthropic species seem to be more successful and rapid in establishing populations in cities compared to carnivorous ones (Zalewski 1994a; Cavia *et al.* 2008; Ferenc *et al.* 2014). Nevertheless, bird species that eat rodents attracted to urban areas may be able to exploit this opportunity. The clustering of rodent species in an urban area depends on the distance from the nearest patch of natural/seminatural vegetation (Baker *et al.* 2003). Rats and house mice, as well as other introduced species, are often the most abundant within and in the surroundings of city centres, cemeteries, urban parks and industrial areas (Bertolino *et al.* 2004; Cavia *et al.* 2008; Martinoli *et al.* 2010). Once established, populations of pioneer potential prey may rapidly increase and spread, if resources are sufficient, even becoming pests (Capizzi *et al.* 2014). Such high concentrations of prey may attract avian predators, mainly generalist feeders (Zalewski 1994b; Dinetti & Fraissinet 2001; Morey *et al.* 2007).

The Long-eared Owl *Asio otus* is a medium sized owl, widely distributed all over the Holarctic region: from Japan to North America throughout Eurasia and Northern Africa (BirdLife International 2012). This species typically live in open areas characterized by the presence of scattered trees used for roosting. It can colonize human environments, i.e. parklands, urban gardens and tree-lined alleys, probably helped by the availability of abandoned nests of Corvids, such as Common Magpie *Pica pica* (Lövy & Riegert 2013) and Hooded Crows *Corvus cornix* (Koop & Berndt 2014). Local densities of this species may be high during the winter in some urban areas (Otto 2009; Sharikov *et al.* 2010; Fabian & Schimkat 2012) and up to 75-100 specimens can be observed sharing the same roost, especially during the winter (Cramp 1985; Pirovano *et al.* 2000; Lövy & Riegert 2013). The rising numbers of this nocturnal raptor in urban environments (also during the breeding season) may have also been helped by population explosions of small rodents, e.g. *Apodemus sylvaticus* in Bruxelles (Dinetti & Fraissinet 2001). The Long-eared Owl is considered a

feeding specialist (Cramp 1985; Cecere & Vicini 2001; Tome 2009), but it can change prey species too (Bertolino *et al.* 2001; Mori *et al.* 2014). Voles and mice represent the staple of its diet, but, when access to ground-dwelling rodents is denied, e.g. by snow, Long-eared Owls may extend their diet to birds (Canova 1989; Bertolino *et al.* 2001).

Although a review of the general diet of the Long-eared Owl has been previously carried out by Birrer (2009), in this paper we summarize the diet of the species concentrating on urban areas in order to investigate how it has adapted its diet to these environments (Sharikov *et al.* 2010; Lövy & Riegert 2013). We compared the percentages of ingested biomass of different prey categories, to avoid overestimating the importance of small prey and underestimating the relevance of heavier prey, which is typical of studies based only on frequency of occurrence. We further evaluated if there was spatial or temporal variation in the diet.

The analysis was carried out by assessing studies on online databases (i.e. ISI Web of Science, Scopus, Zoological Records, Google Scholar). Search terms included all possible combinations of these words: Long-eared Owl, or *Asio otus*, and feeding ecology, diet, city, urban environment. Additional studies were located by analyzing the reference lists of all the collected studies and reviews, and by searching those of interest on Google Scholar. A MSc thesis (Sciolla 2002) from the University of Turin, supervised by one of the authors (SB), was also included in the analysis. We defined urban areas as a location dominated by human-built features in comparison to the areas surrounding it. We retained all studies carried out in big cities (city centers and suburbs), or concerning roost sites located at least 500 meters away from the nearest natural environment; the hunting area of the Long-eared Owl covers an average radius of about two kilometers around the roost (Cramp 1985), although home ranges in urban areas may be larger than in suburban ones (Lövy & Riegert 2013). Only one study from the breeding period was found, therefore we carried out our analysis only for wintering owls.

We grouped the components of the diet into seven prey categories, according to those mainly represented in the analyzed studies: *Arvicola* spp., other Cricetidae, *Rattus* spp., other Muridae, other mammals, birds and insects. Food-niche breadth was measured through the standardized Levins index (Feinsinger *et al.* 1981): $B = 1/(R \cdot \sum p_j^2)$, where R represents the number of food categories and p_j is the proportion of the “j” food category consumed. The Czekanowski index was calculated to estimate dietary overlap for relative biomass [$D = 1 - (1/2) \cdot (\sum |p_{ij} - p_{ik}|)$]. Variations between the proportion of the main taxa identified and the food-niche breadth in different areas were evaluated using Spearman’s rank correlation. Optimal-foraging theory predicts that a predator will feed on the most cost-effective prey to maximize its energy intake per unit time; thus, its food niche gets narrower when the main prey is more common, while it becomes broader when the main prey are scarce (Lacher *et al.* 1982; Pyke 1984).

