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Stomach content and grit ingestion by Rook *Corvus frugilegus* nestlings

Grzegorz Orłowski, Zbigniew Kasprzykowski, Zbigniew Zawada & Grzegorz Kopij

G. Orłowski, Institute of Agricultural and Forest Environment, Polish Academy of Sciences, Bukowska 19, 60-809 Poznań, Poland. E-mail orlog@poczta.onet.pl
Z. Kasprzykowski, Department of Ecology and Nature Protection, University of Podlasie, Prusa 12, 08-110 Siedlce, Poland
Z. Zawada, University of Zielona Gora, Faculty of Biological Sciences,ul. Prof. Z. Szafrana 1,65-516 Zielona Gora, Poland
G. Kopij, Department of Zoology and Ecology, Wrocław University of Environmental & Life Sciences, Pl. Grunwaldzki 24a, 50-363 Wrocław, Poland; Department of Zoology and Ecology, Wrocław University of Environmental Sciences, Kożuchowska 5b, 51-631 Wrocław, Poland

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Stomach content was examined in 53 out of 56 dead Rook *Corvus frugilegus* nestlings found in several breeding colonies in Poland. The stomachs contained 29 different types of items, 46.5% of which were animal, 12.2% plant and 41.2% mineral (small stones, sand and brick fragments). Imagi and larvae of Coleoptera were the most common animal prey (40% of all food items). Small stones and brick fragments were recorded in 27 (48%) chicks and their number per stomach ranged from 1 to 60 (average ± 95%CI = 9.0 ± 3.8–14.1). Statistically significant positive correlation was detected between the chick weight and the number of grit particles found in the stomach.

1. Introduction

Due to the damage that the Rook *Corvus frugilegus* can make in the agricultural crops, its diet has been intensively studied since the middle of the 19th century (reviews in Cramp 1998, Ganzhorn 1986, Jabłoński 1979). Despite this, the stomach contents of dead chicks have not been analyzed to date. Because food availability is an important factor determining the size and distribution of rookeries (Marchant & Gregory 1999, Olea and Baglione 2007) and their reproductive success (Feare *et al.* 1973, Kasprzykowski 2007), the assessment of food composition is a key component of conservation efforts for this species. In Poland, where the Rook is in a steady decline due to rapid changes in the land use of farmland (Jerzak *et al.* 2005; Orłowski & Czapulak 2007); hence the analysis of diet composition of its nestlings may constitute a significant contribution to the knowledge of its ecological requirements.

Although results based on stomach content analysis are often biased – mainly due to postmortem digestion of soft parts of prey and plants (Luniak 1977, Jabłoński 1979) –, this method has frequently been used in the Rook diet analysis

(e.g., Lockie 1956, Fog 1963, Feare *et al.* 1973, Gromadzka 1980). However, with stomach-content analysis studies of the proportion of grit present in stomachs are not biased; the technique appears well suited to determining the use of grit by birds (Barrentine 1980, Alonso 1985, Verbeek 1994, Gionfriddo & Best 1995, 1996). To date, this aspect of the feeding ecology of the Rook has not been investigated in detail.

Key factors affecting Rook productivity are probably the food resources. Food shortage during the nestling rearing may be a crucial cause of high losses and may constitute a form of brood reduction (Owen 1959, van Koersveld 1958). Indeed, dead Rook nestlings are often found in rookeries, especially during unfavourable weather conditions (Rytkönen *et al.* 1993, Kasprzykowski 2001).

The aim of the present study was to analyze the gut contents of dead Rook nestlings found on the ground at several breeding colonies, and to relate the weight of these chicks to the number of mineral, plant and animal food items found in their stomachs.

2. Material and methods

Dead Rook nestlings were collected from 27 April to 7 May 2005, in 12 rookeries situated at the Siedlce (52° 12` N; 22° 07` E) and Wrocław (16° 59` E, 51° 05` N) surroundings, Poland. The rookeries were located in rural areas. The main foraging habitats of adult Rooks at the two areas were crop fields, mainly spring-sown cereals (Kasprzykowski 2003). The rookeries were visited 1–2 times during the breeding season. In each rookery, 1–12 chicks were collected for a total of 56. The birds showed no signs of decomposition, i.e., they had no wounds, suggesting that they may have been dead for only up to 1–2 days before being collected.

On the day of collection all chicks were stored frozen. In June and July 2007 the chicks were defrosted and weighed. Their weight ranged between 4.1 and 252.6 g (average and 95%CI = 36.7 g ± 24.3–49.0 g). Fourteen chicks weighed less than 10 g, 18 weighed 10–30 g and the rest (n = 24) were over 30 g.

