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Diet of the Red-billed Chough *Pyrrhocorax pyrrhocorax* in south-east Spain

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A sample of 140 Red-billed Chough pellets (35 from each season) was collected from communal roosting sites in south-east Spain. In almost every pellet there were three distinct dietary fractions: animal, vegetable and mineral. The animal fraction constituted nearly 50% of the pellet volume in each of the four seasons. Wild grains and cultivated cereals were the most important vegetable elements, while 60% of animal prey (n= 3484) *were beetles (mainly Tenebrionidae). There was marked seasonal variation in the composition of both the vegetable and animal fractions, the latter associated mainly with variation in the occurrence of Orthoptera, Lepidoptera larvae and Formicidae. Mixed flocks of Choughs and Jackdaws were common in the study area though agonistic interspecific interactions were never observed. The diets of the two species differ in that Choughs eat more beetles and wild seeds, whilst Jackdaws prefer ants and cereals. These observations support the hypothesis that competition from Jackdaws is not responsible for the reduction in the Chough's range.*

The Red-billed Chough *Pyrrhocorax pyrrhocorax* is a corvid which has an extensive world distribution. It occurs throughout much of southern Europe, with scattered populations mainly in mountainous areas of the Iberian Peninsula and the northern Mediterranean area; it also breeds in Brittany and on the west coast of Britain.[1] The Chough declined in Britain during the eighteenth and nineteenth centuries[2,3] and recent studies in the Iberian Peninsula have shown the distribution to be much more patchy than was previously thought.[4,5]

The existing information on the diet of the Chough is scanty or incomplete, being mainly brief notes on curious feeding behaviour or the consumption of unusual items.[6,7] Most previous dietary studies provide only the percentage of occurrence of various prey items[8–10] and although a recent paper provides more detailed quantitative information,[11] there is still no information describing biomass composition. Previous studies have tended to cover only one specific period, and only the works of Warnes & Stroud[10] and McCracken *et al.*[11] consider an entire annual cycle (information provided is concerned exclusively with percentage of occurrence). Furthermore, all of the existing studies have been carried out in the British Isles, while on the continent there is practically no recent information concerning the diet of this species.

As Roberts[12] emphasized, more quantitative studies on the numbers and biomass of prey items taken by Choughs would be of great value. The aim of this study was to describe the diet of the Chough throughout an entire year, both in terms of numerical importance and the biomass contribution of each type of prey. In addition, we shall discuss the likelihood of competition for food between Choughs and Jackdaws (*Corvus monedula*), by considering the similarity of the diets of the two species in our study area. It has been suggested that the reduction in the Chough's range has been a consequence of competition with the Jackdaws. However, this is unlikely since these two

species have been sympatric for a considerable time and are likely to have co-evolved in such a way as to minimize competition.[1]

STUDY AREA, MATERIALS AND METHODS

The study was carried out in the south-east of the Iberian Peninsula, in the Hoya de Guadix (37° 18′ N, 3° 11′ W), a cereal-producing plain 900–1100 m asl. Barley and rye are the main crops and there is abundant fallow land (about 25% of the study area). The area has many dry gullies, ravines and clay cliffs which are rich in holes and crevices which provide suitable nesting sites for Choughs. There are approximately 1600 individual Choughs within an area of 18 000 ha.[5]

In 1984 and 1985 we collected a total of 140 pellets, 35 during each of the months November, January, April and August. These are assumed to be representative of autumn, winter, spring and summer, respectively. All 35 pellets were collected on the same day from a single communal roosting site, and only fresh looking pellets were selected. In order to check the adequacy of our sample size, we plotted the cumulative trophic diversity against the number of pellets;[13] Fig. 1 shows that diversity was stable in all seasons before the 10th pellet and therefore 35 pellets constitutes an adequate sample.

Each pellet was viewed under a binocular magnifying glass (4 × 10 magnification) after being moistened and taken apart on a Petri dish. The animal, vegetable and mineral fractions were identified and separated. The volume of each fraction was measured by means of displacement of fluids using graduated test tubes of different sizes to minimize errors.

