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FACTORS AFFECTING PREY PREPARATION BY ADULT MAGPIES FEEDING NESTLINGS[1]

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Abstract. We collected 1,138 prey items from the guts of nestling Magpies (*Pica pica*) using neck collars. We noted the alterations (appendages missing, breakage) shown by the prey, and gave an index of preparation to the most abundant prey types (adult beetles and grasshopper nymphs). We then related these indices to prey size, age of the nestlings, brood size, and sampling date. Fifty-seven percent of the beetles were prepared, most of them being broken. The probability of breaking a beetle increased as the difference between clutch size and brood size increased, and as the residuals of prey size on sampling date increased. The probability of having at least one elytra removed increased as the beetle size increased and as the difference between clutch size and brood size increased. The degree of preparation of beetles decreased as their size decreased, as the nestlings grew older, and as the difference between clutch size and brood size decreased. Seventy-one percent of the grasshopper nymphs were prepared, the degree of preparation decreasing as their size decreased and as the season progressed. We conclude that the degree of prey preparation by Magpies feeding nestlings is the result of a trade-off between the benefits obtained by the nestlings and the costs to the parents.

Key words: Magpies, nestling diet, Pica pica, *prey preparation, Spain.*

INTRODUCTION

When adult birds are feeding nestlings, they sometimes prepare the food items in some way before giving them to the chicks (Davies 1977, Peris 1980, Grundel and Dahlsten 1991). Several reasons have been proposed to explain this behavior, including the removal of toxic, dangerous, or unpalatable parts of the prey, the removal of low-quality or deleterious parts to save space in the nestling gut, or simply the splitting of large prey into smaller pieces that can be swallowed by the nestlings, or the removal of appendages to facilitate ingestion (Barba et al. 1996).

All these reasons imply a benefit to the nestlings, because the ingestion and/or digestion efficiency is improved, or physiological or physical damage is avoided. But prey preparation also implies a cost to the parents, because time devoted to preparing the prey is not available for other activities, including foraging. In the first study dealing with this trade-off, Barba et al. (1996) found that prey preparation by adult Great Tits (*Parus major*) feeding nestlings increased with prey size, and decreased as the nestlings grew older, as brood size increased, and as the season progressed.

Our aim was to determine whether these conclusions apply to other passerine species. We selected the Magpie (*Pica pica*) because a previous study had shown that adult Magpies prepare the prey before feeding their nestlings (Martínez et al. 1990) and that beetles and grasshoppers are regularly brought to the nestlings (Martínez et al. 1992). The degree of preparation of these insects could be quantified in a similar way we have used previously (Barba et al. 1996). Furthermore, the neck collar method can be used to collect food items from the nestling gut (Owen 1956), which allows examination of the alterations made to the prey by the parents. These latter two characteristics facilitate the comparison of our previous study on Great Tits and this one on Magpies.

METHODS

STUDY AREA

The study area was located in the valley of the Pitarque River, eastern Spain (40°30′N 0°35′W, 950–1,200 m elevation). The structure and distribution of the vegetation was intensely conditioned by human activities (agriculture and ranching). The main cultivated species were sainfoins (*Onobrychis viciaefolia*), lucerne (*Medicago sativa*), and potatoes (*Solanum tub-*

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erosum). Some of the fields are being abandoned and recolonized by the semi-evergreen zeen oak (*Quercus faginea*) forest characteristic of the valley. More information about the study area is in Belda et al. (1998).

NESTLING FOOD

We obtained nestling food by placing neck collars on 5–20-day-old nestlings (Owen 1956, Balança 1984) during the 1994 and 1995 breeding seasons. The collars were applied for a 3-hr period to each nestling present in a nest. Total sampling time was 171 hr, and samples were taken from 17 different broods. In total, 1,358 prey items were obtained from 111 different nestlings.

The food collected in each nest was kept in individual vials containing 70% alcohol. We noted the nest number and sampling date on each vial. In the laboratory, the length of each food item, and the type and degree of alteration were noted. "Prey preparation" refers hereafter to any observable alteration of the original prey stage.

