

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

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5 **Short title:** Magpies diet during breeding season

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20

21 **Abstract**

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

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

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

31 **Results** Magpies presented a generalist diet, which included a wide range of foods.  
32 Arthropods and cereal seeds were the most frequently consumed food groups (FO >  
33 60%). Eggs and birds were consumed only occasionally (FO < 6% and 17%,  
34 respectively; percentage of volume, VOL < 4%).

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

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

42

43 **INTRODUCTION**

44 Feeding habits are an important and widely studied aspect of animal ecology and a  
45 fundamental component for understanding the biology and ecology of species. Some  
46 species are frequently perceived as harmful for human interests because of their feeding  
47 habits. These include, for instance, some predators that consume game species or  
48 livestock (Woodroffe *et al.* 2005). From this point of view, the information provided by  
49 studies on predator feeding habits may be relevant to guide appropriate policy and  
50 management decisions that facilitate human–wildlife coexistence (López-Bao *et al.*  
51 2013).

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

62 The Magpie diet has been the object of several studies focusing on different issues; e.g.  
63 seasonal differences, food selection, diet of nestlings or differences between rural and  
64 urban magpies (Birkhead 1991, Soler & Soler 1991, Martínez *et al.* 1992, Ponz *et al.*  
65 1999, Kryštofková *et al.* 2011). According to these studies, Magpies are generalist  
66 predators that feed on a broad spectrum of food types, included both vegetal and animal  
67 resources, which ranged from seeds and small invertebrates to larger vertebrate

68 carcasses and human discarded waste. In general, most studies agree that eggs form  
69 only a small proportion of the Magpie diet (Birkhead 1991, Martínez *et al.* 1992),  
70 although on some occasions Magpies are one of the main predators of artificial and  
71 natural nests (Groom 1993, Herranz 2000, Miller & Hobbs 2000, Roos & Pärt 2004).  
72 Nevertheless, the impact of Magpies on bird populations remains unclear, due to  
73 contrasting results (Gooch *et al.* 1991, Thomson *et al.* 1998, Stoate & Szczur 2001,  
74 Chiron & Julliard 2007, Newson *et al.* 2010), particularly in the Iberian Peninsula,  
75 where the number of studies on this issue is low.  
76 In the present study, our main goal was to characterize the feeding habits of Magpies  
77 during their breeding season in agricultural areas of central Iberia, paying particular  
78 attention to the occurrence and importance of birds and eggs in the diet.

79

## 80 **MATERIAL AND METHODS**

### 81 **Study Area**

82 Magpie feeding habits were studied in two hunting estates located in central Spain  
83 (Area 1: 960 ha, 39° 4.5'N, 3°54'W; Area 2: 547 ha, 39°33'N, 3°12'W), during spring  
84 2006. Both study areas were within the Mediterranean bioclimatic region (Rivas-  
85 Martínez *et al.* 2004), and were similar in habitat composition: an agricultural  
86 dominated landscape with some interspersed patches of natural vegetation, mainly  
87 Mediterranean bushes, some trees in riparian areas and hedgerows. The main crops were  
88 cereals (~50% and 70% of total surface, respectively in Area 1 and Area 2) and, to a  
89 lesser extent, vineyards and olive groves. Hunting was an important activity in both  
90 estates, and the main game species were Iberian Hare *Lepus granatensis*, European  
91 Rabbit *Oryctolagus cuniculus* and Red-legged Partridge. Partridge density was low in  
92 both estates (less than 0.36 partridges/ha, authors unpubl. data) and within the range of

93 other agricultural regions of the Iberian Peninsula (Borrvalho *et al.* 1996, Duarte &  
94 Vargas 2001). Both hunting estates harbour an important community of small breeding  
95 birds, including species of families such as larks *Alaudidae* and finches *Fringillidae*  
96 (Martí & Del Moral 2003). Magpie density in both study areas (Area 1: 0.23  
97 Magpies/ha, Area 2: 0.39 Magpies/ha, before the breeding season; see Díaz-Ruiz *et al.*  
98 2010) was above the average values reported in other European regions (Birkhead  
99 1991).

#### 100 **Sample collection**

101 Magpies were captured during an experimental evaluation of cage-traps as live capture  
102 methods for Magpie population management (for more details see Díaz-Ruiz *et al.*  
103 2010). Captures took place during the Magpie breeding season of 2006. Magpies were  
104 captured earlier in Area 1 (May) than in Area 2 (late May–early June). Birds were  
105 humanely euthanized using standard procedures and following current guidelines on  
106 animal welfare (Close *et al.* 1997). Age was determined from the shape and appearance  
107 of the first outermost primaries; this method allows differentiation between first-year  
108 (hereafter immature) and older magpies (hereafter adult) (Erpino 1968, Birkhead 1991).  
109 Sex was determined for each individual by the assessment of gonadal development  
110 during laboratory autopsies. Gizzard contents were extracted and stored in 70% alcohol  
111 in labelled plastic tubes for subsequent analyses. A total of 118 gizzards were collected,  
112 achieving a similar sample size for each study area (61 from Area 1 and 57 from Area  
113 2), age (51 adult and 67 immature) and sex (48 females and 70 males) (Fig. 1).