The pellet contents were identified by consultation with reference collections of both prepared cereal seed coats and of mandibles and hard parts of arthropods collected in the Chough foraging areas. We have never found fly larvae, earthworms or other softbodied prey items in the Chough foraging habitats during this or other studies.[14] The absence of such prey is probably a consequence of the aridity of the study area. The number of arthropod prey was determined mainly according to the number of mandibles and heads. To estimate the biomass (dry weight) contributed by each type of invertebrate prey, we used arthropods captured in pitfall traps in the study area, as well as data from a previous study in the same area on the stomach contents of the Jackdaw.[15] Vegetable biomass could not be estimated as it is impossible to count seeds in pellets using the remains of the seed coats.

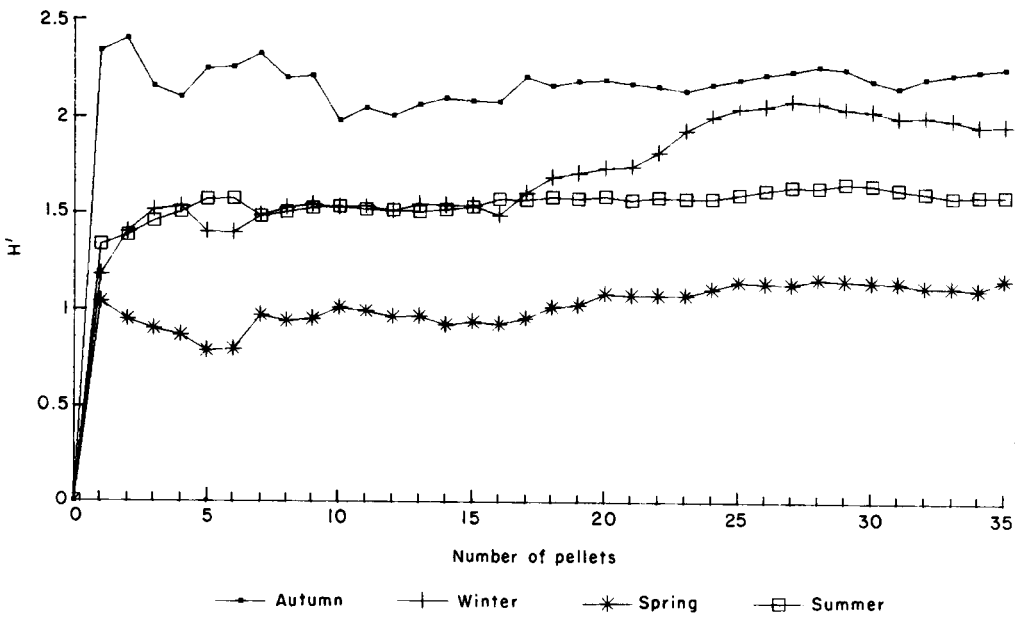

Figure 1. Cumulative trophic diversity (H′) with respect to number of pellets.

The volume of seed coats together with the remains of the pulp, which is what appears in a pellet, cannot be related to a given biomass. We have therefore considered only the volume of each vegetable element of each pellet. The relative importance of each of the three fractions that appear in the pellets (animal, vegetable and mineral) was determined using percentages of the total volume (not mass) in order to avoid overemphasizing the importance of the accompanying mineral fraction.

To analyse the vegetable fraction we used two indices: the percentage of occurrence (O_c%; percentage of pellets examined containing an identified specimen) and the percentage of volume (V%). To analyse the animal fraction we used four indices: percentage of occurrence (O_c%), percentage of biomass (B%), percentage frequency (F%; percentage of the total animal items corresponding to an identified specimen) and the Overall Index of Relative Importance (OI). This last index integrates the three previous indices in the following manner:

$$OI = (F\% + B\%) * O_c\% / 100 \text{ (Ref. 16)}$$

and can be considered to be an objective indicator of the relative importance of each prey item.[17–19]

In order to avoid giving too much weight to the rare taxa in the between season comparisons, only the groups which show an OI value similar or greater than unity are considered, grouping the rest under 'other insects' (See Table 1). In this way 15 animal taxa were used in the analyses.

