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Nestling diet of the Common Magpie (*Pica pica*) in urban and agricultural habitats

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Several processes may be responsible for the urbanization of the Common Magpie (*Pica pica*), a species spreading widely in European towns during the last 50 years. Greater supply or better availability of food could play a role in the successful colonization of urban habitats by this species. We compared the nestling diet of Magpies within (urban) and adjacent to the city (rural) of Prague, Czech Republic, using the neck-collar method, and studied parental foraging behavior and micro-habitat associations in the city of Prague. Although the nestling diet was different between urban and rural areas, invertebrates (mainly Coleoptera) were the most frequent prey in both areas. Anthropogenic food was more abundant in urban than in rural areas. The nestling diet differed from the potentially available food supply in both urban and rural areas: Annelida and Lepidoptera were preferred, while Isopoda, Diplopoda, Orthoptera and Hymenoptera were neglected. In urban areas, Magpies foraged actively (i.e., by walking) and by perching. Prey was collected mostly from the ground. Magpies foraged mainly at sites covered with short vegetation. Utilization of short vegetation was proportional to its availability, whereas tall vegetation was used less than could be expected by availability. Short vegetation dominated the home ranges of Magpies in urban areas, while tall vegetation was more common in the Magpie home ranges in rural areas.

1. Introduction

Expansion of urban areas has become a widespread phenomenon, and it is likely to continue in the future. Adaptation of wild animals to the urban environment is referred to as synurbization (Luniak 1998). Urban avian communities usually consist of omnivorous species adapted to human activities. Generally, the higher the level of urbanization, the lower the number of species, and the higher the population densities of these remaining, urbanized species (Konstantinov 1996). The reasons for higher densities in urban areas, compared to rural areas, may be higher amounts of resources, or urban areas may provide different resources that are better, alternative, or complementary. The reasons for urbanization of various bird species may involve lower predation (e.g., Balança 1984, Dreifke 1994), higher winter temperatures that lead to higher survival and earlier onset of breeding (e.g., Tatner 1982, Eden 1985, Antonov & Atanasova 2003), decreased competition (Kurz & Musil 2003), lower persecution by humans, additional food sources, or increased supply of suitable micro-habitats for foraging (Dreifke 1994).

Additional food sources play a significant role mainly in the urbanization of generalist and opportunistic bird species (Marzluff *et al.* 2001). Changes in diet have been reported for various urbanized species, such as the Great Tit (*Parus major*; Cowie 1988), Starling (*Sturnus vulgaris*; Mennechez & Clergeau 2001) and House Sparrow (*Passer domesticus*; Gavett & Wakeley 1986). The diet change often includes utilization of various kinds of anthropogenic food, which are available throughout the year and accessible irrespective of weather conditions (Balança 1984, Clarkson & Birkhead 1987, Jerzak 1995, Jerzak 2001). Anthropogenic food may also be used to feed nestlings (Dosch 1997, Mennechez & Clergeau 2001, O'Leary & Jones 2006). This may prevent nestling starvation during periods of bad weather when invertebrate food may not be accessible, and may result in higher fledging success (Richner 1992, Dhindsa & Boag 1990). However, a large proportion of anthropogenic food in nestling diet may also have disadvantages. Natural diet, consisting mostly of invertebrates, appears crucial for nestling growth and survival (Cowie & Hinsley 1987, Mennechez & Clergeau 2001, Peach *et al.* 2008). This may explain lower urban reproductive success compared to rural populations in the Florida Scrub-Jay (*Aphelocoma coerulescens*; Bowman & Woolfenden 2001), Starling (Mennechez & Clergeau 2001), Carrion Crow (*Corvus corone corone*; Richner 1989) and House Sparrow (Peach *et al.* 2008). It may also explain the preference of the Australian Magpie (*Gymnorhina tibicen*) for a natural insect diet despite a supply of anthropogenic food (O'Leary & Jones 2006). Another reason for synurbization associated with food may be micro-habitats for foraging, which may be more diverse in urban environments compared to, e.g., intensively-managed agricultural areas (Dreifke 1994).

In this study, we compared the nestling diet of rural and recently urbanized populations of Common Magpies (*Pica pica*; hereafter referred to as Magpie). This species has dramatically increased in European towns in the last 50 years. Urbanization of the Magpie started in north-western Europe (Great Britain and Ireland), and the species has rapidly expanded eastwards through central European towns (Bayens & Jerzak 1997).