The gizzard was cut off just above the esophagus and below the small intestine. Soon afterwards the stomach content was extracted, weighed and stored in 70% alcohol. Food items were identified using a stereo-microscope, and divided into three categories: animal, plant and mineral. During the identification of food items special attention was paid to the earthworm remnants (presence of their chaethae).

Larger chicks were expected to contain more food items in their stomachs, especially in the case of mineral parts (grit) that cannot be digested; additionally, the nestling diet may change during their development. Therefore, all chicks were divided into three weight categories: <15 g (n = 20), 15–35 g (n = 17) and 35–160 g (n = 19). The Chi-square test (χ^2) was used to test the contribution of three types of food items extracted from stomach contents among the nestlings in three weight categories. The t-test was used to compare the weight of chicks whose stomachs contained grit, with the weight of those which did not.

Because the grit presence in the gut may be an important factor in the efficient digestion of some food items, especially hard parts of seeds and insects, the relationships between the number of grit particles and other food items were determined using Pearson correlation coefficient. The distribution of variables (weight of chicks, number of grit particles, animal and plant food items) was tested using the Kolmogorov-Smirnov test. Because not all variables were normally distributed, they were successfully log-transformed to approach a normal distribution. A comparison of the three item types was not possible between eastern (Siedlce; n = 46) and western (Wrocław; n = 10) Poland because no identifiable items were found in nestlings from the latter area.

Results with probability $p \leq 0.05$ are treated as statistically significant below.

3. Results

Stomach content was recorded in 53 out of 56 (88%) analysed Rook nestlings. The mass of stomach contents varied between 0.01 and 8.56 g (average ± 95%CI = 1.04 ± 0.58–1.50; median = 0.44 g). Particular food items were identifiable for 42 chicks. In total 589 items represented by 29 different types were identified: 274 (46.5%) were ani-

Table 1. Stomach content of 42 Rook chicks found dead in ten breeding colonies in Poland. The total number of identified food items amounted to 589. Items = description of food items in the studied stomachs; No. chicks = number of chicks with a given item in their stomachs (% of all studied chicks); Total = total number of identified items (%).

Items	No. chicks	Total
Animal food		
Coleoptera (imagines)	15 (35.7)	26 (4.4)
Coleoptera (larvae)	9 (21.4)	73 (12.4)
Coleoptera: Curculionidae (imagines)	9 (21.4)	27 (4.6)
Coleoptera: Carabidae (imagines)	8 (19.0)	73 (12.4)
Coleoptera: Elateridae (imagines)	6 (14.3)	21 (3.6)
Coleoptera: Elateridae (larvae)	4 (9.5)	21 (3.6)
Coleoptera: Scarabeidae (larvae)	3 (7.1)	12 (2.0)
Unident. Lepidoptera (caterpilars)	3 (7.1)	7 (1.2)
Hymenoptera (imagines)	1 (2.4)	1 (0.2)
Shells of bird eggs	1 (2.4)	5 (0.8)
Orthoptera: Gryllidae (imagines)	1 (2.4)	1 (0.2)
Neuroptera (imagines)	1 (2.4)	1 (0.2)
Coleoptera: Chrysomelidae (imagines)	1 (2.4)	1 (0.2)
Hymenoptera (imagines)	2 (4.8)	2 (0.3)
Diptera: Nematocera (imagines)	1 (2.4)	1 (0.2)
Coleoptera: Scarabeidae (imagines)	1 (2.4)	1 (0.2)
Heteroptera: Miridae (imagines)	1 (2.4)	1 (0.2)
Plant food		
Vegetative parts of plants (stems and leaves)	8 (19.0)	9* (1.5)
Rye (grain)	4 (9.5)	40 (6.8)
Moss (stems)	3 (7.1)	5 (0.8)
Cereals (fragments of roots)	2 (4.8)	4 (0.7)
Wheat (grain)	2 (4.8)	7 (1.2)
Taraxacum officinale (seeds)	2 (4.8)	3 (0.5)
Corn (grain)	1 (2.4)	1 (0.2)
Unident. weed seeds	1 (2.4)	1 (0.2)
Oat (grain)	1 (2.4)	2 (0.3)
Mineral parts		
Small stones (diameter 2–9 mm)	23 (54.8)	166 (28.2)
Fragments of bricks (diameter 3–6 mm)	4 (9.5)	76 (12.9)
Sand	1 (2.4)	1 (0.2)

* Up to 2/3 of all content

mal, 72 (12.2%) were plant and 243 (41.2%) represented mineral parts (Table 1).

