Winter habitat selection of Corvids in an urban ecosystem

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Abstract

Urban areas attract birds during the winter when cities provide a predictable source of food and relatively stable weather conditions. However, many other factors determine the occurrence of birds in cities. This study analysed the relationship between corvids wintering in the city of Poznań, in western Poland and habitat features. Each of 32 research site was investigated three times. The most abundant species was the rook (mean = 17.4 individuals/site); the most frequent was the Eurasian magpie (88% of all sites). To determine variables that influence the abundance of birds, a set of generalised linear models was created, with model averaging being selected for each species. The abundance of hooded crows was positively influenced by surface of parks, water and by the length of tram tracks. The number of rooks was positively linked with the number of walnut trees, garbage cans and the surface of the water and negatively linked with the length of watercourses. Jackdaw was affected positively by the number of garbage cans, the surface of the water and negatively by the cover of trees. The number of magpies was associated with the number of walnut trees, garbage cans and negatively influenced by the surface of trees. None of the investigated habitat variables significantly affected the abundance of European jay. We also found a positive correlation between the abundances of hooded crow, rook, jackdaw and magpie. The results indicate that corvids wintering in urban ecosystems exhibit selectivity toward specific habitat features and that preferences differ among the studied species.

Keywords Corvidae · Foraging · Habitat preferences · Urban landscape · Blue infrastructure · Wintering

Introduction

Urbanisation is proceeding at an ever-growing rate, an increasing part of the globe surface is occupied by human settlements with 55% of the world's human population living in town and cities nowadays (United Nations 2018). Such transformed areas create an entirely new environment, which animals need to either adapt to or abandon (Angold et al. 2006; Nielsen et al. 2014; McKinney 2008; Møller 2009). The presence of humans

in the immediate vicinity, anthropogenic barriers, noise, and artificial light are only a few of the many inconveniences that animals inhabiting cities need to cope with (Fernández-Juricic et al. 2001; Slabbekoorn and Peet 2003; de Molenaar et al. 2006; Møller 2008; Benítez-López et al. 2010; Van Doren et al. 2017). Diamond (1986) has suggested that the formation of such challenging habitats and the attempts of certain species to colonise them were, in the past, an example of rapid evolution, resulting in the creation of new groups of species commensal with humans.

Many taxa (e.g. birds, butterflies and carabid beetles) usually decrease in the number of species in the urbanization gradient (Kowarik 2011). Moreover, intensive management, combined with small surfaces and the spatial isolation of individual parks, greatly reduces the biological richness of urban greenery in terms of, e.g. birds and pollinators (Kowarik 2011; Banaszak-Cibicka et al. 2016; Müller et al. 2018).

On the other side, green urban areas, together with the blue infrastructure, are indisputably the city areas characterised by the highest biodiversity (Chamberlain et al. 2007). However, due to variation in the vegetation composition and landscape structure and management, urban habitats may have a various

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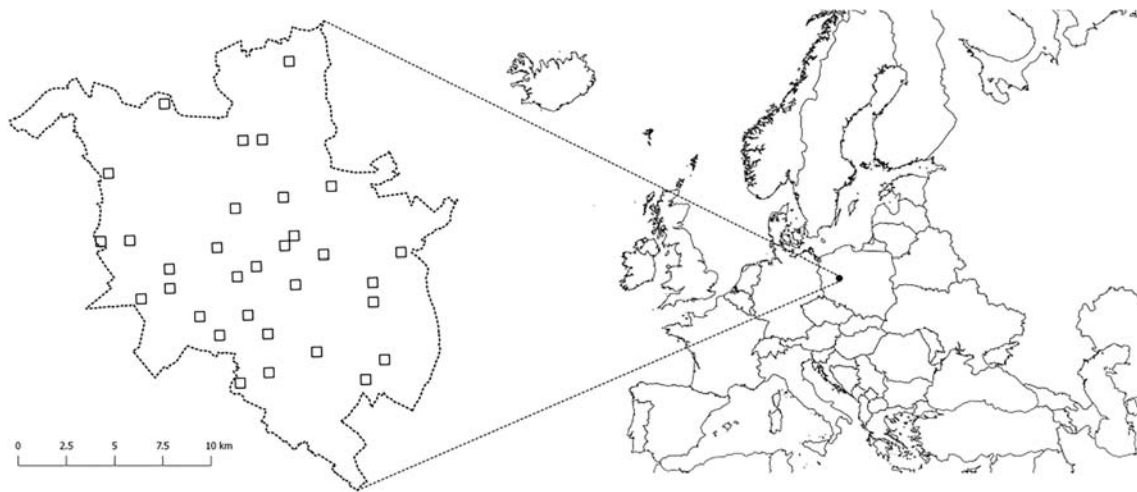3 Institute of Dendrology, Polish Academy of Sciences, Parkowa 5, 62-035 Kórnik, Poland

