Title: Feeding habits of Black-billed Magpie during the breeding season in Mediterranean Iberia: the role of birds and eggs

Short title: Magpies diet during breeding season

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Abstract

Capsule Feeding habits of the Black-billed Magpie are of interest for researchers, conservationists and hunters since magpies are considered as predators of eggs and chicks of both songbirds and gamebirds.

Aims To characterize the feeding habits of magpies during their breeding season in agricultural environments of central Spain, and to assess the occurrence and incidence of birds and eggs in the magpie's diet.

Methods Diet was determined by the analysis of gizzard contents from 118 culled magpies. The diet was described as the frequency of occurrence (FO) and the percentage of volume (VOL) of a certain food item and for each gizzard.

Results Magpies presented a generalist diet, which included a wide range of foods. Arthropods and cereal seeds were the most frequently consumed food groups (FO > 60%). Eggs and birds were consumed only occasionally (FO < 6% and 17%, respectively; percentage of volume, VOL < 4%).

Conclusion Our findings suggest that other birds and their eggs do not represent an important food for magpies in Mediterranean agricultural environments under the conditions found during this study. Nevertheless, more complex studies in different scenarios (i.e. different population sizes of magpies and prey), and over longer temporal scales, are still necessary to clarify this controversial issue.

Key words: corvids, egg predation, game management, generalist diet, *Pica pica*, predator control.

INTRODUCTION

Feeding habits are an important and widely studied aspect of animal ecology and a fundamental component for understanding the biology and ecology of species. Some species are frequently perceived as harmful for human interests because of their feeding habits. These include, for instance, some predators that consume game species or livestock (Woodroffe *et al.* 2005). From this point of view, the information provided by studies on predator feeding habits may be relevant to guide appropriate policy and management decisions that facilitate human–wildlife coexistence (López-Bao *et al.* 2013).

The feeding habits of the Black-billed Magpie *Pica pica* (hereafter the Magpie) gives rise to controversial interpretations between researchers, conservationists and hunters. In Europe, Magpies are considered as a harmful bird species by some conservationists and hunters because of their predation on eggs and chicks of songbirds and gamebirds (Birkhead 1991, Herranz 2000). As a consequence, control of Magpie populations is widespread in Europe (Hadjisterkotis 2003, Chiron & Julliard 2013, Díaz-Ruiz & Ferreras 2013). In Spain, Magpie control is mostly performed by hunters and game managers, who consider these birds as highly efficient predators of nests of Red-legged Partridges *Alectoris rufa* (Delibes-Mateos *et al.* 2013, Díaz-Ruiz & Ferreras 2013), a small game species of socio-economic relevance (Díaz-Fernández *et al.* 2012).

The Magpie diet has been the object of several studies focusing on different issues; e.g. seasonal differences, food selection, diet of nestlings or differences between rural and urban magpies (Birkhead 1991, Soler & Soler 1991, Martínez *et al.* 1992, Ponz *et al.* 1999, Kryštofková *et al.* 2011). According to these studies, Magpies are generalist predators that feed on a broad spectrum of food types, included both vegetal and animal resources, which ranged from seeds and small invertebrates to larger vertebrate carcasses and human discarded waste. In general, most studies agree that eggs form only a small proportion of the Magpie diet (Birkhead 1991, Martínez *et al.* 1992), although on some occasions Magpies are one of the main predators of artificial and natural nests (Groom 1993, Herranz 2000, Miller & Hobbs 2000, Roos & Pärt 2004). Nevertheless, the impact of Magpies on bird populations remains unclear, due to contrasting results (Gooch *et al.* 1991, Thomson *et al.* 1998, Stoate & Szczur 2001, Chiron & Julliard 2007, Newson *et al.* 2010), particularly in the Iberian Peninsula, where the number of studies on this issue is low.

In the present study, our main goal was to characterize the feeding habits of Magpies during their breeding season in agricultural areas of central Iberia, paying particular attention to the occurrence and importance of birds and eggs in the diet.

