'Some like it alien': predation on invasive ring–necked parakeets by the long–eared owl in an urban area

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Abstract

'Some like it alien': predation on invasive ring–necked parakeets by the long–eared owl in an urban area. Predation pressure by native species may limit the spread of alien invasive species, thus playing a pivotal role in the impact and implementation of management strategies. The ring–necked parakeet *Psittacula krameri* is one of the most widespread alien bird species in Europe, with nearly 70 established populations. Predators of this species include diurnal raptors, synanthropic corvids, and rodents. Here we report for the first time that long–eared owls *Asio otus* might have preyed upon parakeets in their night roosts. Analysis of 167 owl pellets showed that ring–necked parakeets made up over 10% of the total volume of the diet of these owls in winter (32.93% of absolute frequency), representing the most important prey species after murid rodents and passerine birds. Further studies are needed to investigate whether parakeet consumption by long–eared owls is only a local occurrence or whether it is widespread in European cities. If so, predation by long–eared owl may eventually lead to a form of parakeet control and may limit the impact of this introduced parakeet on native biodiversity.

Key words: Urban environments, *Asio otus, Psittacula krameri,* Invasive species, Predation pressure

Resumen

El gusto por lo exótico: la depredación de la cotorra de Kramer invasora por el búho chico en una zona urbana. La presión predatoria que ejercen las especies nativas puede limitar la propagación de especies invasoras exóticas y, en consecuencia, tener un papel decisivo en los efectos y la aplicación de estrategias de gestión. La cotorra de Kramer, *Psittacula krameri*, es una de las especies de aves exóticas más extendida de Europa, donde tiene cerca de 70 poblaciones establecidas. Entre los depredadores de esta especie se encuentran rapaces diurnas, córvidos sinantrópicos y roedores. En este estudio observamos por primera vez que el búho chico, *Asio otus*, puede cazar cotorras en sus dormideros. El análisis de 167 excrementos de búho chico mostró que las cotorras de Kramer constituyen el 10% de volumen total de la dieta de estos búhos en invierno (32,93% de frecuencia absoluta) y son la presa más importante después de los roedores múridos y las aves paseriformes. Es necesario seguir estudiando esta cuestión para analizar si el consumo de cotorras de Kramer por el búho chico es solo un fenómeno local o si se ha generalizado en las ciudades europeas. En ese caso, es posible que, la depredación por el búho chico termine suponiendo una forma de control de la cotorra y limite el impacto de esta especie introducida en la biodiversidad autóctona.

Palabras clave: Entornos urbanos, *Asio otus*, *Psittacula krameri*, Especie invasora, Depredación

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Introduction

Biological invasions are one of the main causes of the global biodiversity crisis (Nentwig et al., 2018). Predation by native species may help limit the spread of alien species and thus limit their negative effects on native environments. However, relatively few studies are available on this topic (Santos et al., 2009; Sheehy and Lawton, 2014; Pintor and Byers, 2015). Alien species introduced through the pet market are particularly appreciated (cf. Bertolino, 2009) and often fed by humans, thus facilitating the establishment of naturalized populations, mostly within human settlements, such as in urban parks (Clergeau and Vergnes, 2011; Gyimesi and Lensink, 2012; Mori et al., 2019). Once established, alien species may become part of the diet of native predators (e.g. Fajardo et al., 2018; Nardone et al., 2018; Mori et al., 2018; Macià et al., 2019). Among avian predators, nocturnal raptors have been reported to be effective control agents for alien pest management (Labuschagne et al., 2016), and their presence in urban and suburban areas is increasing (Mori and Bertolino, 2015).