DEGREE OF PREY PREPARATION

We quantified prey preparation in the two most abundant prey types in the nestling diet: adult beetles and grasshopper nymphs (see Results). A preparation index (PI) was assigned to each prey item, depending on the degree of preparation observed. Higher scores were given to those manipulations that presumably took more effort. We based the scoring on the time spent by Grasshopper Sparrows *Ammodramus savannarum* to remove appendages and body parts (head) of grasshoppers (Kaspari 1991). In the grasshopper nymphs (grasshoppers hereafter), we assigned a score of 0.5 for each missing antenna, a score of 1 for each missing foreleg, midleg, or hind tibiae, and a score of 1.5 for each missing hind leg. In the beetles, we assigned a score of 0.5 for each missing leg, a score of 1 for each missing wing, and a score of 1.5 for each missing elytra. In some cases, the head or the head and prothorax were missing; this manipulation was scored 3. Zero scores were assigned to complete prey items. The time required to remove a particular appendage or body part was assumed to be independent of prey size (Kaspari 1991).

For beetles and grasshoppers, and within each family, we calculated the proportional contribution of each body part (head, prothorax, rest of the body) to the total body length. We used these proportions to estimate the total body length of broken prey items.

Preparation of other prey types (larvae, pupae, adult grasshoppers and spiders) also is briefly described.

INDEPENDENT VARIABLES

The PI of beetles and grasshoppers was related to the following variables: prey size, nestling age, number of nestlings present in the nest on the day of sampling (brood size), difference between clutch and brood size, and sampling date. The last three variables provide an estimate of the time available to the parents (see Barba et al. 1996 for details), assuming that food for the nestlings is more difficult to find as the season progresses (Birkhead 1991). For some analyses, these five variables were categorized as follows:

Prey size in beetles: small (< 11.1 mm), intermediate (11.1–16.1 mm), and large (> 16.1 mm).

Age of the nestlings: young (< 10 days), middle-aged (10–16 days), and old (> 16 days).

Brood size: few (< 5), average (5–6), and many (> 6).

Difference between clutch and brood size: none (equal sizes), intermediate (1–2), and high (> 2).

Sampling date: early (May), middle (June), and late (July).

STATISTICAL ANALYSES

Our criteria for prey preparation ranged from 0–11 for beetles and included 23 categories, and from 0–10 in grasshoppers and included 21 categories. Because the frequency distribution was approximately normal, we used stepwise multiple regression to analyze the relationship between PI and the independent variables considered. For these two prey types, the size of the items found within a nest and sampling session were different. As prey size was one of the independent variables considered, each prey actually contributed 1 df to the model. The coefficients (B) of significant variables are presented.

We used logistic regressions to describe the proportion of different manipulations on prey items as a function of the above mentioned independent variables (see Barba et al. 1996 for details). Models were constructed with a stepwise forward procedure, removing the variables from the model using the likelihood ratio test.

The significance of predictor variables was tested using the change in deviance and degrees of freedom when the variable was dropped from the model. The coefficients (*B*) of the significant variables ± SE are presented along with their significance based on the Wald statistic.

Analyses were performed using the SPSS/PC+ 4.0 (SPSS Inc. 1990). Means ± SD are presented.

RESULTS

From the 1,358 prey items collected, the most abundant types were beetles (24%) and grasshopper nymphs (17%). The length of the items brought to the nestlings ranged between 2 and 81 mm, but the maximum length of beetles and grasshopper nymphs was 32 mm.

BEETLES

Magpies prepared 57% of the beetles ($n = 320$) brought to their nestlings. Ninety-three (69%) of these prepared beetles were broken, the head missing in 51%, and the head and prothorax in 49%. The probability of breaking the beetle depended on the difference between clutch and brood size, prey size, and the interaction between prey size and sampling date ($\chi^2_3 = 78.6$, $P < 0.001$). To better understand this relationship, we regressed prey size against sampling date ($r^2 = 0.3$, $P < 0.01$), and used the residuals as a new variable in the logistic regression. The probability of breaking a beetle increased as the difference between clutch and brood size increased ($B = 0.4 \pm 0.1$, Wald statistic = 6.9, df = 1, $P < 0.01$) and as the residuals of prey size on sampling date increased ($B = 0.3 \pm 0.0$, Wald statistic = 48.4, df = 1, $P < 0.001$; $\chi^2_3 = 75.3$, $P < 0.001$; Fig. 1A).