We compared the foraging biology of the Magpie between urban and agricultural (hereafter rural) areas in order to examine (1) the similarity in nestling-diet composition between urban and rural Magpies; (2) whether the composition of nestling diet differs from food supply within Magpie territories; (3) which foraging methods and foraging micro-habitats Magpies use in urban areas; and (4) whether the supply of foraging micro-habitats differs between urban and agricultural areas.

2. Material and methods

2.1. Study design

Parental foraging behavior and nestling diet was studied during the Magpie breeding season (May–June) between 2003 and 2005. Each brood studied belonged to a different parental pair: Magpies were not individually marked, but the nests were situated far enough from each other to avoid home-range overlap. Due to the continuous breeding season, we were not able to distinguish between first and second broods. Urban areas consisted of housing estates of Prague (50°5' N, 14°25' E, Czech Republic), and thus included built-up areas with lawns, shrubbery and scattered deciduous and coniferous trees. Fourteen nests for the diet study, and 16 nests for the parental foraging behavior study, were examined within this area. Rural areas were situated in the surroundings of Prague (agricultural landscape and villages within 20 km from Prague) and Beroun (49°54' N, 14°1' E; 40 km south-west from Prague). In this category, "rural" and "exurban" areas are considered (see Marzluff *et al.* 2001); the category thus includes areas with scattered buildings surrounded by agricultural landscape and also areas with scattered buildings surrounded by meadows with tall grass, shrubbery and scattered trees. Within these areas, nestling diet was studied in 13 nests. Foraging parents could not be studied in these areas because of dense vegetation and long-distance flights of the birds.

2.2. Diet sampling

Nestling diet was studied by the neck-collar method (Rosenberg & Cooper 1990, Krištín 1992) when nestlings were aged from 7 days until fledging (ca. 24 days). In both urban and rural areas,

Table 1. Magpie nestling diet (Diet) and potential food supply (Supply) in urban (U) and rural (R) areas. Total numbers (items; for diet only) and average percentages (%) of items and average percentages of volumes are shown.

	Diet, items		Diet items, %		Diet volume, %		Supply items, %		Supply volume, %	
Food type	U	R	U	R	U	R	U	R	U	R
Annelida	2	31	1	2	1	5	–	–	–	–
Araneida	49	54	5	12	2	7	14	24	10	13
Isopoda	22	49	3	4	1	2	17	7	14	6
Diplopoda	2	0	<1	0	0	<1	6	3	13	3
Orthoptera	6	15	2	3	0	1	11	5	10	3
Heteroptera	8	26	2	2	1	2	4	6	2	2
Lepidoptera	53	139	9	13	7	15	1	1	2	1
Diptera	43	36	7	4	4	3	7	5	5	2
Hymenoptera	8	10	1	1	0	0	3	5	2	4
Coleoptera	700	585	48	51	17	21	34	40	34	53
Rodentia	3	11	1	1	7	24	<1	<1	6	10
Passerine chicks	2	0	1	0	5	0	–	–	–	–
Seeds	41	25	7	4	3	2	–	–	–	–
Wheat products	9	9	7	1	19	12	–	–	–	–
Meat products	24	2	5	<1	31	<1	–	–	–	–
Other	35	1	1	2	2	6	3	4	2	3
Total	1,007	993	100	100	100	100	100	100	100	100

85% of visits were carried out during the second and third weeks of nestling age. The timing of breeding was similar in urban and rural areas (hatching date 1 May ± 2.6 days and 3 May ± 1.6 days, respectively); diet samples were collected from the first ten days of May to the first ten days of June. Neck collars were made from plastic-coated wire (diameter 1–2 mm, length 2–4 cm) and were applied for 4–5 hours (according to nestling age). The collars prevent the nestlings from swallowing food that accumulates in their crops. The food may then be easily extracted by forceps from the crop. After each application of neck collars, nestlings were fed chicken meat to compensate for food items taken away. Food samples were stored in ethanol; one sample equals food brought by both parents to a given nestling during one observation interval (4–5 hours). Nests were visited repeatedly, up to five times, to obtain sufficient material from each nest; the interval between two successive visits was usually two days. Samples from all visits of the same nest were pooled for the analysis. A total of 1,007 food items were collected in urban areas (132 samples; 14 nests) and 993 items in rural areas (111 samples; 13 nests).