The ring–necked parakeet *Psittacula krameri* (hereafter, RNP) is the most widespread alien bird species in Europe and the Mediterranean basin, with 69 populations in at least 37 countries, mostly in urban and peri–urban areas (Menchetti et al., 2016; Pârâu et al., 2016; Grandi et al., 2018; Le Louarn et al., 2018). In addition, 116 alien populations have been identified elsewhere in the world, in the Americas, Africa, Asia, and Oceania (Menchetti et al., 2016). The RNP is a hole–nesting species that prefers tree cavities. It is gregarious with shared nocturnal roosts consisting of up to thousands of individuals (Luna et al., 2016; Pârâu et al., 2016; Le Louarn et al., 2017). Being very widespread as a pet animal and due to its bright colour (Menchetti and Mori, 2014), RNPs are widely appreciated by the general public (Clergeau and Vergnes, 2011; Le Louarn et al., 2016; Berthier et al., 2017), which may lead to precaution when planning management action (Crowley et al., 2019). Despite this global appreciation, this species has been reported to have a negative impact on native biodiversity, human activities, and the health of human/native species (for reviews, Menchetti and Mori, 2014; Menchetti et al., 2016; White et al., 2019). The most evident and severe impact of RNP is related to competition for roost sites with a threatened European species of conservation concern, the greater noctule bat *Nyctalus lasiopterus* (Hernández–Brito et al., 2014a, 2018). Very few anecdotal data on predators of RNPs in the invasive range occur in the scientific literature (Menchetti and Mori, 2014). In the UK and in Italy, the Eurasian sparrowhawk *Accipiter nisus*, the goshawk *Accipiter gentilis,* the peregrine falcon *Falco peregrinus* and the hobby *Falco subbuteo* may prey upon RNPs (Pithon and Dytham, 1999; Menchetti and Mori, 2014; Harris, 2015). Grey squirrels *Sciurus carolinensis* and Eurasian red squirrels *Sciurus vulgaris* may represent occasional predators on RNP chicks (Shwartz et al., 2008; Mori et al., 2013). Black rats *Rattus rattus* are potential nest predators and several aggressive interactions towards RNPs defending their nests have been recorded (Hernández–Brito et al., 2014b). Domestic cats *Felis catus* have been reported to be effective killers of RNPs in central Italy (Menchetti and Mori, 2014). Corvids (i.e. the jackdaw *Corvus monedula* and the carrion crow *Corvus corone*) are predators of parakeet chicks in Belgium and Italy (Menchetti and Mori, 2014), but a quantification of predation rate is lacking.

Predation on parrots by nocturnal raptors (e.g. the tawny owl *Strix aluco*, the barn owl *Tyto alba* and the long–eared owl *Asio otus*) has been suggested to occur at roosts, but no published scientific evidence is available (cf. Harms and Eberhard, 2003; Grandi et al., 2018). Despite being mainly specialized on *Microtus* voles (Selçuk et al., 2019), long–eared owls may adapt their feeding habits in the urban environments of European cities (where they commonly overwinter (Lövy and Riegert, 2013; Mori and Bertolino, 2015) to the most profitable prey, i.e. black rats and birds (Mori and Bertolino, 2015). In a recent study in Follonica in central Italy (Mori et al., 2017), it was reported that the population of RNPs declined notably after a winter roost in 2017 following the establishment of the long–eared owl in the immediate surroundings of the parakeet roost. The aim of present study, therefore, was to analyze the winter diet of the long–eared owl in this urban area to quantify the level of predation on RNPs. We also compared our results with the winter diet of long–eared owls in two other urban areas in central Italy to assess whether diet overlap occurred.

Material and methods

Study area

Our study was conducted within the urban area of Follonica, in central Italy (Province of Grosseto: 42.92 ºN, 10.7 6 ºE: 0–7 m a.s.l.; fig. 1). The mean annual temperature was 16.8 ºC, with annual precipitation of 650–700 mm (Mori et al., 2017). This urban area is surrounded by farmland, mainly cereal and sunflower fields) and wide coastal pinewood forests with *Pinus pinea* (Mori et al., 2017). The first control site was located in the southern peripheral area of the city of Grosseto (42.77 ºN, 11.13 ºE: 14–18 m a.s.l.; fig. 1), in a small pinewood around the the city hospital (Martelli and Fastelli, 2013). A further control area was located in the plain area surrounding the International Airport of Pisa (43.68 ºN, 10.41 ºE: 1–2 m a.s.l.; fig. 1), characterized by fallows and cultivated areas surrounded by irrigation channels. Climatic conditions were similar in the study area and the two control sites (Martelli and Fastelli, 2013; Giunchi et al., 2014).