Statistical methods

To test for differences between the value of the indices (OI or O_c%) calculated for each of the prey (animal and vegetable, respectively) we used the *G* test. Rank correlation was used to test for associations between pairs of OI indices for different prey types. To determine which prey items best explained seasonal variation in the animal Chough diet we used stepwise discriminant analysis[20] after normalizing the data by transforming the number of different prey in every sample logarithmically (Y=Log (X+1)).

RESULTS

Overall analysis

In our study area the Chough is omnivorous, having three distinct dietary fractions which appear together in almost every pellet: animal, vegetable and grit. The animal fraction was absent in only 1.4% of the pellets analysed, the vegetable fraction in 0.7% and the grit in 4.3%. The animal fraction reached values very close to or above 50% of the pellet volume in each of the four seasons, clearly exceeding the vegetable fraction, especially in spring (Fig. 2). The seasonal differences in volume were significant in the animal and vegetable fraction ($F_{3,136}$= 5.1, P <0.005; $F_{3,136}$= 4.3, P< 0.01, respectively) as well as in the grit ($F_{3,136}$= 26.4, P<0.001).

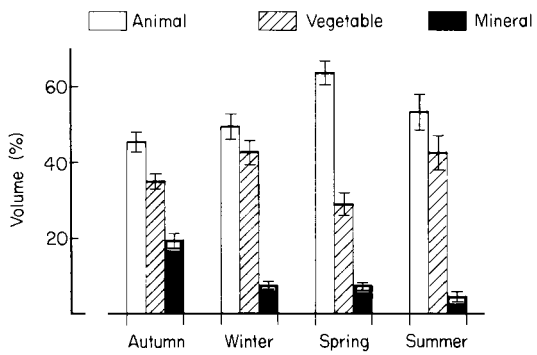

Figure 2. Volumetric percentage of animal, vegetable and mineral fractions in each of the four season. The vertical bars are 95% confidence limits.

Vegetable fraction

Wild grains were the most important element of the vegetable fraction in summer and winter, while cultivated cereals predominated in spring and autumn (Table 2). The high percentages of other types of vegetable material, particulary in summer and autumn, were due to the great quantity and variety of wild seeds found in the pellets, among which *Clozhophora tinctoria* was the dominant seed (and is therefore presented separately).

The composition of the vegetable fraction varied significantly between seasons (G= 71.36; df= 12; P<0.001). This was caused mainly by variation in the volume of cultivated cereals

Table 1. Percentages of frequency (F%), occurrence (O_c%), Biomass (B%) and the Overall Index of Relative Importance (OI) of each prey group