Information on food items available in each Magpie territory (hereafter referred to as “food supply”) was collected using pitfall traps (200 ml plastic cups with 4% water solution of formaldehyde) and by sweeping the vegetation with insect nets. Three traps were exposed for five days and 50 sweeps were performed once in each plot (micro-habitat) established within the home range of each studied breeding pair (300-m diameter circle with the nest in the center). This diameter corresponds with the observed home-range size of Magpies at the study localities (P. Fousová, unpubl. data). Samples were stored in ethanol. With both methods combined, a total of 3,486 invertebrates were collected in urban areas (14 home ranges) and 5,700 items were collected in agricultural areas (13 home ranges).

All food items were identified to the family level and then grouped into categories for further analyses: Annelida, Araneida, Isopoda, Diplopoda, Orthoptera, Heteroptera, Lepidoptera, Diptera, Hymenoptera, Coleoptera, Rodentia, passerine chicks, seeds, wheat products (mainly bakery products), meat products (mainly roasted meat and sausage), and other (Table 1). In insects, the categories included both larvae and adults. The volume of the items was measured using a measurement cylinder. The average volume of the diet sample per nestling was 1.4 ml in both areas.

2.3. Observations of foraging behavior

Parental foraging behavior during nestling feeding was observed in urban areas in days when neck-collars were not applied. Both parents were observed, provided that they were visible. Observations were not carried out in rainy weather. Observations were tape-recorded and then evaluated using the Observer Video-Pro 3.0 software (Noldus Information Technology, Wageningen, the Netherlands) to obtain measurements of numbers and durations of all recorded behaviors. A total of 9.5 hours of parental foraging behavior were recorded in 16 urban nests, i.e., on average 35.7 (± 9 SE) min per nest.

Parental foraging behavior was classified into the following categories: (1) active searching: walking, running, and hopping on the ground; (2) sit-and-wait searching: perching on elevated posts or on the ground; (3) flying; (4) attacking prey; and (5) handling and/or eating the prey. Foraging substrate was recorded for category 4 as being ground, foliage, building or air. The foraging micro-habitat was also recorded for each behavioral activity (except flying). For this purpose, the following categories were applied: short vegetation (up to 15 cm), tall vegetation (over 15 cm) and mixed vegetation. In urban areas, the micro-habitat preferences were evaluated using maps of all the observed home ranges (the 300-m diameter circles), where the availability of each micro-habitat type was calculated as the proportion of home range covered by a particular micro-habitat type, using the IMAGE TOOL program. For the comparison of microhabitat distribution between urban and agricultural areas, 22 urban and 22 agricultural home ranges were mapped and analyzed using the same method.

2.4. Statistical analysis

The numbers of different types of food were used for statistical analysis to compare nestling diet and food supply between urban and rural areas. The numbers of items were used because they illustrate the parental investment into foraging particular food types better than the volume of items. In addition, volume data are shown in Table 1, which illustrate the amount of various food types the nestlings obtained. Average percentages are shown in Table 1, i.e., percentage of every food type was first calculated within each nest, and subsequently averaged over all nests to eliminate the effect of different numbers of nestlings and samples between nests.

Log-linear analyses of frequency tables were used for comparison of nestling diet and food supply between urban and rural areas, and for comparison of nestling diet with the food supply within Magpie home ranges in both areas. Food items that are difficult to assess, such as anthropogenic food, seeds and passerine chicks, were excluded from the latter analyses. Food preferences were evaluated using Ivlev's index (Jacobs 1974) calculated for volume data.

Mann-Whitney *U* tests were used for comparisons of dominant food types in nestling diet (anthropogenic food and categories >3%) as well as dominant food types in food supply (categories >10%) between urban and rural areas. Wilcoxon matched-pairs test was used for comparisons of dominant food types between nestling diet and food supply within Magpie home ranges of both areas (categories >10% in at least one area). Micro-habitat preferences within urban areas were evaluated using Wilcoxon matched-pairs test. For the analysis of micro-habitat distribution between urban and rural home ranges Mann-Whitney *U* test was used. Bonferroni correction was applied for all Mann-Whitney *U* tests and Wilcoxon matched-pairs tests (Quinn & Keough 2002). All calculations were carried out using Statistica 6.0 (StatSoft, Inc., Tulsa, USA).