Fig. 1 Study area: 32 randomly selected research sites within the boundaries (dotted line) of the city of Poznań [52° 24′ 30.85″ N, 16° 56′ 2.44″ E], Western Poland

effect on urban flora and fauna create local hot-spot and cold-spots in the cityscape (Vilisics and Hornung 2009; Tonietto et al. 2011). The high degree of heterogeneity of the urban landscape, which favoured the co-occurrence of species with different habitat requirements, has led to an increased number of specific taxa, e.g. bees (Banaszak-Cibicka et al. 2016), butterflies (Hogsden and Hutchinson 2004), birds (Blair 1999), mammals (Racey and Euler 1982). Moreover, urban green areas provide refuges for rare and threatened species (Ives et al. 2016).

In addition, supplementary provision of food in cities, both intentional (bird feeders) and incidental (e.g. garbage cans, places where leftover food is dumped), reduces starvation and facilitates the survival of birds, particularly during the winter (Brittingham and Temple 1988; Robb et al. 2008). Another advantage of living in the city is

the higher air temperature in the urban areas compared to surrounding areas ("urban heat island"). During the winter, higher temperature resulting in the thinner snow cower in city is favourable for foraging birds and help them to save energy (Møller 1983).

The compositions of avian communities change along the urbanisation gradient. The number of species decreases toward the city centre, where the avifauna is composed of several abundant synanthropic species and without habitat specialists (Marzluff 2001; Chace and Walsh 2006; Clergeau et al. 2006). Urban environments require great environmental tolerance (Møller 2009) and behavioural plasticity (Slabbekoorn and Peet 2003) from animals. Omnivores are in a favourable position (Chace and Walsh 2006). Corvids, with large brains compared to their body size and high behavioural plasticity, are

Table 1 Definitions of categories of landscapes

Name of category	Definition
Block of flats	Big, multifamily buildings with flat roof, usually with 4, 10 or 16 floors
Garden plots	Aggregations of little summer 'houses' surrounded by gardens with fruit trees and small vegetable growing, used by owners mainly in the warm part of the year
Houses	Smaller cube shaped building with sloping or flat roof, usually with 2 floors, inhabited by single families and surrounded by a garden
Industrial areas	Factories, industrial enterprises
Open areas	Fields, meadows, broad lawns
Parks	Municipal parks, cemeteries, urban greenery
Wastelands	Railway sidings, areas with abandoned and destroyed buildings, construction sites, 'wild' parkings
Tenement houses	Old-fashioned downtown buildings with sloping roof, usually with 4–5 floors
Trees	Municipal forests, dense aggregations of trees apart parks
Water	Lakes, ponds, pools, Warta river (smaller streams were not taken under count)

Table 2 Summary of abundance of species on all research sites. Table shows mean number of individuals, standard deviation, minimum and maximum number of individuals per research site and species frequency (percent of research sites, where each species were observed at least once). Last row shows all mentioned values for all species together

Species	Mean number of individuals	SD	min	max	Frequency (% of research sites)
Hooded crow *Corvus cornix*	3.9	10.2	0	62	63
Rook *Corvus frugilegus*	17.4	34.7	0	197	53
Jackdaw *Corvus monedula*	7.6	14.6	0	82	47
Magpie *Pica pica*	9.5	9.5	0	35	88
Jay *Garrulus glandarius*	0.8	1.5	0	8	69
All together	39.0	53.8	0	315	28

assumed to possess a relatively high level of cognitive abilities (comparable even to those demonstrated by great apes) and exhibit a high degree of dietary diversity (Seed et al. 2009). This, along with the ability to discover and use new food resources, is extremely advantageous in cities, where garbage cans with plenty of food leftovers are common.

