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The contribution of the Barn owl (*Tyto alba*) feeding ecology to confirm bat species occurrence in north Portugal

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Abstract: The Barn owl (*Tyto alba*) is an opportunistic species which feeds mainly on small mammals but also on birds, bats, reptiles, amphibians, insects and fishes. With regard to bats, several studies in Europe suggest that this group constitutes a small portion of the Barn owl diet representing less than 1% of its prey items. Through the analysis of 2,934 Barn owl pellets, collected between 2006 and 2014 in 27 sites/nests located in north Portugal, the remains of six bats belonging to five species were identified in a total of 9,103 prey items identified: the Western barbastelle (*Barbastella barbastellus*), the Grey long-eared bat (*Plecotus austriacus*), the Brown long-eared bat (*Plecotus auritus*), the European free-tailed bat (*Tadarida teniotis*) and the Common pipistrelle (*Pipistrellus pipistrellus*). These findings are of great interest as they represent new data on the Brown long-eared bat and European free-tailed bat distributions, and allow to confirm an historical record of the Western barbastelle in the region.

Keywords: Bats distribution, Feeding ecology, Portugal, Pellets, *Tyto alba*.

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The Barn owl (*Tyto alba),* a cosmopolitan nocturnal bird, is an opportunistic species which feeds mainly on small mammals (Taylor 1994, Meek et al. 2012). However, depending on prey's availability, birds, bats, reptiles, amphibians, insects and fishes represent alternative preys (Mikkola 1983, Taylor 1994, Sommer et al. 2005, Roulin & Dubey 2012, 2013, Roulin & Christe 2013, Roulin, 2015). Since the information from Barn owl pellets provides consistent information on the proportion and availability of prey through the species feeding territories (Taylor 1994), the analysis of the respective prey items is an extremely valuable indirect method to document their diversity, geographical distribution and population ecology (Colvin & McLean 1986, Love et al. 2000, Torre et al. 2004, Avenant 2005).

Although some species of mammals, birds (including raptors), reptiles, amphibians and fishes are potential predators of bats, only few of them are specialized on this prey group (Gillette & Kimbrough 1970, Sparks et al. 2000). Nevertheless, some studies reported that bats might represent between 27% and 51% of the prey items in the diet of some specialized raptors (Vargas et al. 2002, Sommer et al. 2009), particularly in favourable contexts, such as in the case of Tawny owl (*Strix aluco*) (Obuch 1998) and the Common kestrel (*Falco tinnunculus*) (Negro et al. 1992). These are, for instance, contexts where these raptors hunt bats as main prey in habitats associated with urban areas, mostly captured when emerging from roosts at dusk (Lesiński et al. 2009, Lima & Keefe 2013). Conversely, the studies based on the feeding ecology of Barn owl in Europe suggest an opportunistic behaviour where bats constitute, on average, less than 1% of the prey items (Mikkola 1983, Obuch 1998, Avenant 2005, Sommer et al. 2005, Roulin & Christe 2013, Bekker et al. 2014).

This study documents several bat species from Barn owl pellets collected in the north region of Portugal. The main goal is to update the knowledge about the distribution/occurrence of some of these species in this region. Potential Barn owl nest and roost sites were searched in the north-eastern districts of Vila Real, Bragança, Viseu and Guarda, in order to detect indirect evidences of the species occupation and to

Table 1. Dental formulas and main distinctive characteristics of each bat genus identified in the Barn owl pellets collected from north of Portugal (Palmeirim, 1985; Paz & Benzal, 1990; Jenrich et al., 2012).

Genus	Dental formulas ($I^n.C^n.PM^n.M^n/I_n.C_n.PM_n.M_n$)	Main distinctive characteristics
Barbastella	2.1.2.3/3.1.2.3	Depressed short rostrum. Upper C^1 with elongate section and flat inner surface with a sharply defined cingulum.
Plecotus	2.1.2.3/3.1.3.3	Maximal diameter of tympanic bulla twice as large as the distance between them.
Tadarida	1.1.2.3/3.1.2.3	Single pair of upper incisors. The skull is depressed and its dorsal profile straight and almost horizontal.
Pipistrellus	2.1.2.3/3.1.2.3	Gap between PM^2 and C^1. Nyctalodont molars.