#### 114 **Diet analysis**

115 Magpie diet was determined through the analysis of gizzard contents, a frequent method  
116 used in diet studies of several bird species (Jiguet 2002, Kopij 2005, Bur *et al.* 2008).  
117 Gizzard contents were analysed following the methods described in other corvid diet

118 studies (Soler *et al.* 1990, Soler & Soler 1991, Herranz 2000). Food items were  
119 identified to the lowest possible taxonomic level using published literature (Day 1966,  
120 Barrientos 1988, Devesa 1991, Teerink 1991, Chinery 1997), as well as a dedicated  
121 reference collection of seeds, invertebrates, bird eggs and mammal hairs. The thickness  
122 of eggshells was measured with a digital calliper (precision 0.01 mm) to assign the eggs  
123 at least to the family level (Herranz 2000). All identified items were pooled in nine food  
124 classes: arthropod, gastropod, cereal seed, fruit, other vegetal, bird, bird egg, reptile and  
125 mammal, and two non-food items: gastrolith and plastic (Table 1).

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

134 To detect possible biases in the interpretation of diet description, we explored potential  
135 differences in overall Magpies' diet between study areas, sex and age classes. We  
136 pooled all food classes in four main categories to avoid groups with very low FO (<5%;  
137 e.g. fruits, reptiles and mammals). The four categories were invertebrates (arthropods  
138 and gastropods), cereal seeds, vegetal (encompassing fruits and other vegetal material,  
139 see below) and vertebrates (eggs, birds, reptiles and mammals). We used multivariate  
140 analysis of variance (MANOVA) with the VOL of each main food category as response  
141 variables and the study area, age and sex and all interactions between them as fixed  
142 factors. We used VOL because this index considers the amount of each food class in

143 each Magpie gizzard (Reynolds & Aebischer 1991). The individual gizzard was  
144 considered as the sampling unit in the statistical analyses. Prior to statistical analyses,  
145 the VOL for each food class (dependent variables) were  $\log(x + 1)$  transformed to  
146 achieve normality (Zar 1984). Statistical analyses were performed using Statistica 10.0  
147 software (Statsoft INC 2011) and the significance level was set at  $\alpha = 0.05$ .

## 148 **RESULTS**

149 Overall, we identified 1016 food items in the gizzard contents belonging to 26  
150 taxonomic groups (Table 1). Magpies consumed a wide range of food items among  
151 which arthropods and cereal seeds were the most frequent classes, followed by other  
152 vegetal material and birds (Table 1). Other food classes (gastropods, mainly small  
153 snails, bird eggs, fruits, mammals and reptiles) were present in much lower FO (<10%,  
154 Table 1). Coleoptera and formicidae species represented 90% of the items consumed  
155 among the arthropoda (Table 1). We were able to identify 84% of the seeds found in the  
156 gizzards, and most of them corresponded to *Hordeum* sp. (64%), *Avena* sp. (27%) and  
157 *Triticum* sp. (9%) (Table 1). The ‘other vegetal’ class was composed mainly by grass  
158 stalks and leaves of unidentified herbaceous plants, likely from cereal crops. We only  
159 could differentiate bird remains to the taxonomic order level by the microscopic  
160 structure of feathers (Day 1966). Most bird remains belonged to passeriformes, and only  
161 one of them corresponded to galliformes (Table 1). Bird egg remains always appeared  
162 highly fragmented, making the identification of the species very difficult. Nevertheless,  
163 according to the thickness of eggshells, four (<0.09 mm) were compatible with eggs of  
164 small birds (likely passeriformes), one (0.14 mm) with those of doves and one with  
165 those of partridges (0.23 mm, Herranz 2000). The rest of the vertebrate prey items were  
166 remains of two Wood Mice *Apodemus sylvaticus*, hairs from cats *Felis* sp., one  
167 undetermined mammal and one undetermined reptile species (Table 1). MANOVA

168 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  
169  $_{107} = 9.15, P < 0.001$ ) and that there was a statistically significant effect of the sex–area  
170 interaction ( $F_{4, 107} = 3.48, P = 0.01$ ).

171

## 172 **DISCUSSION**

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

182 Eggs were detected in a low proportion and volume in Magpie gizzards (<6%), which is  
183 in agreement with most previous studies (Birkhead 1991). A higher occurrence of eggs  
184 in magpie diet has been recorded in a previous study conducted in central Spain (FO =  
185 13–20%, Herranz 2000); a large proportion of which were attributed to Red-legged  
186 Partridges (77–80%). In contrast, only one of the egg remains found in our study (17%)  
187 coincided with partridge egg thickness. This suggests that partridge eggs do not  
188 represent an important food for Magpies during the breeding season in our study areas.  
189 However, several studies conducted in the Iberian Peninsula have shown that Magpies  
190 are one of the main predators of dummy partridge nests (Herranz 2000, Blanco-Aguilar  
191 *et al.* 2001, Ferreras *et al.* 2010). From this perspective, we cannot reject the hypothesis  
192 that nest predation by Magpies could represent some risk for partridge breeding success.