A hierarchical cluster analysis was carried out to identify homogeneous subgroups of feeding aggregations (Quinn & Keough 2002) by study areas. The similarity matrices obtained with the Percent Similarity index were entered in the cluster analyses through the UPGMA (unweighted pair-group method, using arithmetic averages) method. The output dendrogram was visually inspected to evaluate diet similarity among studies. Furthermore, differences in linear distances between roosts and the nearest natural or seminatural environment between clusters identified by this dendrogram were evaluated through the Mann–Whitney *U*-test, to verify whether owls preying mainly on different species roost at different distances from natural environments.

Eight studies included data on ingested biomass in urban areas and thus were retained for the analysis (Table 1). All these studies were carried out for a single year, apart from Martelli & Fastelli (2013), who collected pellets for two consecutive winters; in this case we used the

total amount of data reported by the authors, since no difference in composition of prey taxonomic category was detected between the two years of sampling. The cluster analysis identified two clusters (Fig. 1). The first group included diets very similar one to another (mean \pm SD niche overlap with pairwise comparisons: 0.73 ± 0.10) and dominated by small Cricetidae, mainly *Microtus arvalis* (Romanowski 1998; Laiu *et al.* 2002; Dziemian *et al.* 2012); the second one was more heterogeneous (mean niche overlap: 0.49 ± 0.24), with a prevalence of rats (*Rattus* spp.: 23.5%-65.1%). No significant difference between clades was found in the distance from the roost to the border of the urban area (Mann–Whitney $U = 9$; $p = 0.25$). Other Muridae (*Mus musculus* and *Apodemus* spp.) represented the main prey category for the study by Martelli & Fastelli (2013): these species are only secondary prey in other studies.

The ingested biomass of *Rattus* spp. increased in areas with a lower consumption of other Cricetidae ($r_s = -0.93$, $N = 10$, $p = 0.00014$). The food-niche breadth ranged from 0.22 to 0.58 (Table 1). The ingested biomass of other Cricetidae (mainly *Microtus* spp.) was inversely correlated with the trophic niche breadth ($r_s = -0.77$, $N = 10$, $p = 0.012$); conversely, rats were positively correlated with the trophic niche breadth ($r_s = 0.68$, $N = 10$, $p = 0.03$).

Long-eared Owls fed mainly on *Microtus*, but in some areas rats dominated the ingested biomass. The food spectrum of this nocturnal raptor in natural habitats has been extensively reported, and also reviewed by Birrer (2009) who compared the frequencies of occurrence of prey classes: mammals constitute over the 90% of prey items, with voles (*Microtus* spp.) being the most common. Voles belonging to the genus *Microtus* are typical of open areas and edges of woodlands, which represent the main habitat used by Long-eared Owl for hunting (Wijnandts 1984; Cramp 1985; Lövy & Riegert 2013). The remaining green *refugia* within city areas allow urban owls to hunt small mammals: usually rodents typical of open areas and/or generalist species, e.g. *Microtus* voles and *Apodemus sylvaticus*, or commensal species of the genus *Rattus*. We confirmed Cricetidae (mainly *Microtus* spp.) as the favoured prey in the diet of Long-eared Owl also in urban environments, having the highest significant negative correlation with food-niche breadth. In some study sites rats represented the most important prey, while *Microtus* voles were a second choice (Bezzel 1972; Laiu & Murariu 1998; Pirovano *et al.* 2000; Sciolla 2002). Rats may be more profitable prey with respect to *Microtus* spp., because they are larger and heavier than voles (Pirovano *et al.* 2000). However, the cost of catching them could be high and the balance between cost and benefit has not yet been quantified. According to our analysis, *Microtus* species are the main prey of the Long-eared Owl in urban habitats, while rats should be considered as important alternative prey.

Linear distances between roosts of owls feeding mainly on small Cricetidae and the border of the urban areas were not significantly different with respect those of owls eating mainly rats. Thus, *Microtus* may represent the main prey both in suburbs (Romanowski 1988) and in city centers (Laiu *et al.* 2002; Dziemian *et al.* 2012), where they can live in urban green areas, as well as rats. Only Martelli & Fastelli (2013) found other Murids (*Apodemus sylvaticus* and *Mus musculus*) as the main prey category. The genus *Arvicola* also includes large species, but is poorly represented in the diet of urban Long-eared Owls, probably because they are not common in urban areas and are mainly active during the day (Pita *et al.* 2011). In natural environments, birds may represent an important component of the Long-eared Owl diet during the breeding period, while in winter they are probably exploited in case of deep snow cover, when access to ground-dwelling rodents is denied (Wijnandts 1984; Canova 1989; Bertolino *et al.* 2001). In our review, birds were significantly represented in three studies (Bezzel 1972; Laiu & Murariu 1998; Martelli & Fastelli 2013).