Although there have been numerous papers about the habitats and foraging preferences of corvids during the breeding season, the literature concerning the selectivity of wintering birds is scanty and usually concerns farmlands (e.g. Wilson et al. 1996; Jadczyk 2009). Very little research of relatively recent date has been conducted in urban landscapes during the winter (e.g. Jokimäki et al. 1996; Jokimäki and Suhonen 1998; Tryjanowski et al. 2015). As well, there have been few papers about interspecific relationships in winter assemblages of corvids (e.g. Waite 1984a, b). Therefore, this study aimed at a comparison of the abundances of corvids wintering in an urban ecosystem with habitat features in order to analyse birds' habitat preferences.

Methods

Data collection

The study was conducted in the city of Poznań [52° 24′ 30.85″ N,

16° 56′ 2.44″ E] located in western Poland. With a population of approx. 540,000 citizens and an area of 262 km² it is fifth the biggest city in Poland. Mean human population density is 2063 citizens per 1 km² (Central Statistical Office 2017). The urban greenery is composed of three concentric rings and four connecting them green corridors (wedges) diverging from the centre to the boundaries of the city. There are 42 municipal parks (approx. 2% of the city territory), urban forests (covering 13.7% of the territory) and abundant blue infrastructure: Warta river with numerous smaller watercourses and several natural and artificial water reservoirs

(covering 1.9% of the territory) (Klimko et al. 2009; Majkowska et al. 2017). Research sites (Fig. 1) were randomly selected in QGIS (QGIS Development Team 2016). A vector grid of polygons (squares of 500 × 500 m), limited by the boundaries of the city, was formed, with 32 polygons randomly selected using the 'random extract' tool. Research sites differed in terms of the land use structure (see Data analysis).

Fieldwork was carried out in the winter 2016/2017. The mean daily ambient temperature was −0.5 °C (range: −10 to 9 °C). The sum of precipitation during the trimester was 60.68 mm (data from Weather Underground https://www.wunderground.com, Poznań-Ławica Airport meteorological station (EPPO), accessed 15 December 2017). Thin snow cover (approx. 1–2 cm of thickness) was present during 12 of 36 days of the fieldwork, mainly in the second part of January and the beginning of February. Study sites were visited once a month. Observations were always performed by the same observer (KS). All countings were done between 8 a. m. and 2 p.m., to meet the daily activity of corvids.

Each field investigation consisted of a zigzag walk with binoculars aimed at surveying every part of the research sites (Supplementary material: Fig. A1). During each visit, the track was recorded with a smartphone with the GPS localisation application, the Geo Tracker, version.3.3.0.1338 (Bogdanovich 2016). The mean time spent on one visit was 45 min (range: 13–96). The minimal time applied to time spent in open areas (crop fields) with very few barriers (e.g. trees, buildings) obstructing the view. Consequently, observation with binoculars from a number of locations in the middle of the research site was entirely sufficient to determine the presence and abundance, or absence, of birds. This is a reliable method used in counting medium and large birds in an open area (Jankowiak et al. 2015). Contrastingly, the maximal periods applied to areas with trees, houses, tenement houses, and blocks of flats, where every part of the research site needed to be checked during a field visit in order to detect all birds. In purpose to avoid double-counting of the same individuals, the census was conducted quite quickly (mean = 18 min per 10 ha) (Jokimäki and Suhonen 1998). Backyards of houses could not be checked. Field visits were not conducted in

Table 3 Result of the generalised linear models, statistically significant variables are bolded (variables: surface of parks, length of tram tracks, surface of the water, length of watercourses, distance from the research site to Warta river, surface of wastelands, surface of tenement houses, number of walnut trees, number of garbage cans, surface of trees, surface of industrial areas)