Proportions of the three item types were not significantly different between the three specified nestling weight categories (Fig. 1; chi-square test; $\chi^2 = 8.47$, df = 4, $p = 0.08$). Among particular chick groups, statistically significant differences were recorded only between those weighing 15–35 g versus 35–160 g ($\chi^2 = 6.48$, df = 2, $p < 0.05$). Among the animal food the most numerous items were imagines and larvae of Coleoptera ($n = 255$). Plant material was dominated by seeds of rye. The vegetative parts of plants (mainly stems and leaf fragments) comprised maximum of 66% of stomach content.

Small stones and fragments of bricks (together referred to as grit) were recorded in 27 chicks (48%). The proportion of mineral items increased with chick weight category, i.e., 32.6%, 37.8%; 45.3%, respectively (Fig. 1). The number of grit particles ranged from 1 to 60 per stomach (average ± 95%CI = 9.0 ± 3.8–14.1). The weight of the two smallest chicks with small stones and brick fragments in their stomachs was 5.11 and 6.63 g. A statistically significant and positive correlation was recorded between chick weight and the number of

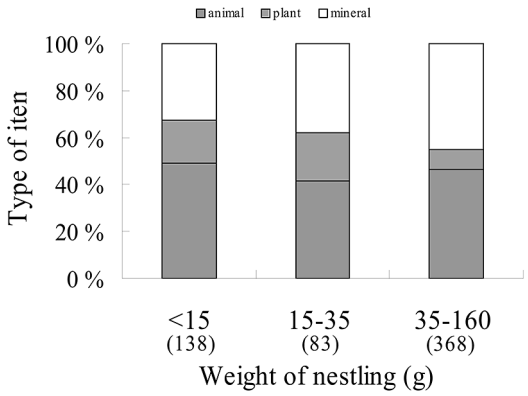

Fig. 1. Proportions of food items (animal, plant and mineral) found in stomachs of dead Rook chicks arranged in three weight categories: <15 g (n = 19), 15–35 g (n = 11), 35–160 g (n = 12). The total number of food items recorded is given in brackets.

grit particles recorded in their stomachs ($r = 0.76$, $p = 0.004$, $n = 27$). However, chick weight was not significantly correlated with the number of other food items ($r = 0.03$, $p = 0.91$, $n = 22$ and $r = –0.10$, $p = 0.70$, $n = 37$ for plant and animal items, respectively). The average weight of chicks having grit particles was similar to those without grit (40.67 vs 36.14 g; $t = 0.37$, df = 54, $p = 0.71$).

The number of grit particles was significantly and negatively correlated with the number of animal food items ($r = –0.58$, $p = 0.05$, $n = 21$). For plant and both animal and plant items, this relationship was not statistically significant ($r = –0.33$, $p = 0.29$, $n = 12$ and $r = –0.51$, $p = 0.09$, $n = 21$, respectively).

4. Discussion

The present study revealed two little expected findings. First, the adult Rooks had apparently provided grit for their chicks, which was not coincidental of them feeding the chicks earthworms. Second, the lack of earthworms and their remnants in the diet of nestlings suggests that these food are not available for Rooks that breed in the studied rookeries.

Under laboratory conditions, Luniak (1977) showed that 30–40 minutes after ingestion earthworms are totally digested in stomachs of adult Rooks. He also demonstrated that food is still digested after the bird's death; our results can therefore be biased. The relatively large proportion of mineral items – which are indigestible – can be at least partly explained by this fact. However, although we paid special attention to the presence of earthworm chaetae (these are well preserved in stomach contents; Fog 1963), these were not recorded in our material. Therefore, they provide important comparative data to these previous studies. No such studies have been conducted in recent years, and most of the earlier ones only refer to the diet of adult Rooks (Jabłoński 1979; review in Cramp 1998).

In the four papers on Rook nestling diet, compiled by Cramp (1998), the contribution of earthworms varied from 0 to 60.5% of the food volume, and the lack of earthworms was described only in the paper based on stomach analysis (Gerber 1956; after Cramp 1998). Jabłoński (1979) recorded a much higher proportion of earthworms in the material collected using neck collars than in that obtained from stomachs. On the other hand, the proportion of earthworms in the diet may also result from local availability of this prey. Based on a large dataset, earthworms were recorded only in 10% of stomachs of adult Rooks between March and May (Gromadzka 1980). In the north-western Europe, under more humid conditions, the frequency of earthworms in the Rook diet appears to be much higher than in central and eastern Europe, where conditions are drier and where beetles are more important prey (Jabłoński 1979).