Our results provide an insight into the diet of Long-eared Owls in European cities over multiple sites. The species is generally considered as a specialist feeder, although able to exploit different food categories which are locally abundant. *Microtus* voles were confirmed

to be the main prey caught by this nocturnal raptor, because these rodents are able to colonize the few remaining green areas within urban centers (Wijnandts 1984; Birrer 2009). Moreover, when predominant, they count for more than 80% of the ingested biomass: therefore, diets characterized by a high prevalence of *Microtus* voles are all similar to each other. Rats represent alternative prey in urban areas, but they rarely exceed 50% of the ingested biomass (see Table 1), thus resulting in more heterogeneous diets for the owls. To clarify the role of rats in the energy budget of the Long-eared Owl, further researches should compare prey importance with their availabilities in urban areas and in their surroundings.

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Table 1. Prey biomass and Levins index of the diet of *Asio otus* in the studies included in the analysis. The number of prey individuals is given in brackets, near the name of the study. CC, city centre; SU, suburb.

Study (number of prey)	Country	Type of study site	Biomass (%)							Levins index (B)
			<i>Arvicola</i> spp.	Other Cricetidae	<i>Rattus</i> spp.	Other Muridae	Other Mammals	Birds	Insects	
Martelli & Fastelli 2013 (159)	Italy	CC	0.0	0.0	5.1	73.7	0.0	21.1	0.1	0.24
Pirovano <i>et al.</i> 2000 (2760)	Italy	CC	1.1	9.5	65.1	20.0	0.3	4.0	0.0	0.35
Laiu & Morariu 1998 (1025)	Romania	CC	0.0	4.7	53.2	19.5	0.0	22.6	0.0	0.45
Sciolla 2002 (580)	Italy	SU	2.2	32.9	27.3	34.9	0.4	2.3	0.0	0.55
Bezzel 1972 (334)	Germany	CC	2.0	33.0	23.5	11.0	0.5	30.0	0.0	0.54
Laiu <i>et al.</i> 2002 (741)	Romania	CC	0.0	62.0	0.0	32.8	0.2	5.0	0.0	0.29
Romanowski 1988 (1113)	Poland	SU	0.4	86.3	0.4	6.7	0.1	6.1	0.0	0.22
Dziemian <i>et al.</i> 2012 (1976)	Poland	CC	2.4	81.5	0.0	15.79	0.05	0.25	0.01	0.24

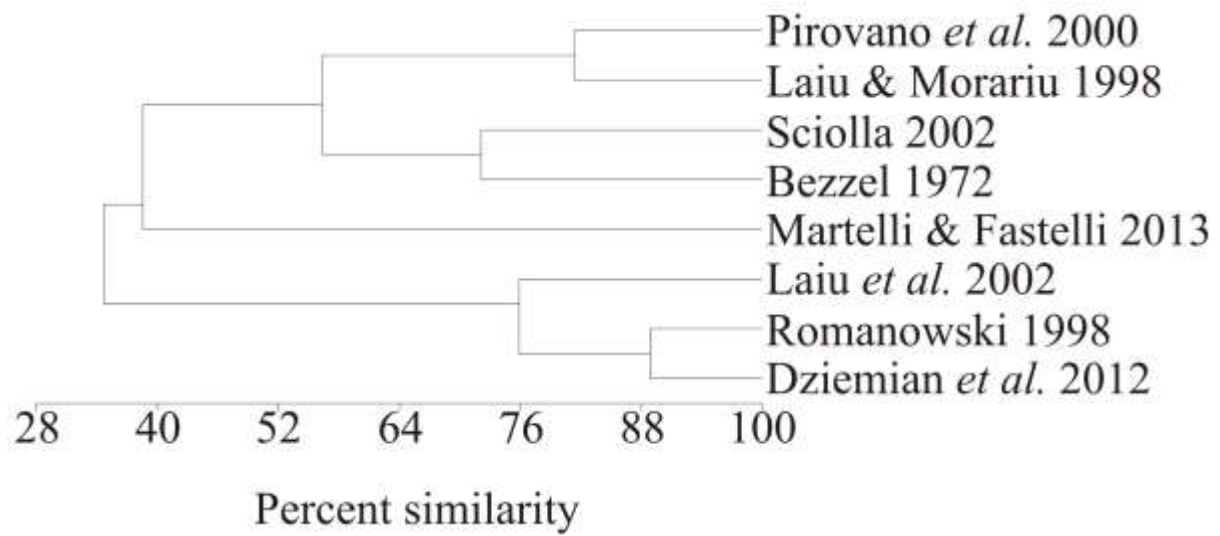


Figure 1 Dendrogram resulted from cluster analysis using the percentage similarity of relative biomass frequency and the UPGMA method, with prey grouped into seven main categories.