Thirty-two percent of the beetles prepared ($n = 184$) were found with one or two elytra removed. The probability of removing at least one elytron increased as the beetle size increased ($B = 0.2 \pm 0.0$, Wald statistic = 38.1, df = 1, $P < 0.001$) and as the difference between clutch and brood size increased ($B = 0.3 \pm 0.2$, Wald statistic = 3.9, df = 1, $P < 0.05$; $\chi^2_2 = 54.7$, $P < 0.001$; Fig. 1B).

The mean PI was 2.26 ± 3.04 ($n = 320$). The degree of preparation of beetles decreased significantly as their size decreased ($B = 0.34$, $P < 0.001$), as the nestlings grew older ($B = -0.12$, $P < 0.001$), and as the difference between clutch and brood size decreased ($B = 0.32$, $P < 0.05$; $F_{3,316} = 47.2$, $r^2 = 0.3$, $P < 0.001$; Fig. 2).

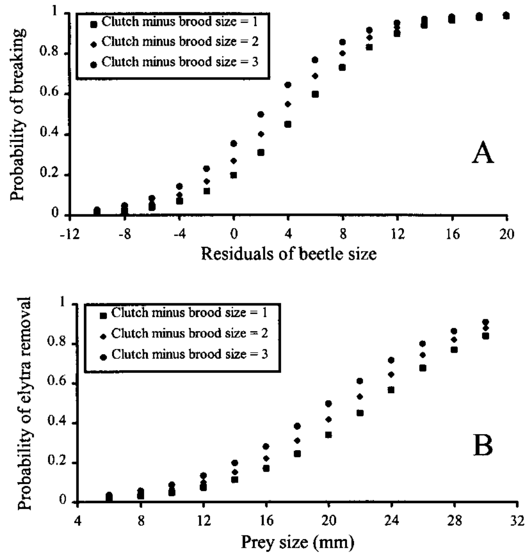

FIGURE 1. (A) Probability of Magpies breaking beetles as a function of the residuals of beetle size against sampling date and the difference between clutch and brood size. (B) Probability of Magpies removing at least one elytron in relation to the size of the beetle and the difference between clutch and brood size.

GRASSHOPPERS

Seventy-one percent of the grasshoppers ($n = 236$) were prepared before being given to the nestlings. The head was missing on only 19 nymphs. There were no significant differences between the body length of nymphs with (16.17 ± 4.63 mm, $n = 217$) or without a head (17.45 ± 4.56 mm, $n = 19$; $t_{234} = 1.2$). In 93% of the prepared items ($n = 168$), the hind legs were partly or completely removed.

The mean PI was 1.85 ± 1.86 ($n = 236$). The degree of preparation of these nymphs decreased significantly as the nymph size decreased ($B = 0.11$, $P < 0.001$), and as the season progressed ($B = -0.02$, $P < 0.01$; $F_{2,233} = 8.5$, $r^2 = 0.1$, $P < 0.001$; Fig. 3).

OTHER PREY

Thirty-one percent of the Lepidoptera and Coleoptera larvae brought to the nestlings ($n = 139$) showed some preparation. Among these, the most common preparation was a single peck (53% of the cases). This peck was usually found