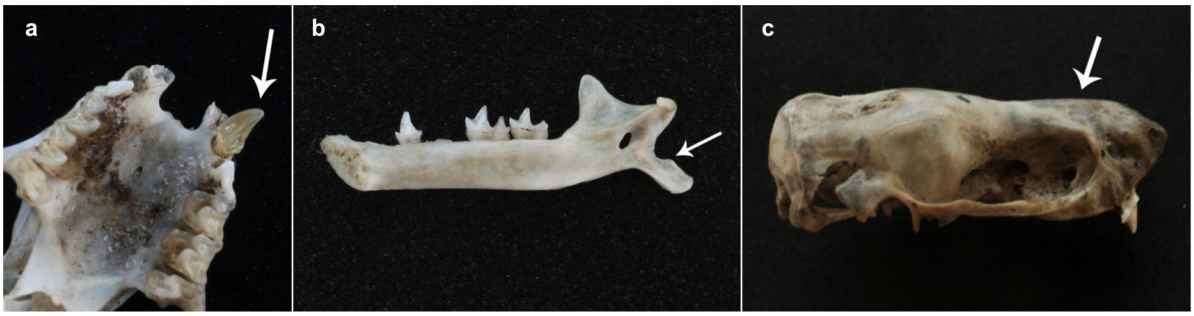

Fig. 1 - Bat skull remains identified in Barn owl pellets collected from north of Portugal: a - Upper canine of the Western barbastelle (*Barbastella barbastellus*) with elongate section and flat inner surface with a sharply defined cingulum; b - lower mandible of the Grey long-eared bat (*Plecotus austriacus*) with a salience on the processus angularis in the posterior part; c - a depressed and the dorsal profile of the European free-tailed bat (*Tadarida teniotis*) is straight and almost horizontal. The arrows indicate the respective distinctive morphological details.

confirm their potential as sampling points (Vale-Gonçalves & Cabral 2014). Bat species were assessed by the analysis of Barn owl pellets collected between 2006 and 2014, following the methodological protocol described in Vale-Gonçalves & Cabral (2014). Genera were identified through the dental formula and some other general distinctive characteristics (Table 1) (Palmeirim 1985, Paz & Benzal 1990), whereas the species confirmation was carried out as described in Jenrich et al. (2012), particularly to *Plecotus* and *Pipistrellus*.

Among a total of 9,103 prey items identified, from the analysis of 2,934 Barn owl pellets collected in 27 sites/nests, six belong to five bat species (n=6; 0.07%): the Western barbastelle (*Barbastella barbastellus*, n=1; 0.01%; Fig. 1a), the Grey long-eared bat (*Plecotus austriacus*, n=2; 0.02%; Fig. 1b), the Brown long-eared bat (*Plecotus auritus*, n=1; 0.01%), the European free-tailed bat (*Tadarida teniotis*, n=1; 0.01%; Fig. 1c) and the Common pipistrelle (*Pipistrellus pipistrellus*, n=1; 0.01%). Species of the genus *Plecotus* were distinguished by the differences in the shape of the processus angularis in the posterior part of the mandibles (Fig. 1b) (Jenrich et al. 2012). Regarding the species of the genus *Pipistrellus*, the identification was determined by comparisons of the size between the I^1 and I^2, and the shape of the processus angularis of the mandible (Table 1) (Jenrich et al. 2012).

When projected on a 10x10km UTM grid (datum WGS84), the localization of the pellets with bat remains allowed us to trace unknown occurrence areas for two species, namely the Brown long-eared bat and the European free-tailed bat, as well to confirm an historical record of the Western barbastelle (Fig. 2) (Rainho et al. 2013). The spatial localization of the pellets with these bat remains was displayed in a GIS environment (ArcMap 10.0®).

The Western barbastelle is a forest-dwelling bat, the occurrence of which is strongly associated to the presence of old-grow deciduous forests (Russo et al. 2010; Barros & Braz 2013). In Portugal this species exhibits a fragmented distribution with higher abundances in the north and centre of the country (Rainho et al. 2013). With regard to the foraging habitat selection, this species is quite flexible, hunting in a range of habitats, including clearings, riverbanks, meadows and forests.