	Autumn				*Winter*				*Spring*				*Summer*			
	F%	*O_c%*	*B%*	*OI*	*F%*	*O_c%*	*B%*	*OI*	*F%*	*O_c%*	*B%*	*OI*	*F%*	*O_c%*	*B%*	*OI*
Gasteropoda (Snails)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	8.6	0.5	0.1
Spider egg sacs	0.4	8.6	3.7	0.4	0.0	0.0	0.0	0.0	0.4	11.4	1.6	0.2	0.1	2.9	0.8	0.0
Diplopoda (Millipedes)*	2.3	62.9	23.4	16.1	0.5	8.6	4.6	0.4	0.4	11.4	1.9	0.3	0.1	2.9	0.9	0.0
Insects	97.3	100	67.0	164.3	99.5	100	95.4	194.8	99.2	100	95.8	194.9	99.5	100	86.0	185.5
Dermaptera (Earwigs)	0.5	14.3	1.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ootheca (Mantids)	0.1	2.9	2.4	0.1	0.0	0.0	0.0	0.0	0.2	5.7	2.1	0.1	0.0	0.0	0.0	0.0
Orthoptera	3.6	65.7	10.3	9.1	0.5	8.6	0.8	0.1	0.3	8.6	1.6	0.2	12.3	94.3	34.7	44.3
Grillids (Crickets)*	0.5	14.3	4.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	48.6	20.3	11.2
Grillotalpids (Mole Crickets)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.9	1.4	0.0	0.0	0.0	0.0	0.0
Acridids*	2.9	57.1	5.4	4.7	0.5	8.6	0.8	0.1	0.2	5.7	0.2	0.0	9.6	94.3	14.4	22.6
Tetigonids	0.1	2.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heteroptera (Plant bugs)	0.8	22.9	1.1	0.4	1.3	17.1	1.4	0.5	0.9	25.7	0.5	0.4	2.4	60.0	2.6	3.0
Neuroptera (Ant lions)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	11.4	0.2	0.1
Lepidoptera (Butterflies)	1.3	8.6	3.4	0.4	0.2	2.9	0.5	0.0	40.4	88.6	62.4	91.1	5.6	37.1	15.8	7.9
Larvae*	0.8	5.7	2.9	0.2	0.2	2.9	0.5	0.0	40.4	88.6	62.4	91.1	5.6	37.1	15.8	7.9
Pupae	0.4	2.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hymenoptera	44.9	88.6	8.9	47.6	22.2	94.3	3.2	23.9	4.9	71.4	1.2	4.3	6.4	57.1	1.7	4.6
Ants*	44.1	88.6	6.0	44.4	22.0	94.3	2.6	23.2	4.4	62.9	0.3	2.9	6.1	54.3	0.7	3.7
Others*	0.7	20.0	2.9	0.7	0.2	2.9	0.6	0.0	0.5	14.3	0.9	0.2	0.3	8.6	1.0	0.1
Coleoptera (Beetles)	45.8	100	38.4	84.2	75.1	100	88.9	163.9	52.5	100	28.0	80.5	72.2	100	30.4	102.6
Larvae*	17.3	71.4	5.9	16.6	0.0	0.0	0.0	0.0	5.0	57.1	0.8	3.3	42.3	91.4	11.9	49.6
Adults	28.5	100	38.4	66.9	75.1	100	88.9	163.9	47.6	97.1	28.0	73.4	29.9	97.1	30.4	58.6
Cicindelids	0.1	2.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	17.1	1.1	0.3
Carabids	4.7	77.1	1.4	4.7	3.2	42.9	0.8	1.7	4.2	85.7	0.5	4.0	2.6	31.4	0.6	1.0
Estafilinids	0.2	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.9	0.0	0.0	0.0	0.0	0.0	0.0
Elaterids	0.1	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Meloids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.9	0.6	0.0	0.0	0.0	0.0	0.0
Tenebrioids	15.8	82.9	21.7	31.1	59.0	100	68.6	127.5	35.8	97.1	22.2	56.3	21.4	94.3	24.2	43.0
Escarabeids	0.1	2.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.9	0.1	0.0
Crisomelids	1.3	34.3	2.9	1.4	1.6	25.7	3.1	1.2	0.7	20.0	0.7	0.3	0.7	20.0	1.3	0.4
Curculionids	2.0	40.0	0.7	1.1	4.1	48.6	1.2	2.6	4.7	82.9	0.7	4.5	1.6	40.0	0.5	0.8
Histerids	0.7	20.0	0.5	0.3	0.5	8.6	0.3	0.1	0.4	11.4	0.1	0.1	0.0	0.0	0.0	0.0
Nitidulids	0.9	25.7	0.3	0.3	0.0	0.0	0.0	0.0	0.7	20.0	0.1	0.2	2.0	57.1	0.6	1.5
Mélolontids	0.9	25.7	6.9	2.0	0.4	5.7	2.2	0.2	0.9	17.1	3.0	0.7	0.2	5.7	1.2	0.1
Other Coleoptera	1.6	42.9	3.7	2.3	6.3	74.3	12.6	14.0	0.0	0.0	0.0	0.0	0.4	11.4	0.8	0.1
Other insects	0.3	8.6	1.3	0.1	0.2	2.9	0.6	0.0	0.0	0.0	0.0	0.0	0.2	5.7	0.7	0.1
Total	954				558				988				984			

*Prey groups considered in the seasonal comparisons.