Variable	Estimate	SE	Z-value	p value
Abundance of hooded crow				
Surf_park	**0.63**	**0.07**	**7.67**	**<0.001**
Tram_track	**0.56**	**0.12**	**4.66**	**<0.001**
Surf_water	**0.56**	**0.08**	**6.78**	**<0.001**
Watercourses	−0.46	0.36	1.20	0.230
Dist_river	−0.54	0.41	1.24	0.206
Wasteland	0.16	0.20	0.80	0.425
Abundance of rook				
Ten_House	0.20	0.29	0.68	0.498
Walnut	**1.35**	**0.31**	**4.18**	**<0.001**
Dist_river	−0.98	0.63	1.51	0.131
Garb_cans	**1.87**	**0.43**	**4.27**	**<0.001**
Watercourses	**−1.50**	**0.61**	**2.38**	**0.017**
Surf_water	**0.65**	**0.19**	**3.26**	**0.001**
Surf_park	−0.08	0.17	0.45	0.652
Abundance of jackdaw				
Garb_cans	**1.59**	**0.36**	**4.28**	**<0.001**
Surf_water	**0.78**	**0.35**	**2.12**	**0.034**
Surf_tree	**−10.51**	**4.96**	**2.05**	**0.041**
Surf_indst	0.32	0.24	1.26	0.207
Walnut	0.53	0.46	1.12	0.262
Watercourses	−1.19	0.78	1.47	0.143
Abundance of European jay				
Surf_tree	0.34	0.18	1.81	0.069
Tram_track	−0.46	0.40	1.09	0.278
Walnut	0.24	0.27	0.84	0.399
Garb_cans	−0.43	0.50	0.84	0.403
Surf_indst	0.16	0.19	0.82	0.412
Abundance of magpie				
Walnut	**0.45**	**0.18**	**2.35**	**0.019**
Garb_cans	**0.74**	**0.28**	**2.57**	**0.010**
Watercourses	0.33	0.19	1.64	0.102
Surf_tree	**−0.61**	**0.27**	**2.19**	**0.029**
Ten_house	0.46	0.23	1.90	0.057
Tram_track	0.18	0.15	1.17	0.242
Surf_park	0.17	0.17	0.96	0.337

adverse weather conditions, e.g. snow or heavy rain (Sliwinski et al. 2016).

In our study, we considered the following species of corvids: the hooded crow *Corvus cornix*, the rook *Corvus frugilegus*, the jackdaw *Corvus monedula*, the magpie *Pica pica*, the jay *Garrulus glandarius*, and the raven *Corvus*

corax. Due to the low frequency of the raven during the research (5 individuals), only the first five species were taken under consideration in subsequent data analysis. We counted all birds that were observed foraging, sitting on the ground, perches, or roofs, or flying low while visibly linked with the ground (Fontana et al. 2011). Individuals that were heard only or that overflew the research site were not counted unless they were seen landing within the boundaries of the site.

Data analysis

Each research site was transformed into a vector layer (shapefile) in QGIS. Each different type of landscape was assigned to one of the following categories: blocks of flats, garden plots, houses, industrial areas, open areas, parks, wastelands, tenement houses, trees, or water, based on the definitions presented in Table 1. The areas of each category at each research site were measured in QGIS. The mean, minimum, and maximum values and standard deviation for each landscape category for each research site are presented in Supplementary material (Table A1). The length of watercourses and tram tracks (with broken stone and wooden or concrete railway ties – rails on concrete were not counted) and the distance from the research site to the Warta River were noted. Walnut trees *Juglans regia* and garbage cans were counted in the field.

The mean values of abundance for each species were taken from three counts for statistical analyses. A Z-score scale transformation was used to standardise independent variables prior to the analyses. To avoid multicollinearity in models, the variance inflation factor (VIF) was computed. Variables with a VIF > 4 were excluded from all models: houses, open areas, and tenement houses. The multicollinearity of the remaining explanatory variables in all models was not excessive (VIF < 3). We used generalised linear models (GLM's) with a negative binomial distribution to determine factors affecting the abundance of hooded crow, rook, jackdaw, European jay and magpie. In order to best determine factors explaining the abundance of corvids, we used the model averaging function, which created a set of various models from all variables. We employed the information-theoretic approach (Burnham and Anderson 2002) to identify the most parsimonious models explaining variation in all dependent variables. Based on the full model, in each analysis, we constructed a set of candidate models that included different combinations of the predictors. We ranked all possible model combinations according to their ∆AICc values. We used models with the lowest AICc together with associated weight values (the probability that a given model is the best) as those best describing the data. We considered candidate models differing by less than 2 AICc units