MATERIAL AND METHODS

Study Area

Magpie feeding habits were studied in two hunting estates located in central Spain (Area 1: 960 ha, 39° 4.5′N, 3°54′W; Area 2: 547 ha, 39°33′N, 3°12′W), during spring 2006. Both study areas were within the Mediterranean bioclimatic region (Rivas-Martínez *et al.* 2004), and were similar in habitat composition: an agricultural dominated landscape with some interspersed patches of natural vegetation, mainly Mediterranean bushes, some trees in riparian areas and hedgerows. The main crops were cereals (~50% and 70% of total surface, respectively in Area 1 and Area 2) and, to a lesser extent, vineyards and olive groves. Hunting was an important activity in both estates, and the main game species were Iberian Hare *Lepus granatensis*, European Rabbit *Oryctolagus cuniculus* and Red-legged Partridge. Partridge density was low in both estates (less than 0.36 partridges/ha, authors unpubl. data) and within the range of other agricultural regions of the Iberian Peninsula (Borralho *et al.* 1996, Duarte & Vargas 2001). Both hunting estates harbour an important community of small breeding birds, including species of families such as larks *Alaudidae* and finches *Fringillidae* (Martí & Del Moral 2003). Magpie density in both study areas (Area 1: 0.23 Magpies/ha, Area 2: 0.39 Magpies/ha, before the breeding season; see Díaz-Ruiz *et al.* 2010) was above the average values reported in other European regions (Birkhead 1991).

Sample collection

Magpies were captured during an experimental evaluation of cage-traps as live capture methods for Magpie population management (for more details see Díaz-Ruiz *et al.* 2010). Captures took place during the Magpie breeding season of 2006. Magpies were captured earlier in Area 1 (May) than in Area 2 (late May–early June). Birds were humanely euthanized using standard procedures and following current guidelines on animal welfare (Close *et al.* 1997). Age was determined from the shape and appearance of the first outermost primaries; this method allows differentiation between first-year (hereafter immature) and older magpies (hereafter adult) (Erpino 1968, Birkhead 1991). Sex was determined for each individual by the assessment of gonadal development during laboratory autopsies. Gizzard contents were extracted and stored in 70% alcohol in labelled plastic tubes for subsequent analyses. A total of 118 gizzards were collected, achieving a similar sample size for each study area (61 from Area 1 and 57 from Area 2), age (51 adult and 67 immature) and sex (48 females and 70 males) (Fig. 1).

Diet analysis

Magpie diet was determined through the analysis of gizzard contents, a frequent method used in diet studies of several bird species (Jiguet 2002, Kopij 2005, Bur *et al.* 2008). Gizzard contents were analysed following the methods described in other corvid diet studies (Soler *et al.* 1990, Soler & Soler 1991, Herranz 2000). Food items were identified to the lowest possible taxonomic level using published literature (Day 1966, Barrientos 1988, Devesa 1991, Teerink 1991, Chinery 1997), as well as a dedicated reference collection of seeds, invertebrates, bird eggs and mammal hairs. The thickness of eggshells was measured with a digital calliper (precision 0.01 mm) to assign the eggs at least to the family level (Herranz 2000). All identified items were pooled in nine food classes: arthropod, gastropod, cereal seed, fruit, other vegetal, bird, bird egg, reptile and mammal, and two non-food items: gastrolith and plastic (Table 1).

For the diet description we calculated two dietary indices frequently used in diet studies (Soler *et al.* 1993, Herranz 2000, Hadjisterkotis 2003, Kryštofková *et al.* 2011): the frequency of occurrence (FO), expressed as the percentage of gizzards in which a food item was found, and the percentage of volume (VOL), estimated as the percentage of total volume corresponding to a certain food item upon the total content of each gizzard. For VOL estimation, the remains from each gizzard were spread by group in a Petri dish; this enabled quantification of percentage volume by comparing the different sizes of remains for the food groups.

To detect possible biases in the interpretation of diet description, we explored potential differences in overall Magpies' diet between study areas, sex and age classes. We pooled all food classes in four main categories to avoid groups with very low FO (<5%; e.g. fruits, reptiles and mammals). The four categories were invertebrates (arthropods and gastropods), cereal seeds, vegetal (encompassing fruits and other vegetal material, see below) and vertebrates (eggs, birds, reptiles and mammals). We used multivariate analysis of variance (MANOVA) with the VOL of each main food category as response variables and the study area, age and sex and all interactions between them as fixed factors. We used VOL because this index considers the amount of each food class in each Magpie gizzard (Reynolds & Aebischer 1991). The individual gizzard was considered as the sampling unit in the statistical analyses. Prior to statistical analyses, the VOL for each food class (dependent variables) were log (x + 1) transformed to achieve normality (Zar 1984). Statistical analyses were performed using Statistica 10.0 software (Statsoft INC 2011) and the significance level was set at $\alpha = 0.05$.