Table 2. Average of the percentage of volume (V%), standard error (se) and percentage of occurrence (O_c%) of each vegetable item. The group 'Others' includes a variety of wild seeds, almonds, acorns and grapes

	Autumn (n=35)			*Winter (n=35)*			*Spring (n=35)*			*Summer (n=35)*		
	V%	*se*	O_c%	*V%*	*se*	O_c%	*V%*	*se*	O_c%	*V%*	*se*	O_c%
Cultivated cereals	48.0	4.7	96.0	1.3	1.3	2.9	51.5	4.5	65.7	19.7	4.2	31.4
Wild seeds	35.7	7.6	45.7	96.1	2.9	97.1	42.8	7.2	62.9	68.7	6.9	80.0
Cereals germinating	0.2	0.2	2.9	0.1	0.1	2.9	3.0	1.7	28.6	2.6	2.6	2.9
Clozhophora tinctoria	3.8	2.3	8.6	2.0	1.4	5.7	0.2	0.2	2.9	0.0	0.0	0.0
Others	9.5	3.1	32.0	0.6	0.4	14.3	2.6	2.3	8.6	9.0	3.3	28.6

($F_{3,136}$= 15.7, $P < 0.0001$), which never exceeded 2% of the total volume in winter, but was much higher in other seasons. The volume of wild grains in Chough pellets also varied significantly between seasons (($F_{3,136}$= 18.2, P <0.0001), being most abundant in winter and summer when cultivated cereals were more scarce.

Animal fraction

In all, we identified 3484 animal prey, of which more than half (59.8%) were Coleoptera (beetles), the most abundant prey in every season (Table 1). The second most abundant group was Hymenoptera (mostly Formicidae or ants), followed by Orthoptera (Table 1). Within the Coleoptera, Tenebrionidae (principally the genus *Pimelia*) were prevalent throughout the year. The Formicidae were an important part of the diet in autumn and winter, exceeding even the Tenebrionidae (in terms of percentage frequency), whereas in the spring Lepidoptera larvae predominate (in every used index, Table 1).

The composition of the animal fraction (as measured by the overall index (OI)) varied significantly between seasons (G= 304.9; df= 36; P <0.0001). Stepwise discriminant analysis indicated that changes in the number of three prey types (Lepidoptera larvae, Orthoptera (Acrididae) and ants (Formicidae)) were the best discriminators of the seasonal variation in the composition of the animal fraction (Table 3a). Although ants were available throughout the year, they were consumed more frequently in autumn and winter whereas Orthoptera were most commonly consumed in summer (Table 1). Using only the three significant discriminant prey types (above), the canonical function (Table 3b) correctly classified 80.7% of the samples, thus confirming clear seasonal variation in the diet of the Chough.

Relationships between Choughs and Jackdaws

The animal diet of Jackdaws from the same study area[14] (as measured by the overall index OI) differed significantly from that of Choughs (this study) in three of the four seasons (autumn: G= 20.4, df= 14, P>0.1; winter: G= 43.0, df= 14, P <0.001; spring: G= 62.5, df= 14, P <0.001; summer: G= 69.1, df= 14, P <0.001) while the vegetable diet differed in all four seasons (autumn: G= 35.2, df= 9, P <0.001; winter: G= 123.3, df= 9, P <0.001; spring: G= 39.1, df= 9, P <0.001; summer: G= 72.8, df= 9, P <0.001). The most important differences can be summarized as follows: (a) in all seasons the animal fraction (% volume) of the diet was larger in the Chough than in the Jackdaw (autumn: t= 9.7, df=68, P <0.001; winter: t= 12.0, df= 68, P <0.001; spring: t= 14.6, df= 68, P <0.001; summer: t= 10.4, df= 68, P <0.001); (b) Choughs fed mainly on Coleoptera (Tenebrionidae) and larvae (Coleoptera and Lepidoptera), while Jackdaws fed mainly on ants; (c) in Jackdaws, the vegetable fraction is dominated by cereals in all seasons (autumn: %V= 65.3; winter: %V= 57.7; spring: %V= 78.7; summer: %V= 94.4), whilst in Choughs wild seeds are more important (see Table 2).