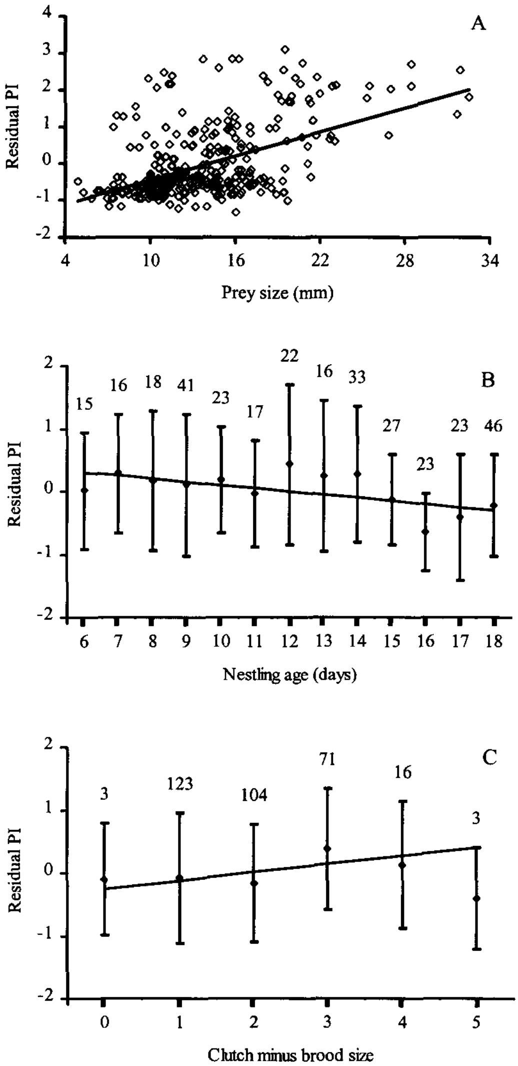

FIGURE 2. Linear regression of the standardized residuals of the beetle preparation index (PI) by Magpies, after removing the effects of the rest of the independent variables, on (A) prey size: y = 0.11x − 1.56, r^2 = 0.27, n = 320, $P < 0.001$, (B) nestling age: y = −0.05x + 0.6, r^2 = 0.03, n = 320, $P < 0.01$, and (C) difference between clutch and brood size: y = 0.13x − 0.25, r^2 = 0.01, n = 319, $P < 0.05$. Mean and SD for each age (B) or difference between brood and clutch size (C) are presented for clarity, instead of all the data points, but regressions were calculated over the original data.

on the head (61%), but in only five cases were the larvae decapitated. Two larvae were found with two pecks and one with three. None of the pupae collected (n = 91) showed preparation.

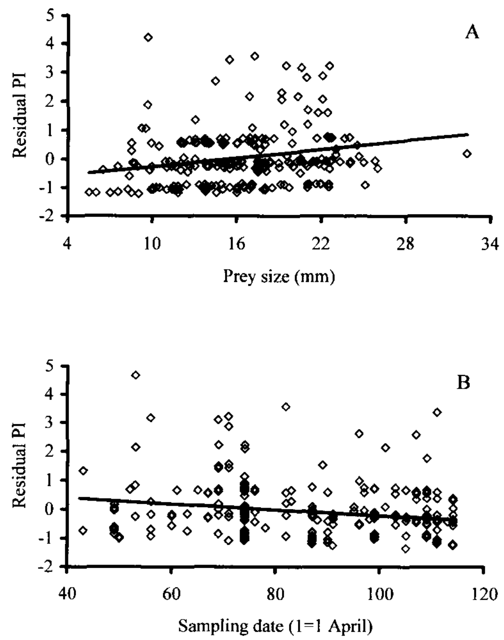

FIGURE 3. Linear regressions of the standardized residuals of the grasshopper preparation index (PI) by Magpies, after removing the effects of the rest of the independent variables, on (A) grasshopper size: y = 0.05x − 0.76, r^2 = 0.05, n = 236, $P < 0.001$, and (B) sampling date: y = −0.01x + 0.79, r^2 = 0.03, n = 236, $P < 0.01$.

Sixty-six of the 78 adult grasshoppers (85%) were prepared, and 20% of these had the head removed. The wings were never removed. At least one hind tibia was missing in 94% of the prepared grasshoppers.

Sixty-two spiders (71%, n = 87) exhibited some kind of preparation, most of them the removal of appendages. Among the 268 miscellaneous animal prey items, 156 exhibited preparation. Thirty-seven percent of these were found broken.

DISCUSSION

Two main factors affect prey preparation by Magpies feeding nestlings. On one hand, Magpies invest more time preparing large prey, which may be viewed as a benefit to the nestlings in terms of ingestion or digestion efficiency. On the other hand, Magpies invest less time preparing the food when presumably they have other priorities, in this case foraging. For example, the prey preparation index is larger when there are fewer nestlings than expected due to hatching failure or nestling mortality, and therefore the food demand also is lower than expected. Also, the prey preparation index is larger at the beginning of the nestling period, when food is probably more abundant. Our results support the idea that the degree of prey preparation is a trade-off between the benefits to the nestlings and the costs to the parents.

PREY PREPARATION AND PREY SIZE

The quantitative relationship between the degree of prey preparation and prey size was first reported by Barba et al. (1996) in Great Tits. Our results on the Magpie completely agree with this study in that bigger prey items are more prepared than smaller ones. This is valid both for the overall preparation of the item and for the removal of specific parts.