RESULTS

Overall, we identified 1016 food items in the gizzard contents belonging to 26 taxonomic groups (Table 1). Magpies consumed a wide range of food items among which arthropods and cereal seeds were the most frequent classes, followed by other vegetal material and birds (Table 1). Other food classes (gastropods, mainly small snails, bird eggs, fruits, mammals and reptiles) were present in much lower FO (<10%, Table 1). Coleoptera and formicidae species represented 90% of the items consumed among the arthropoda (Table 1). We were able to identify 84% of the seeds found in the gizzards, and most of them corresponded to *Hordeum* sp. (64%), *Avena* sp. (27%) and *Triticum* sp. (9%) (Table 1). The 'other vegetal' class was composed mainly by grass stalks and leaves of unidentified herbaceous plants, likely from cereal crops. We only could differentiate bird remains to the taxonomic order level by the microscopic structure of feathers (Day 1966). Most bird remains belonged to passeriformes, and only one of them corresponded to galliformes (Table 1). Bird egg remains always appeared highly fragmented, making the identification of the species very difficult. Nevertheless, according to the thickness of eggshells, four (<0.09 mm) were compatible with eggs of small birds (likely passeriformes), one (0.14 mm) with those of doves and one with those of partridges (0.23 mm, Herranz 2000). The rest of the vertebrate prey items were remains of two Wood Mice *Apodemus sylvaticus*, hairs from cats *Felis* sp., one undetermined mammal and one undetermined reptile species (Table 1). MANOVA results showed that diet composition only varied significantly between study areas ($F_{4, 107} = 9.15$, $P < 0.001$) and that there was a statistically significant effect of the sex–area interaction ($F_{4, 107} = 3.48$, $P = 0.01$).

DISCUSSION

Our findings show that, during the breeding season, Magpies fed on a range of different food types, with arthropods and cereal seeds being the most frequently consumed food classes. Invertebrates are the principal contribution of protein for a large number of bird species (Capinera 2010), including the Magpies in this study. Our results are in agreement with previous studies conducted in Spain, which indicate that, although invertebrates and seeds are consumed throughout the year, the consumption of the former increases during the breeding season, when their availability is higher and nestling demand is higher (Buitron 1988, Soler & Soler 1991, Martínez *et al.* 1992, Ponz *et al.* 1999, Herranz 2000).

Eggs were detected in a low proportion and volume in Magpie gizzards (<6%), which is in agreement with most previous studies (Birkhead 1991). A higher occurrence of eggs in magpie diet has been recorded in a previous study conducted in central Spain (FO = 13–20%, Herranz 2000); a large proportion of which were attributed to Red-legged Partridges (77–80%). In contrast, only one of the egg remains found in our study (17%) coincided with partridge egg thickness. This suggests that partridge eggs do not represent an important food for Magpies during the breeding season in our study areas. However, several studies conducted in the Iberian Peninsula have shown that Magpies are one of the main predators of dummy partridge nests (Herranz 2000, Blanco-Aguiar *et al.* 2001, Ferreras *et al.* 2010). From this perspective, we cannot reject the hypothesis that nest predation by Magpies could represent some risk for partridge breeding success.

In addition, partridge nest predation by Magpies may be underestimated in diet studies, which hardly detect remains of eggshells (Chiron & Julliard 2007). This is probably because magpie behaviour during egg predation and ingestion varies with egg size. While smaller eggs are entirely swallowed, including the eggshell, larger ones are broken and only the egg content and small eggshell pieces are swallowed (Suvorov *et al.* 2012), decreasing the likelihood of eggshell ingestion. Also, we do not know if nest predation intensity by Magpies varies with their breeding stage in our study area. In this sense, Suvorov *et al.* (2012) showed that Magpies predated dummy nests more frequently during incubation than during the nestling phase, probably because magpies preferentially feed invertebrates to nestlings (Martínez *et al.* 1992). From this perspective, diet studies from different breeding stages may be biased and non-comparable, since detection probability of eggshells could be higher in the early breeding stage (incubation) than during later stages (nestling provisioning).

We found a relatively high consumption of passerines (12.7% FO) in comparison to other studies performed during the breeding season (FO < 8%; Birkhead 1991, Herranz 2000, Kryštofková *et al.* 2011). It has been suggested that Magpie predation on breeding birds may be related to high bird densities (Birkhead 1991). However, Fernández-Juricic *et al.* (2004) found that Magpie predation on other bird species was opportunistic and was mainly observed during the breeding season. Magpies might increase their predatory pressure on birds when invertebrates, the main animal component of their diet, are less available. Nevertheless, we lack data to test this hypothesis, which may be worth exploring in future studies. In any case, our findings agree with previous studies, which suggest that birds and eggs may be a secondary source of protein for Magpies during the breeding season (Birkhead 1991).

Magpie diet varied between localities but not in relation to Magpie age or sex. This result was potentially related to food availability, as suggested by the similar consumption of cereal seeds between areas, which had similar cereal crop land cover. Nevertheless, we must be cautious with this interpretation for two reasons. First, we lacked data about the availability of the other food groups and, second, Magpies can select food items independently of their availability, as reported for some invertebrate groups (Martínez *et al.* 1992, Kryštofková *et al.* 2011).