193 In addition, partridge nest predation by Magpies may be underestimated in diet studies,  
194 which hardly detect remains of eggshells (Chiron & Julliard 2007). This is probably  
195 because magpie behaviour during egg predation and ingestion varies with egg size.  
196 While smaller eggs are entirely swallowed, including the eggshell, larger ones are  
197 broken and only the egg content and small eggshell pieces are swallowed (Suvorov *et*  
198 *al.* 2012), decreasing the likelihood of eggshell ingestion. Also, we do not know if nest  
199 predation intensity by Magpies varies with their breeding stage in our study area. In this  
200 sense, Suvorov *et al.* (2012) showed that Magpies predated dummy nests more  
201 frequently during incubation than during the nestling phase, probably because magpies  
202 preferentially feed invertebrates to nestlings (Martínez *et al.* 1992). From this  
203 perspective, diet studies from different breeding stages may be biased and non-  
204 comparable, since detection probability of eggshells could be higher in the early  
205 breeding stage (incubation) than during later stages (nestling provisioning).  
206 We found a relatively high consumption of passerines (12.7% FO) in comparison to  
207 other studies performed during the breeding season (FO < 8%; Birkhead 1991, Herranz  
208 2000, Kryštofková *et al.* 2011). It has been suggested that Magpie predation on  
209 breeding birds may be related to high bird densities (Birkhead 1991). However,  
210 Fernández-Juricic *et al.* (2004) found that Magpie predation on other bird species was  
211 opportunistic and was mainly observed during the breeding season. Magpies might  
212 increase their predatory pressure on birds when invertebrates, the main animal  
213 component of their diet, are less available. Nevertheless, we lack data to test this  
214 hypothesis, which may be worth exploring in future studies. In any case, our findings  
215 agree with previous studies, which suggest that birds and eggs may be a secondary  
216 source of protein for Magpies during the breeding season (Birkhead 1991).

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

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

233

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240

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369 **Table 1.** Detailed description of Magpie diet composition. The number of analysed  
370 gizzards containing each food group is shown. For each food group, we present the  
371 frequency of occurrence (FO) and the average % volume (VOL). Data are  
372 independently presented in terms of overall Magpie diet (Total) and for each study area  
373 (A1 and A2). Bold values are the values estimated for each main food class, which  
374 summarises other food classes. There are 9 main food classes (i.e. arthropod, gastropod,  
375 cereal seed, fruit, other vegetal, bird, bird egg, reptile and mammal), which should be  
376 highlighted in bold to differentiate from subclasses.  
377

**TABLE 1**

Food type	Gizzards			FO			VOL		
	Total (n = 118)	A1 (n = 61)	A2 (n = 57)	Total	A1	A2	Total	A1	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
<b>Arthropoda</b>	<b>111</b>	<b>56</b>	<b>55</b>	<b>94.07</b>	<b>91.80</b>	<b>96.49</b>	<b>41.14</b>	<b>29.16</b>	<b>53.96</b>
<b>Gastropoda</b>	<b>11</b>	<b>10</b>	<b>1</b>	<b>9.32</b>	<b>16.39</b>	<b>1.75</b>	<b>3.07</b>	<b>5.89</b>	<b>0.05</b>
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
<b>Cereal seeds</b>	<b>79</b>	<b>43</b>	<b>36</b>	<b>66.95</b>	<b>70.49</b>	<b>63.16</b>	<b>36.10</b>	<b>36.43</b>	<b>35.75</b>
<b>Fruits</b>	<b>5</b>	<b>5</b>	<b>0</b>	<b>4.24</b>	<b>8.20</b>	<b>0.00</b>	<b>1.55</b>	<b>3.00</b>	<b>0.00</b>
<b>Other vegetal</b>	<b>40</b>	<b>27</b>	<b>13</b>	<b>33.90</b>	<b>44.26</b>	<b>22.81</b>	<b>10.75</b>	<b>16.20</b>	<b>4.93</b>
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
<b>Birds</b>	<b>20</b>	<b>17</b>	<b>3</b>	<b>16.95</b>	<b>27.87</b>	<b>5.26</b>	<b>3.87</b>	<b>5.90</b>	<b>1.70</b>
<b>Eggs</b>	<b>6</b>	<b>5</b>	<b>1</b>	<b>5.08</b>	<b>8.20</b>	<b>1.75</b>	<b>2.63</b>	<b>3.61</b>	<b>1.58</b>
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
<b>Mammals</b>	<b>4</b>	<b>4</b>	<b>0</b>	<b>3.39</b>	<b>6.56</b>	<b>0.00</b>	<b>0.07</b>	<b>0.13</b>	<b>0.00</b>
<b>Reptiles</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>0.85</b>	<b>1.64</b>	<b>0.00</b>	<b>0.21</b>	<b>0.41</b>	<b>0.00</b>

## Figures legend

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