3. Results

3.1. Composition of nestling diet and food supply

In the nestling diet, insects (mainly Coleoptera) were the most frequently encountered food type in both urban and rural areas (both numerically and

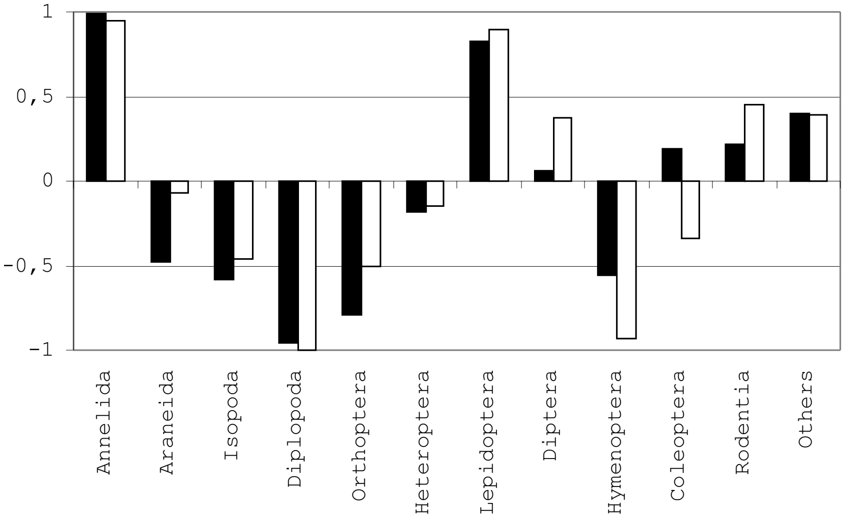

Fig. 1. Comparison of nestling diet and food supply in urban (black columns) and rural (white columns) areas by Ivlev's index (average percentages of volume for food types).

by volume; Table 1). The composition of nestling diet differed significantly between the areas (χ^2 = 179.95, df = 19, $p < 0.001$). Meat products were significantly more abundant in urban than in rural areas (Mann-Whitney *U* test: $Z = 3.32$, $n_1 = 14$, $n_2 = 13$, $p < 0.001$), but the proportion of other food types did not differ markedly between the areas. However, urban nestlings were on average fed more wheat products and seeds, while rural nestlings were fed more Araneida and Lepidoptera, especially when volume data were considered (Table 1). Although volume data were not always exactly consistent with numerical data (Table 1), the dominance of anthropogenic food in nestling diet in both data sets appeared particularly pronounced in urban areas. Interestingly, Isopoda and Orthoptera were proportionally more abundant in the diets of urban nests, while Araneida and Coleoptera were proportionally more abundant in those of rural nests (Table 1).

Food supply differed significantly between urban and rural areas (χ^2 = 1303.6, df = 13, $p <$ 0.001). Among dominant food types, Orthoptera were more abundant in urban than in rural areas (Z = 2.38, $n_1 = 14$, $n_2 = 13$, $p = 0.017$), but the other items showed no significant differences between the areas.

3.2. Comparisons between nestling diet and food supply

Within urban areas, nestling diet differed significantly from food supply (χ^2 = 1083.5, df = 13, $p <$ 0.001). Orthoptera and Isopoda were more abundant in food supply than in nestling diet (Wilcoxon matched-pairs tests: $Z = 3.3$, $n = 14$, $p = 0.001$ and $Z = 2.48$, $n = 14$, $p = 0.013$, respectively). Lepidoptera and Coleoptera were more abundant in nestling diet than in food supply (Wilcoxon matched-pairs tests: $Z = 2.42$, $n = 14$, $p = 0.016$, and $Z = 2.04$, $n = 14$, $p = 0.041$, respectively).

According to the comparison of volume data by Ivlev's index, Annelida and Lepidoptera were preferred (used more than could be expected based on their potential availability, i.e., food supply), while Isopoda, Diplopoda, Orthoptera and Hymenoptera were used less often than expected (Fig. 1).

Nestling diet differed significantly from the food supply also in rural areas (χ^2 = 950.31, df = 13, $p < 0.001$). Lepidoptera and Coleoptera were more abundant in nestling diet than in food supply ($Z = 2.97$, $n = 13$, $p = 0.003$ and $Z = 1.85$, $n = 13$, p = 0.064, respectively), while Araneida showed an opposite pattern ($Z = 1.78$, $n = 13$, $p = 0.075$). According to the comparison of volume data by Ivlev's index, Annelida and Lepidoptera were preferred, while Diplopoda, Orthoptera and Hymenoptera were used less often than expected (Fig. 1).