Martínez et al. (1990) concluded that there was no significant relationship between prey size (dry weight) and complexity of the preparation. However, the "complexity" was not quantified, and all the prey of the same taxonomic order were grouped. Therefore, we think that this was too rough of an analysis to detect the relationship between prey size and prey preparation.

Although big grasshopper nymphs are more prepared than small ones, a very common preparation, the removal of hind tibiae, was found in 93% of the items. This agrees with the observations of Martínez et al. (1990) on nestling Magpies, and those of Kaspari (1991) on adult Grasshopper Sparrows. A major function of this removal, also found in adult grasshoppers, is probably avoiding injuries to the nestlings.

The removal of other appendages, both in grasshoppers and in beetles, may have the function of improving ingestion and digestion efficiency, because cylindrical items are more easily swallowed (Kaspari 1990) and appendages are usually very chitinous and contain little digestible matter (Kaspari 1991). Results presented by Martínez et al. (1990) also point to this conclusion.

The head of the grasshopper nymphs was rarely removed, and there was no relationship between this removal and the size of the nymph. However, heads of the beetles were much more often removed, the head being almost always removed if the beetle was prepared in some way. A reason for removing the head, other than killing the prey, is avoiding the risk of injury to, or even death of, nestlings, either by biting or by choking if the prey holds on to the throat (Perrins 1979).

PREY PREPARATION AND NESTLING AGE

Grundel and Dahlsten (1991) found that the percentage of prey prepared by adult Mountain Chickadees *Parus gambeli* feeding nestlings decreased as chicks grew older, and Barba et al. (1996) found an inverse relationship between prey preparation and nestling age in Great Tits. Martínez et al. (1990), considering all prey types together, showed that Magpie nestlings 1–5 days old received more prey items with appendages removed than did older nestlings. However, the differences do not seem to be large, because they reported that 39% of the items brought to 1–5-day-old nestlings had some appendages removed, whereas the figure for 16–20-day-old nestlings was 30%.

We only found a relationship between overall preparation of beetles and nestling age. In other words, specific removal of some parts of the beetle (head, prothorax, forewings) or grasshoppers (mainly hind legs) are more dependent on other factors than nestling age. Prey items brought to nestling Magpies are relatively small compared with even the smallest nestlings studied here. We did not take samples from 1–4-day-old nestlings, so it might be possible that more appendages are removed when feeding very young chicks. In any case, prey size relative to nestling size probably is not so important to Magpies as it is to Great Tits. The increase in food demand as the nestlings grow older also may have contributed to the relationship between beetle preparation and nestling age (see next section).

PREY PREPARATION AND AVAILABILITY OF TIME TO THE PARENTS

Barba et al. (1996) suggest, assuming a constant time allocated to other activities, that the time available for prey preparation will depend on the food demand by the nestlings relative to the foraging ability of the parents and the availability of prey. They found evidence of this in Great Tits, where the degree of prey preparation decreased as the number of nestlings increased. Grundel and Dahlsten (1991) also found that the percentage of prey prepared by Mountain Chickadees decreased as the number of visits to the nest increased.

The results presented here on Magpies suggest that time available to parents is a major factor affecting prey preparation for the nestlings. However, the degree of prey preparation is not so closely related to the number of nestlings present, but to the difference between expected and realized brood size. This is clearly observed in the preparation of beetles, which is highly dependent on the difference between clutch and brood size. In other words, parents that lose part of the brood (either unhatched eggs or nestling mortality), and therefore have less work than expected, have a higher preparation index, i.e., the items are prepared more. On the other hand, the decrease in the preparation index of grasshoppers as the season progressed is probably a consequence of the increasing difficulties in finding food late in the season. Therefore, there is evidence of a trade-off between time allocated to foraging and that allocated to preparing food.

PREPARATION OF OTHER PREY

Larvae and pupae were less frequently prepared than adult insects, a result also found by Martínez et al. (1990). The lack of appendages of these prey is probably the main reason. Great Tits sometimes break a pupa with one peck, probably to facilitate digestion (Barba et al. 1996), a behavior not found in Magpies. Most adult grasshoppers received the same preparation as nymphs, namely the removal of hind tibiae. Martínez et al. (1990) also reported this removal, although they did not distinguish between adults and nymphs. In spiders, the preparation consisted mainly in the removal of appendages, as observed by Pinkowski (1978) and Martínez et al. (1990).

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