The ring–necked parakeet in the study area

A pair of RNP was first observed in Follonica in 1999 and the population peaked at 30–35 individuals in 2016 (Pârâu et al., 2016; Mori et al., 2017). In winter 2017, a group of eight long–eared owls established a roost at a distance of about 300 m from the parakeet roost. The following parakeet count (refer Luna et al., 2016, for methods) showed a dramatic decline in the local parakeet population (fig. 2).

Fig. 1. Location of the study area (Follonica) and the control areas (Grosseto and Pisa).

Fig. 1. Ubicación de la zona de estudio (Follonica) y las zonas de control (Grosseto y Pisa).

Owl pellet analysis

A total of 167 long–eared owl pellets, egested between November 2017 and February 2018, were collected once a week under the winter roost. Each collection lasted for at least one hour, for a total of 18 hours of pellet collection throughout the study. In the laboratory, pellets were dried and softened in hot water and 95% ethanol, to better separate parts corresponding to prey species, e.g. skulls, mandibles, insect fragments, beaks and feathers (Andrews, 1990; Cecere and Vicini, 2000). Food items were determined through a binocular microscope with 400× magnification (Olympus BX 51 microscope). After determination, they were stored in tubes at –20 ºC for successive analyses. Feathers and beaks of birds, mandibles of small mammals (Muridae and Soricidae) and insects (Coleopterans) were compared using national atlases (Nappi, 2001; Gaggi and Paci, 2014; Bird Skull Collections web page) and local reference collections were stored at the University of Siena (Ciampalini and Lovari, 1985).

We calculated absolute (AF, number of occurrences of each prey category, when present/total number of pellets × 100) and relative (RF, number of occurrences of each prey category, when present/total number of occurrences of all prey items × 100) frequencies of occurrence for each prey category (Khan et al., 2018), using the R software (version 3.6.1., R Foundation for Statistical Computing, Vienna, Austria). In addition, we estimated the volume occupied in pellets by each prey category when present (VWP, volume of each prey category, when present, estimated by eye/total estimated volume × 100) (Ciampalini and Lovari, 1985; Marassi and Biancardi, 2002) using the same software (Khan et al., 2018). As both AF and VWP were calculated only when the prey category was present, their summation may exceed 100 % (Khan et al., 2018). We evaluated the total volume in diet of each prey category by plotting AF and VWP in a graph (Kruuk, 1989), with isopleths connecting points of the same volume in diet (Kruuk and Parish, 1981; Marassi and Biancardi, 2002). The trophic niche breadth was measured using Levins standardised index (B_{sta}), which ranges from 0 (minimum breadth) to 1 (maximum breadth):

$$B_{sta} = (B - 1) / B_{max} - 1)$$

where: B is the Levins index ($B = 1/\Sigma p_i^2$ where p_i is the proportion of each *i*–prey category identified in every pellet), and B_{max} is the total number of prey categories (Krebs, 1999).

Our results were then compared with those on winter feeding habits of the long–eared owl in an urban roost from nearby cities (i.e. Grosseto: Martelli and Fastelli, 2013; Pisa: N = 137 pellets collected near the airport and analyzed as described above). Diet overlap between the study area and the control area was estimated through the Pianka index (Pianka, 1974), which ranges between 0 (no overlap) and 1 (total overlap). In the control area, RNPs are not present. This index is computed by taking into account the proportion of records of each prey category at both study sites:

$$O_{jk} = [\sum p_{ij} * p_{ik} / \sum p^2_{ij} * \sum p^2_{ik}]^{1/2}$$

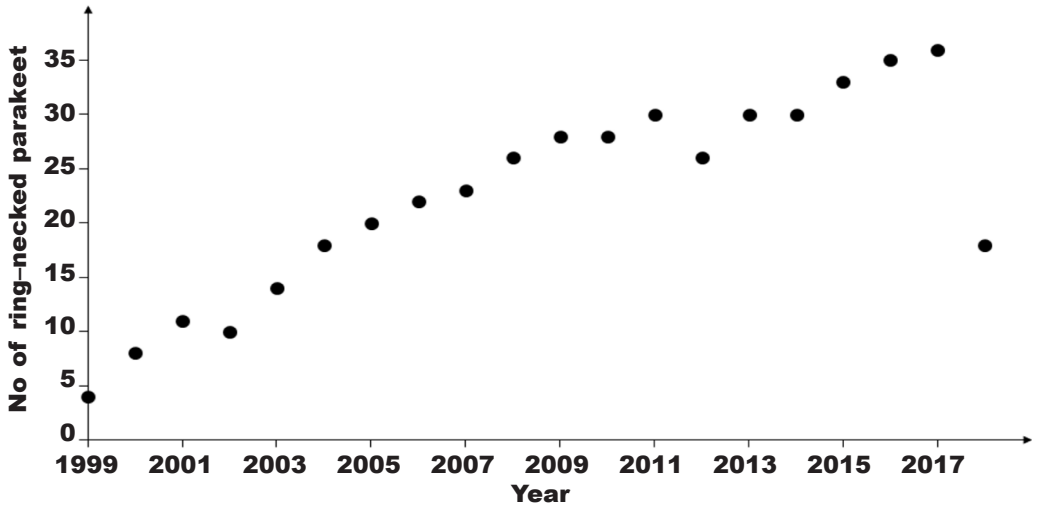

Fig. 2. Ring–necked parakeet population size in Follonica between 1999 and 2018 (Mori et al., 2017, modified).

Fig. 2. Tamaño de la población de la cotorra de Kramer en Follonica entre 1999 y 2018 (Mori et al., 2017, modificado).

where p_{ij} and p_{ik} are the proportions of each *i*–prey category identified in every pellet, respectively in the study site (*j*) and in the control area (*k*). The comparison was made by using these combined prey categories which are present at all the study sites: (*i*) murid rodents, (*ii*) voles, (*iii*) shrews, (*iv*) birds, and (*v*) insects.

Results

We obtained a total of 422 prey fragments. Eight prey categories were identified: (i) house mouse *Mus domesticus*; (ii) long–tailed field mouse *Apodemus sylvaticus*; (iii) black rat *Rattus rattus*; (iv) undetermined murid rodents; (v) shrews (Soricidae); (vi) RNP; (vii) other birds; and (viii) insects. The dominant dietary item in terms of relative frequency was the house mouse, followed by birds and long–tailed field mice (table 1). Insects were poorly represented (1.20 %), despite covering half of the pellets, when present.

Accordingly, the house mouse represented nearly 50 % of the total volume in the owl diet, long–tailed field mice and urban avifauna represented 20 %, and RNP made up over 10 % (fig. 3).

The standardised Levins index was 0.47 (i.e. 47 % of trophic niche breadth). Table 2 shows the proportion of prey species (relative frequency %) in control areas

The diet of the long–eared owl in our study area overlapped with that of the control areas in Grosseto and Pisa by 96 % and 63 %, respectively (Pianka index = 0.96; 0.63). Diet overlap between Grosseto and Pisa was 65 %.

Discussion

Throughout its range, the long–eared owl is reported mostly as a vole predator (see Birrer, 2009, for a review of 312 studies). Despite this, in urban environments, this raptor may shift its diet towards synanthropic, more profitable prey species (Mori and Bertolino, 2015). The long–eared owl hunts mainly in areas with low and sparse vegetation (Bertolino et al., 2001; Aschwanden et al., 2005), thus explaining presence of woodland prey species in its diet (Birrer, 2009). Urbanisation may reduce the availability of many rodent species, including forest–dwellers and semifossorial voles (Pirovano et al., 2000a; Baker et al., 2003; Angold et al., 2006). However, if winter roosts are located near woodlands or in rural areas, forest rodents (e.g. the bank vole *Myodes glareolus*) may be highly represented in the diet of this owl (Mori et al., 2014). Usually, in human–modified environments, this nocturnal raptor mainly feeds on large (e.g. rats) or gregarious prey species (e.g. birds: Mori and Bertolino, 2015), which provide it with highly profitable, easily captured prey items (Wijnandts, 1984; Pirovano et al., 2000b).