3.3. Parental foraging behavior and microhabitat preferences in urban areas

In urban areas, Magpies allocated equal time between active searching, i.e., walking and hopping on the ground, and sit-and-wait searching (43% ± 2.94 and 40% ± 3.62 of time, respectively). When searching from elevated posts, they used trees and anthropogenic structures up to five meters height in 46% (± 10.79) of cases. Prey handling and consumption took 11% (± 1.69) of time and flying between foraging site and nest took 6% (± 0.90). Prey were almost always caught on the ground (94% ± 4.97), seldom in the foliage (6% ± 4.97) and only exceptionally on walls of buildings or in the air (0.05% ± 0.04). When searching for prey on the ground, Magpies spent 77% (± 6.84) of the foraging time at sites covered by short vegetation, 13% (± 5.36) at sites covered by mixed vegetation, and only 1% (± 0.54) at sites covered by tall vegetation. Other surfaces, such as paths and sidewalks, were used 9% (± 4.94) of the time.

The utilization of micro-habitats with short vegetation was proportional to its supply within Magpie home ranges (Wilcoxon matched-pairs test: $Z = 1.54$, $n = 22$, $p = 0.123$), which also held for mixed-vegetation micro-habitats ($Z = 0.89$, $n = 22$, $p = 0.37$). However, micro-habitats with tall vegetation were used significantly less frequently than could be expected by their proportion within the home ranges of Magpies ($Z = 2.37$, $n = 22$, $p = 0.018$).

The proportions of micro-habitats covered by short and tall vegetation differed significantly between home ranges situated in urban and rural areas (Mann-Whitney U test: $Z = 3.98$, $n_1 = 22$, $n_2 = 22$, $p < 0.001$ and $Z = -5.56$, $n_1 = 22$, $n_2 = 22$, $p < 0.001$, respectively). Short vegetation predominated in urban areas: 72% (± 7.65) in comparison with 23% (± 4.71) in rural areas, while long vegetation dominated in rural areas: 66% (± 6.15) against 5% (± 1.91) in urban areas. The areas appeared similar in terms of mixed-vegetation micro-habitats ($Z = 0.85$, $n_1 = 22$, $n_2 = 22$, $p = 0.398$), represented by 22% (± 7.42) in urban and 11% (± 3.57) in rural areas.

4. Discussion

4.1. Nestling diet, food supply and diet preferences in urban and rural areas

Contrary to our expectation, the urbanized Magpies were not specialized in anthropogenic food but mostly fed nestlings with various invertebrates, which thus represent the "natural" and probably nutritionally crucial food for Magpie chicks. O'Leary & Jones (2006) found similar compositions in the nestling diet of urbanized Australian Magpies (*Gymnorhina tibicen*). Lepidoptera and Annelida were the most commonly encountered nestling-food items in both urban and rural areas. The preference for the latter could have been overestimated, since the methods used for assessment of food supply did not cover edaphic invertebrates.

Interesting patterns emerge from comparisons between nestling diet and our measure of food supply. For example, Orthoptera, Hymenoptera, Diplopoda and Isopoda were found in the diet less frequently than could be expected based on our food-supply samples in both areas. In the case of Orthoptera, this pattern may have resulted from their phenology: in late spring only early larval instars, that may be too small for Magpies, are available. Diplopoda probably showed a similar pattern due to their ability for chemical defense, and Isopoda due to their predominantly nocturnal activity. It is important to note, however, that our measure of food supply may not reliably reflect true abundances of the sampled invertebrates (see general literature on sampling invertebrates), nor their realized availability for Magpies, due to biases associated with sampling techniques, invertebrate behavior and life cycles, and so on.

Passerine chicks were found only in the diets of urban nestlings, and were rare items. Some authors have reported considerable negative impact of Magpie predation on passerine reproductive success (e.g., Vercauteren 1992, Groom 1993, Cresswell 1997), while others have not found such an effect (e.g., Dix *et al.* 1998, Thomson *et al.* 1998, DeLap & Knight 2004). Perhaps Magpies predate upon passerine nests only if passerines breed in very high densities (Clarkson & Birkhead 1987).

4.2. The role of anthropogenic food

To our knowledge only one study on Magpie diet in an urban environment has been conducted: Tatner (1983) found no anthropogenic material in Magpie diet. However, this study only examined faecal samples and contents of digestive tracts, which may underestimate the presence of anthropogenic food items. Apart from anthropogenic food, the present and Tatner's (1983) results are consistent in that nestlings in urban areas are mostly fed Coleoptera, Lepidoptera, Diptera and Araneida.