Overall, we found no evidence that Magpies pose a big threat for other birds. However, the possible sources of bias associated with our methodology, such as how we quantified the bird remains and eggs, as well as the fact that even a low rate of predation may affect a prey species when the predator is abundant, should make us cautious about this conclusion. Therefore, more complex and experimental studies over greater time and spatial scales are necessary, including localities with different densities of Magpies and potential prey species. Diet data should be complemented with the monitoring of the abundances of potential prey species and Magpies, prey breeding success and predation rates of Magpies on nests, chicks and adult birds.

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Ethical standards: This work was performed in compliance with current Spanish legislation, and follows the European Union's recommendations regarding animal welfare. All procedures were carried out with all legal permits required by the concerned administrations.

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Table 1. Detailed description of Magpie diet composition. The number of analysed gizzards containing each food group is shown. For each food group, we present the frequency of occurrence (FO) and the average % volume (VOL). Data are independently presented in terms of overall Magpie diet (Total) and for each study area (A1 and A2). Bold values are the values estimated for each main food class, which summarises other food classes. There are 9 main food classes (i.e. arthropod, gastropod, cereal seed, fruit, other vegetal, bird, bird egg, reptile and mammal), which should be highlighted in bold to differentiate from subclasses.

TABLE 1

Food type	Gizzards Total (n = 118)	Gizzards A1 (n = 61)	Gizzards A2 (n = 57)	FO Total	FO A1	FO A2	VOL Total	VOL A1	VOL A2
Coleoptera	98	47	51	83.05	77.05	89.47	29.69	14.18	46.30
Formicidae	29	25	4	24.58	40.98	7.02	5.76	10.07	1.16
Isopoda	8	5	3	6.78	8.20	5.26	1.84	1.84	1.84
Hymenoptera	5	2	3	4.24	3.28	5.26	1.97	1.34	2.63
Dermaptera	5	2	3	4.24	3.28	5.26	0.47	0.25	0.70
Araneida	5	3	2	4.24	4.92	3.51	0.64	1.07	0.19
Diptera	1	0	1	0.85	0.00	1.75	0.21	0.00	0.44
Arthropoda larva	1	1	0	0.85	1.64	0.00	0.17	0.33	0.00
Hemiptera	3	2	1	2.54	3.28	1.75	0.39	0.10	0.70
Arthropoda	**111**	**56**	**55**	**94.07**	**91.80**	**96.49**	**41.14**	**29.16**	**53.96**
Gastropoda	**11**	**10**	**1**	**9.32**	**16.39**	**1.75**	**3.07**	**5.89**	**0.05**
Hordeum sp.	27	19	8	22.88	31.15	14.04	14.05	18.77	9.00
Avena sp.	13	2	11	11.02	3.28	19.30	4.92	1.48	8.61
Triticum sp.	8	7	1	6.78	11.48	1.75	2.92	4.26	1.49
Unknown seeds	31	13	18	26.27	21.31	31.58	14.20	11.92	16.65
Cereal seeds	**79**	**43**	**36**	**66.95**	**70.49**	**63.16**	**36.10**	**36.43**	**35.75**
Fruits	**5**	**5**	**0**	**4.24**	**8.20**	**0.00**	**1.55**	**3.00**	**0.00**
Other vegetal	**40**	**27**	**13**	**33.90**	**44.26**	**22.81**	**10.75**	**16.20**	**4.93**
Passeriforme	15	13	2	12.71	21.31	3.51	1.20	2.21	0.12
Galliforme	1	1	0	0.85	1.64	0.00	0.04	0.08	0.00
Birds	**20**	**17**	**3**	**16.95**	**27.87**	**5.26**	**3.87**	**5.90**	**1.70**
Eggs	**6**	**5**	**1**	**5.08**	**8.20**	**1.75**	**2.63**	**3.61**	**1.58**
Apodemus sylvaticus	2	2	0	1.69	3.28	0.00	0.05	0.10	0.00
Felis sp.	1	1	0	0.85	1.64	0.00	0.01	0.02	0.00
Unknown mammal	1	1	0	0.85	1.64	0.00	0.01	0.02	0.00
Mammals	**4**	**4**	**0**	**3.39**	**6.56**	**0.00**	**0.07**	**0.13**	**0.00**
Reptiles	**1**	**1**	**0**	**0.85**	**1.64**	**0.00**	**0.21**	**0.41**	**0.00**

Figures legend

Figure 1. Summary of the sample sizes for both study sites, according to the sex and age of sampled Magpies.