The results from our study area are in line with previous studies showing that urban owls mainly focus on small sized murid rodents, including synanthropic house mice together with long–tailed field mice, possibly caught at ecotones with woodlands and peripheral areas (Wijnandts, 1984; Birrer 2009), followed by black rats (Mori and Bertolino, 2015). Interestingly, birds were also highly represented. Birds are usually a rare occurrence in the diet of the long–eared owl (~6 %, in the whole of its range: Birrer, 2009), However, some studies have found them to be significantly represent-

Table 1. Absolute frequency (AF in %), relative frequency (RF in %) and volume when present (VWP in %) of each prey category identified in the diet of the long–eared owl.

Tabla 1. Frecuencia absoluta (AF en %), frecuencia relativa (RF en %) y volumen (VWP en %) de todas las categorías de presas identificadas presentes en la dieta del búho chico.

Prey categories	AF (%)	RF (%)	WWP (%)
House mouse	85.03	36.44	53.79
Long–tailed field mouse	52.69	18.43	44.70
Black rat	20.96	7.42	57.03
Undetermined murids	8.38	3.18	42.00
Shrews (Soricidae)	2.99	1.06	23.00
Ring–necked parakeet	32.93	11.44	32.69
Other birds	32.34	21.61	57.47
Insects	1.20	0.42	50.00

ed in urban areas in winter (e.g. Bezzel, 1972; Laiu and Murariu, 1998; Martelli and Fastelli, 2013). The most commonly found are colonial roosting species (e.g. the Europen serin *Serinus serinus*, the hawfinch *Coccothraustes coccothraustes* and sparrows *Passer* spp.) as they are easily caught in shared roosts, e.g. on bare tree branches (Laiu and Murariu, 1998; Martelli and Fastelli, 2013). Many predator species are known to adapt their diet to local prey availability and prey selection often reflects ease of capture (cf. Pavey et al., 2008; Paspali et al., 2013; Nardone et al., 2018). In our study, the RNP was an important prey for the long–eared owl, contributing over 10% of the total volume in the diet. This parrot species shares colonial roosts (Clergeau and Vergnes, 2011; Luna et al., 2016) and is relatively large (125–135 gr; Tabethe et al., 2013), thus possibly providing owls with a large amount of food (Birrer, 2009). Only one roost of RNPs occurred in our study area (Pârâu et al., 2016), and it was located a few hundred meters from that of the long–eared owl. After winter 2017, the population size of RNPs declined sharply and six new roosting sites, used by 2–9 individuals, were detected along the coastline, from the study site to ~19 km northwards (with the northernmost currently established in Piombino, province of Livorno). However, we cannot rule out the possibility that predation by owls occurred while parakeets were still active (i.e. before sunset).