The low contribution of earthworms in the diet of the studied Rooks can possibly be linked with the fact that most rookeries are situated within arable landscapes, where the biomass and availability of this prey is considerably lower than in meadows and pastures (Feare *et al.* 1973, Jabłoński 1979). Grasslands determine the spatial pattern of rookeries (Gimona & Brewer 2006) and the reproductive success of the Rook (Kasprzykowski 2007). The present study reported a high contribution of beetles, supporting Gromadzka (1980). In intensively-managed crop fields the density, biomass and also availability of beetle adults and larvae is up to several times higher than that of earthworms (Ryszkowski 1985), especially during prolonged droughts, when the soil moisture deficit appears (Gruar *et al.* 2003). For example, the density of beetle larvae in cereal cultivations in spring in Po-

land ranged between 30 and ca. 300 ind. m^{-2} (Karg 1985, Szeflińska *et al.* 2003) while that of earthworms did not exceed 10 ind. m^{-2} (Ryl 1984). Also the authors' own observations of Rooks foraging near breeding colonies located in arable landscape, especially on cereal cultivations, do not support feeding on earthworms.

According to Tomek (1976; after Gromadzka 1980), the diet of Rook chicks was similar to that of adult birds, but plant material constituted only a small proportion of the food throughout the growing period of nestlings. In Europe, grain cereals are the dominant plant food in the diet of Rook chicks (up to 24% by number; Cramp 1998). In the present study these constituted 14% of all plant and animal food items, which points to the potential damages the Rook may be causing to cereal cultivations.

The use of grit is an intriguing but little-studied aspect of the Rook's feeding ecology. Przystalski (1985) provides general information on the presence of grit in several adult Rooks examined. Many bird species supply grit to their young, presumably to help in the mechanical breakdown of food and as a source of minerals for skeleton formation and other physiological needs (Verbeek 1994). Grit was also recorded in stomachs of slightly more than 50% of adult American Crows *Corvus brachyrhynchus* examined (Gionfriddo & Best 1996), a frequency similar to the present results on Rook chicks. In the House Sparrow *Passer domesticus* (a species of similar mixed plant-animal diet), the efficient digestion of hard-bodied beetles may require an increased grit use (Gionfriddo & Best 1995). Pinowska (1975) reported that grit mass increased with the proportion of insects in gizzard of House Sparrow females during the breeding season and concluded that grit may assist in the digestion of chitinous insect parts. Grit is also used to aid the mechanical breakdown of hard seeds, especially the grain (Alonso 1985, Verbeek 1994).

The negative relationship between the number of animal food items and grit particles in the present study may indicate that animal food is effectively digested in the stomach. The relatively small proportion of the animal and plant items in the stomach contents may also indicate that these items could have been digested after death of the chicks (post-mortem digestion). The presence of grit in the youngest Rook chicks (<10 g) suggests that parents provide grit for their offspring just after hatching. The positive relationship between the weight of the chicks and the number of grit particles indicates that some grit is retained in stomachs with the advance of the nestling age. For a comparison, in the Barn Swallow *Hirundo rustica* which feeds almost exclusively on insects, no relationships were recorded between the chick age and the number of grit ingested (Barrentine 1980). A high proportion of hard-bodied beetles and grain in the diet of Rook chicks may mean that parents must add a large quantity of grit to the offspring diet after hatching in order to adequately facilitate digestion.

Any analysis of bird diet based on stomach contents, including dead individuals, may be biased due to the differences in digestion rates of various kinds of prey (Lockie 1956, Custer & Pitelka 1974). Dead individuals may still be used in such analysis if killing of birds for scientific purposes is not acceptable, especially concerning rare and endangered species (e.g., Cuthbert *et al.* 1999). It should also be stressed that stomach analysis on birds killed by starvation or disease may nevertheless be representative of the presence of grit and may be only useful in the assessment of the amount of this material in the nestlings' gut.

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Mustavariksen pesäpoikasten vatsan sisältö ja pikkukivien nauttiminen

Työssä tutkittiin 53 mustavariksen pesäpoikasen vatsan sisältö useista puolalaisista pesimäyhdyskunnista. Aineisto koostui 29 ravintotyypistä, joista 46,5 % oli eläinperäistä, 12,2 % kasvi- ja 41,2 % mineraaliperäistä (pikkukiviä, hiekkaa ja tiilenpalasia). Kovakuoriaisten eri toukkavaiheet olivat tavallisin eläinravinto (40 % kaikista ravintopartikkeleista). Pikkukiviä ja tiilenpalasia havaittiin 27 poikasella (48 %), ja niitä löytyi 1–60 per tutkittu vatsalaukku (keskiarvo ja 95 % luottamusväli 9,0 ± 3,8–14,1). Poikasen painon ja hiekanjyvien määrän vatsalaukussa välillä oli merkitsevä positiivinen korrelaatio.

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