Several studies on Magpie nestling diet, also using the neck-collar method, have been done in agricultural areas in Europe (Owen 1956, Eigelis 1964, Högstedt 1980, Spaans *et al*. 1982, Balança 1984, Krištín 1988). Most reported a similar composition of dominant food types as found in our study. Coleoptera appears to be the dominant food component, but also Lepidoptera, Araneida, Diptera and seeds can be frequent. Compared to the present results Annelida has sometimes been more frequent and Araneida less frequent in these other studies. Interestingly, anthropogenic material was commonly reported at agricultural areas in France, with over 40% of proportion (Balança 1984), contrary to 14% in our study.

4.3. Food searching strategies

Urban Magpies foraged by active searching (walking and hopping on the ground) as well as by a sit-and-wait strategy. The time spent in sit-and-wait could have been overestimated, because the Magpies used to sit on elevated posts also when watching for potential predators or searching for suitable foraging sites. Active foraging was mostly observed at sites with short vegetation. The preference of foraging Magpies for short vegetation is well known (Møller 1982, 1983, Balança 1984, Birkhead 1991, Dreifke 1994). In an agricultural environment in France, the preferred micro-habitats were lawns and stubble fields (Balança 1984), and in the outskirts of Sheffield, UK, Magpies preferred permanent pastures, whereas tall grass and areas of bare soil were neglected (Birkhead 1991). The amount of grazed areas and mowed grassland in the territory was positively correlated with the duration of territory occupancy and breeding success of the Magpies in Denmark and UK (Møller 1982, Birkhead 1991).

In urban areas, we did not observe short flights over sites of tall vegetation nor attacks on prey in tall vegetation following sitting on high-vantage posts, a behavior earlier reported by Holyoak (1974) and Deckert (1980) for agricultural areas. These less common foraging techniques might be used by Magpies in agricultural areas, where vegetation can be tall and hence does not allow for walking on the ground. It is also possible that Magpies in agricultural areas may maintain larger home ranges to compensate for smaller proportions of preferred micro-habitats of short vegetation, as previously reported for the Northern Wheatear (*Oenanthe oenanthe*; Exnerová *et al*. 2002).

The scarcity of sites covered with short vegetation, such as pastures, in the intensively-managed agricultural landscapes has been suggested as being the main factor responsible for synurbization of Magpies (Dreifke 1994). Thus, this scarcity may have forced Magpies to move to suburban and urban areas, where frequently-cut, short vegetation (lawns) is present throughout the breeding season. Our results provide indirect support for this hypothesis. Firstly, the observed, urban Magpies used to catch prey mainly on the ground and at sites covered with short vegetation, and secondly, in urban areas the dominant micro-habitat type in the proximity of Magpie nests were lawns, while tall vegetation was more common in rural areas.

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Harakan pesäpoikasten ravinto kaupunki- ja maaseutuympäristöissä

Useat tekijät voivat selittää harakan (Pica pica) menestyksen kaupunkiympäristössä. Laji on levittäytynyt laajalti Euroopan kaupunkeihin viimeisten 50 vuoden aikana. Suuremmat ravintoresurssit tai ravinnon helpompi saavutettavuus kaupungeis-

sa voivat olla menestyksen taustalla. Vertailimme harakan pesäpoikasten ravintoa Prahan (Tsekin Tasavalta) keskustassa ja lähialueilla käyttäen kaulurimenetelmää, ja tutkimme vanhempien ruokailu- ja pienympäristömieltymyksiä keskusta-alueella. Vaikka pesäpoikasten ravinto oli erilaista kaupunki- ja maaseutuympäristöjen välillä, selkärangattomat (eritoten kovakuoriaiset) muodostivat molemmilla alueilla pääravinnon. Ihmisperäinen ravinto oli tavallisempaa kaupungissa.

Poikasravinto erosi molemmilla alueilla potentiaalisesti saatavilla olevasta (kuoppapyydyksin ja lyöntihaavinäyttein arvioituna): kastemadot ja päiväperhoset olivat suositumpia mutta siirat, kaksoisjalkaiset, suorasiipiset ja pistiäiset vähemmin edustettuja kuin saatavuuden perusteella oletettiin. Kaupungissa harakat saalistivat aktiivisesti (kävelemällä) ja istumalla tähystäen. Saalis siepattiin useimmiten maasta. Harakat ruokailivat pääasiassa paikoilla, joilla kasvillisuus oli lyhyttä. Lyhyttä kasvillisuutta hyödynnettiin saatavuuden mukaan, mutta korkeaa kasvillisuutta hyödynnettiin vähemmän. Harakoiden kaupunkielinpiireillä lyhyt kasvillisuus oli vallitsevaa, mutta maaseudun elinpiireillä korkea kasvillisuus oli tavallisempaa.

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