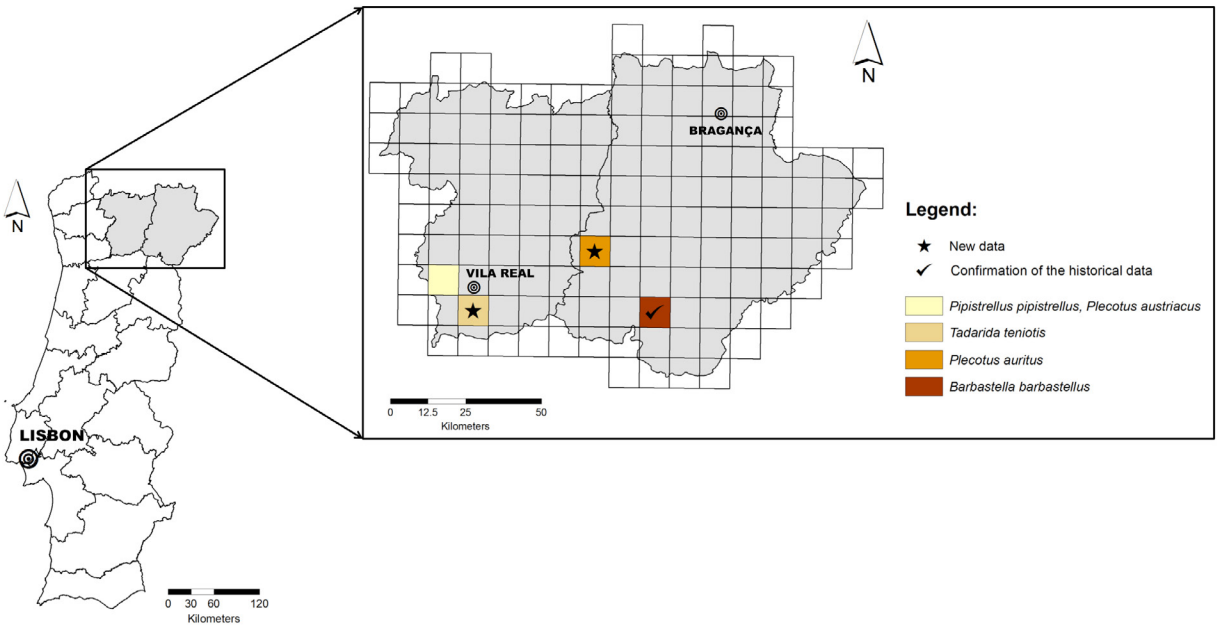

Fig. 2 - Localization of the bat species identified in the Barn owl pellets from north Portugal in a 10x10km UTM grid cells (Datum WGS84).

The Grey long-eared bat is primarily an open or edge habitat forager relatively common and well distributed throughout Portugal (Rainho et al. 2013). Its roosts are often located at the edge of villages, surrounded by open grasslands, well developed hedgerows and woodland patches. During summer this species seems to prefer available shelters in man-made roosts, mainly in the roof space of buildings, churches and barns, and in winter it can hibernate in underground galleries, mines and caves.

There are few records of the Brown long-eared bat in Portugal, which appears to be more abundant in the north, with a very fragmented distribution (Rainho et al. 2013). As an arboreal species, associated with the presence of forested areas, its roosts are usually cavities or cracks in trees, but also buildings (attics and caves, on churches and abandoned houses), usually located close to the feeding areas. During hibernation this species can be found in underground roosts (caves and mines). It is clearly a species more generalist than the congener Grey long-eared bat.

The European free-tailed bat is a medium-large crevice-dweller, with a wide distribution in most of the mainland territory, although more abundant in the north (Rainho et al. 2013). It feeds in a wide variety of habitats, mostly above forests and olive grove areas, but it can also hunt over water bodies, urban and cultivated areas, with a home range from the roosts vicinity to more than 30 km away, between 10 and 300 meters above the ground.

The Common pipistrelle is a crevice-dweller bat actually considered the most generalist of the bat species with a widespread distribution and higher abundances in Portugal (Rainho et al. 2013). It can forage in a variety of habitats, such as agricultural areas, deciduous and evergreen forests, coniferous forests, urban and peri-urban areas and riparian galleries.

Three of these five bat species usually occur in artificial roosts, such as human houses. The Brown long-eared bat and the Western barbastelle are almost exclusively associated with woodlands, although they can also roost sporadically in bridges and buildings (Ruprecht 1979, Uhrin et al. 2010, Rainho et al. 2013).

Although the Barn owls are not specialized on hunting bats (Petrželková et al. 2004), several explanations have been proposed to clarify this unusual prey selection, suggesting a certain opportunism, namely when bats arrive at their hibernation sites and are caught during the exploratory flights (Sommer et al. 2009), or at the roosts' entrance during the periods of emergence and return (Petrželková et al. 2004, Lesiński et al. 2012, Lima & Keefe 2013), or when both predator and prey shared a common roost (Lesiński et al. 2012).

Our results confirm that bats are not a preferential prey of the Barn owl in northern Portugal. However, although the number of items found in Barn owl pellets is residual, the data collected for bats may represent very important contributions, particularly for rare species, such as Western barbastelle, or species classified with the conservationist status of "data deficiency", as in the case of Western barbastelle, Brown long-eared bat and European free-tailed bat (Cabral et al. 2005). This is of particular relevance, since even in the most recent Atlas of bats in Portugal (Rainho et al. 2013) the data on the distribution of some species remain very scarce and incomplete, especially for species like the Western barbastelle, which is confirmed only in about 10% of the total of 1,008 10X10km grid cells. Additionally, for bat species that are difficult or impossible to distinguish by acoustic methods, such as Brown long-eared bat, less than 2% of the referred grids were confirmed. Therefore, the new records for the Western barbastelle, the Brown long-eared bat and the European free-tailed bat represent an important update of the respective distribution data in the study area.

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