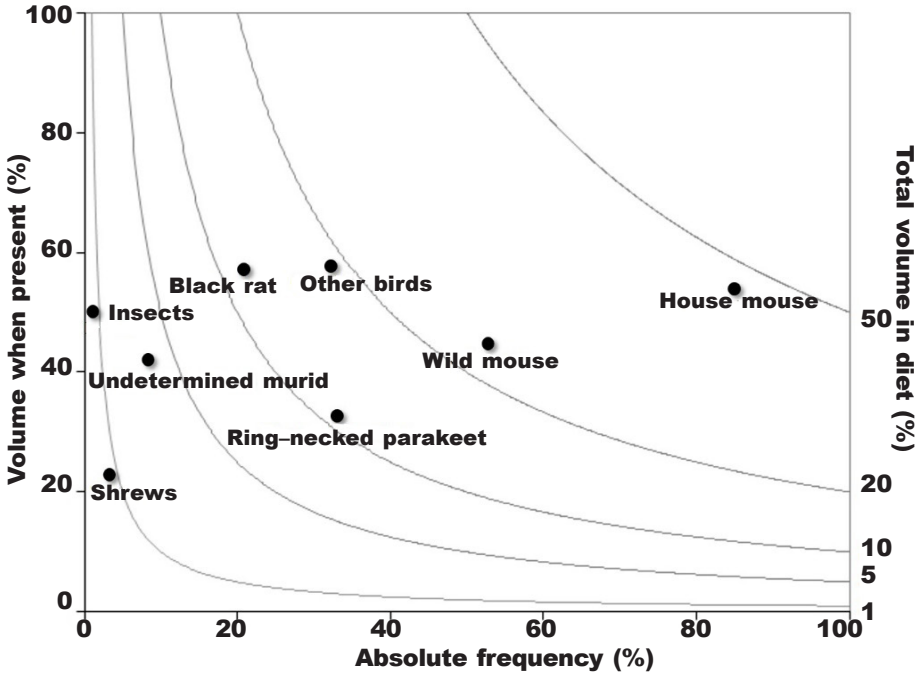

Fig. 3. Diet of the long–eared owl: absolute frequency of occurrence (%) plotted versus the volume (%) of each food category, when present. Isopleths connect points of the same total volume in diet (%).

Fig. 3. Dieta del búho chico: frecuencia absoluta de presencia (%) representada en relación con el volumen (%) de cada categoría de alimento presente. Las isolíneas conectan puntos del mismo volumen total en la dieta.

Table 2. Relative frequency (RF %) of each prey category identified in the diet of the long–eared owl at each control area.

Tabla 2. Frecuencia relativa (RF %) de todas las categorías de presas identificadas en la dieta del búho chico en cada zona de control.

	Control area	
Prey species	Grosseto	Pisa
Apodemus flavicollis	0.00	5.84
Apodemus sylvaticus	25.16	13.14
Apodemus sp.	0.00	14.60
Mus domesticus	49.69	8.76
Rattus norvegicus	0.00	8.03
Rattus rattus	0.63	7.30
Total murids	**75.48**	**57.66**
Arvicola italicus	0.00	22.63
Microtus savii	0.00	5.11
Total voles	**0.00**	**27.74**
Crocidura leucodon	0.00	0.73
Total shrews	**0.00**	**0.73**
Erithacus rubecula	0.00	0.73
Passer italiae	0.00	2.19
Turdus merula	0.00	1.46
Phoenicuros ochruros	0.00	0.73
Prunella modularis	0.00	0.73
Unidentified birds	23.27	0.00
Total birds	**23.27**	**5.84**
Coleoptera Tenebrionidae	1.26	13.87
Total insects	**1.26**	**13.87**

When using clustered food categories (i.e. murid rodents, voles, shrews, birds, and insects), diet habits of the long–eared owl in Follonica almost overlapped with those of the nearest other urban roosts of this species. Despite RNPs not being present, a high proportion of urban birds was also detected in the control area of Grosseto. Overlap was lower between our study area and the control area of Pisa where the main prey was the endemic Italian water vole *Arvicola italicus* (i.e. near 15% of total volume in diet), as a local adaptation. Large voles (i.e. those belonging to the genus *Arvicola*) are mentioned as prey in 420 out of 1,215 long–eared owl prey lists (Birrer, 2009), but relative frequencies are between 1 and 9.3%, with only seven studies showing higher frequencies, of between 10% and 27%. In central Italy, RNPs outcompeted native, declining scops owls from nesting sites, forcing them to occupy suboptimal breeding habitats to minimize competition (Mori et al., 2017). RNPs are early breeders (Luna et al., 2017) and use tree cavities before they return from their African wintering grounds. Although RNPs may also be highly aggressive against larger predators (Hernández–Brito et al., 2014a), their antipredatory behaviour is mainly focused on breeding areas, showing a greater vulnerability at nocturnal roosts, which could be exploited by nocturnal predators. Hence, we confirm that long–eared owl may adapt their diet to the most profitable prey species, thus showing a wide diet plasticity ranging from small voles, when available (Birrer, 2009), to large synanthropic rodents and urban colonial birds (Laiu and Murariu, 1998; Martelli and Fastelli, 2013; Mori and Bertolino, 2015).

Our findings show that this nocturnal raptor may also feed on RNPs, and that this prey species may be frequent in winter. To the best of our knowledge, this is the first report of a native owl preying on an alien parrot. Future work should better establish the magnitude of this impact on the local population of RNP and determine the potential effect on the scops owl population after the removal of the alien competitor.

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