Fig. 2 Relationship between hooded crow abundance and statistically significant habitat features. Black line represents linear regression, gray filling is standard error
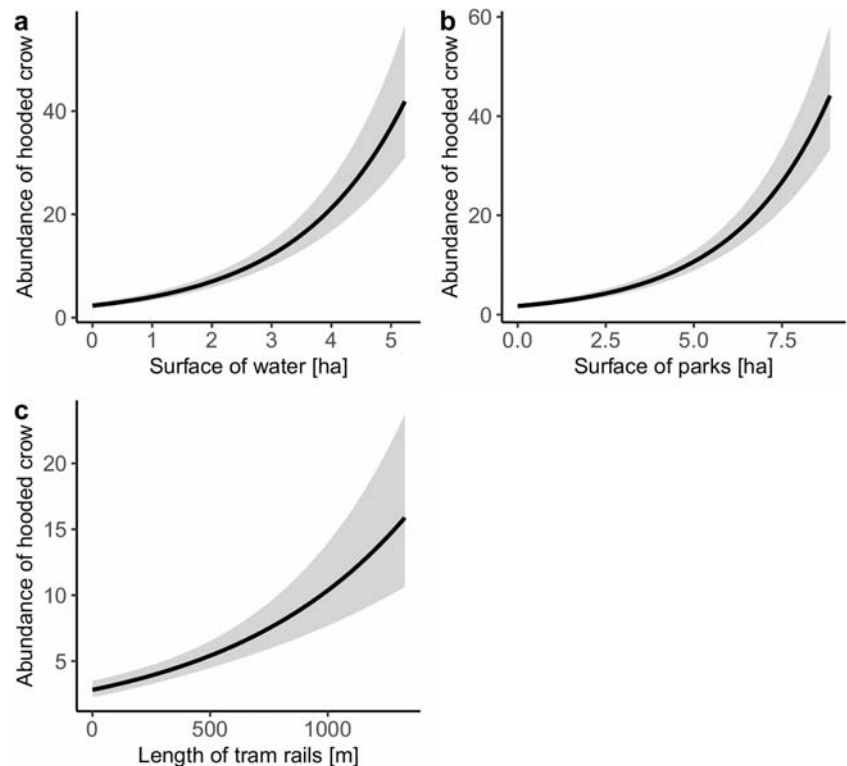
(ΔAICc <2.0) to be equally informative and subject to possible model averaging. For averaging, we used models with weights which had ΔAICc values lower than 4 (Burnham and Anderson 2002). The best models explaining the abundance of corvids are presented in Supplementary material (Table A2).

We used the canonical correspondence analysis (CCA) to correlate the corvids community composition with environmental factors. Based on the variance inflation factor, we excluded all multicollinearity variables from the model. Finally, we used following environmental variable: surface of tree, surface of water, surface of parks, surface of wasteland, surface of industrial, surface of tenement house, surface of open space area, number of garbage cans, number of walnut, length of tram tracks, distance to river, length of watercourses. We forward the selection of explanatory variables to choose the model, including only significant variables ($p \leq 0.05$). We also calculated Spearman's rank correlation coefficient between mean abundances of studied species.

All analyses were carried out in R (R Development Core Team 2016) and CANOCO 5 (Braak and Šmilauer 2012; Šmilauer and Lepš 2014). The VIF was calculated in the 'usdm' package (Naimi et al. 2014); the visualisation was performed in the 'ggplot2' package (Wickham 2009). The interspecific correlation was carried out in the 'Hmisc' package (Harrell Jr 2016), the model selection in the 'glmulti' package (Calcagno 2013).

Results

All counted species (except ravens) were recorded together at 28% of all study sites. The mean number of individuals per research site was 39.0 (SD = 53.8, range 0–315). The most frequent species was the magpie (88% of all study sites), the least frequent was the jackdaw (47% of all study sites). The most abundant species was the rook (mean = 17.4 individuals, max. = 197) with the highest standard deviation of abundance; the least abundant was the European jay (mean = 0.8 individuals) with the lowest standard deviation of abundance (details in Table 2).