DISCUSSION

Overall analysis

The Chough is considered to be principally an insectivorous bird,[21] and in some areas feeds almost exclusively on invertebrates.[9,22] Nevertheless Warnes & Stroud[10] found, as we have, a large vegetable component to the diet. We do not know of any previous study that has indicated the existence of grit in Chough pellets,

Table 3. Results of stepwise discriminant analysis to identify the components of the animal diet which best explain the seasonal variation in the composition of the animal diet. The prey items and associated significance levels are given in (a), and the coefficients for canonical variables are given in (b).

	Steps	*Variable*	*df*	F	P
(a)					
	1	Larvae of Lepidoptera	3–136	16.56	< 0.0001
	2	Acrididae	6–270	59.47	< 0.0001
	3	Formicidae	9–326	47.07	< 0.0001
	4	Other Invertebrates	12–352	38.36	< 0.0001
	5	Larvae of Coleoptera	15–364	33.45	< 0.0001
	6	Other Coleoptera	18–371	30.22	< 0.0001
	Variable	*Coefficients for canonicical variables*			
(b)					
	Acrididae	2.45	−2.92	−2.27	
	Larvae of Lepidoptera	−2.58	−1.28	0.86	
	Formicidae	1.01	0.85	1.67	
	Larvae of Coleoptera.	1.14	−0.74	0.77	
	Other Coleoptera	0.27	−3.01	−1.55	
	Other Invertebrates	1.72	0.03	2.91	

which in our region would be associated with grain consumption.[23]

Vegetable fraction

Cereals have been identified as an important source of food for Choughs in NW Britain.[10] In south east Spain both cereals and wild grains are important sources of food for Choughs. The importance of wild grains may be related to the greater availability of arthropods (mainly Tenebrionidae) in fallow land, because it is in this type of habitat where wild grains are most abundant.[14]

Animal fraction

In agreement with the existing literature,[10,11] this study has shown that Coleoptera are in general the most important prey of the Chough. Nevertheless, in winter, when arthropods are less common[14] and other preferred prey such as larvae (of Coleoptera and Lepidoptera), are difficult to find, the Chough, like other birds in meridional latitudes,[24] resorts to less preferred prey such as ants. In other studies the importance of the ants varies from not being recorded in the diet of the Chough[10] to being considered a major food source.[25] These variations are probably due to differences in foraging habitat and prey availability between study areas.

Similarly, the Tenebrionidae (particularly the genus *Pimela*) are most important as a source of food in winter, which is due not only to the low availability of other preferred prey but also to the inactivity of Tenebrionidae in winter (they often lie under rocks half buried). In our study area the Chough is the predator best adapted to exploit this type of prey.[14]

In spring and summer, when the preferred prey (larvae) are relatively common, we found that more larvae of both Lepidoptera (in spring) and Coleoptera (in summer) are consumed. This is a similar to that reported for Choughs in north-west Britain.[10] The seasonal differences in the diet of the Chough in south-east Spain are a logical consequence of the seasonal variations in the populations of arthropods, variations which are strongly marked in the Mediterranean.[26,27]

Relationships between Choughs and Jackdaws

In our study area the diet of Jackdaws is significantly different from that of Choughs, and mixed flocks of these two species are common, particularly in winter.[28] Antagonistic interactions were never observed between Choughs and Jackdaws, although conflicts occurred among individuals of the same species.

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