The analysis revealed that each investigated species showed selectivity for a different set of habitat features (Table 3). The abundance of hooded crows was positively influenced by surface of the parks ($p < 0.001$), the surface of the water (p < 0.001) and by the length of tram tracks (p < 0.001, Fig. 2). The number of rooks was positively linked with the number of walnut trees (p < 0.001), the number of garbage cans (p < 0.001) and the surface of the water ($p < 0.01$) and negatively linked with the length of watercourses ($p < 0.05$, Fig. 3). Jackdaws were positively influenced by the number of garbage cans (p < 0.001), by the surface of the water (p < 0.05) and negatively influenced by the surface of trees (p < 0.05, Fig. 4). The number of magpies was associated with the number of walnut trees (p < 0.05), the number of garbage cans (p < 0.05) and negatively affected by the surface of trees (p <
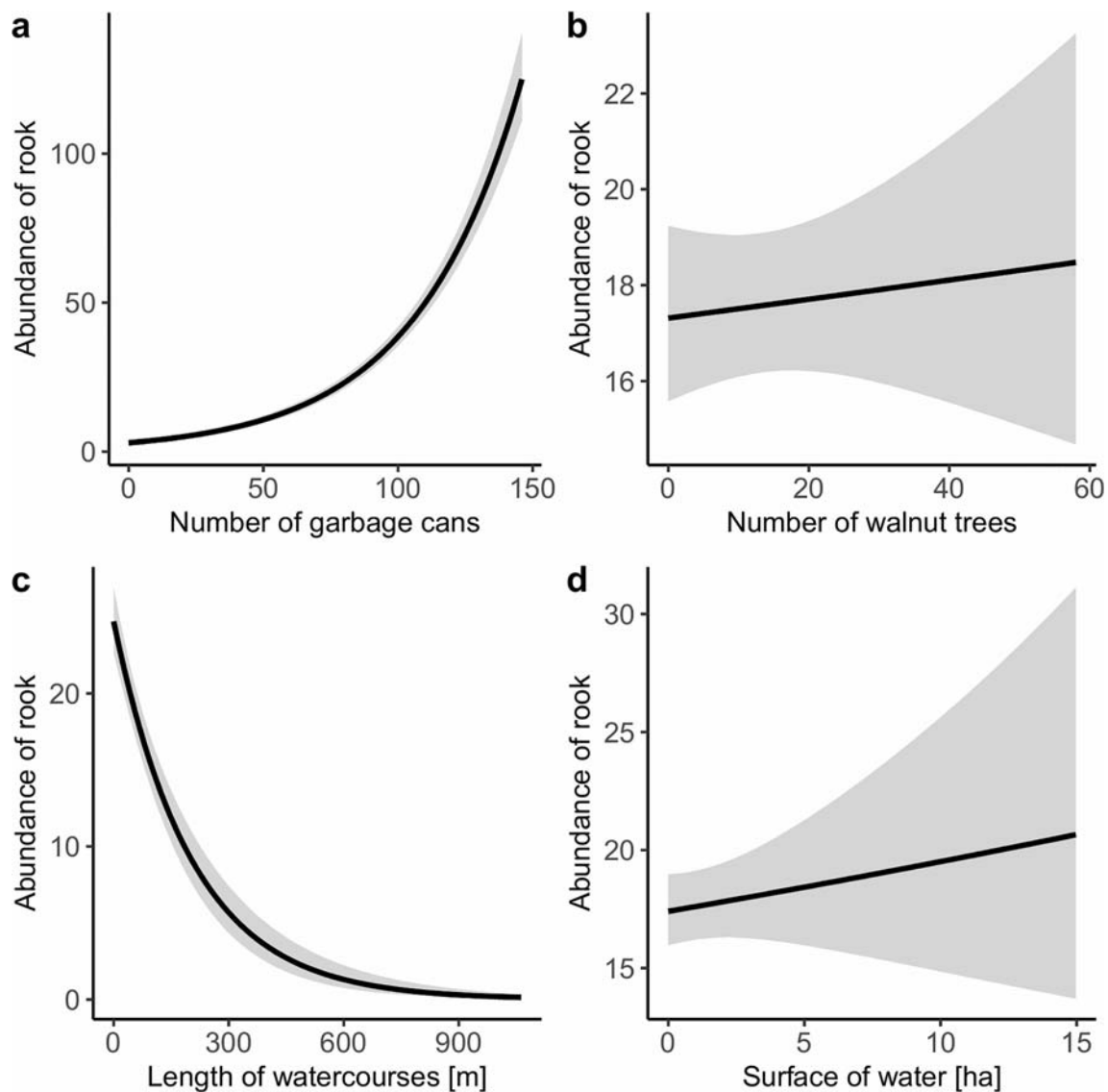
Fig. 3 Relationship between rook abundance and statistically significant habitat features. Black line represents linear regression, gray filling is standard error

0.05, Fig. 5). None of the investigated habitat variables significantly affected the abundance of European jay.

Environmental factors significantly predicted the corvids community in the urban environment in the winter period (test for all axes, pseudo-F = 2.6, $p = 0.002$). The environmental variables explain of the 54.76% variation in corvids data. The eigenvalues (importance measures of ordination axes) and explained cumulative variance for the selected CCA axes 1 and 2 were 0.23 and 41.05%, and 0.05 and 50.07%, respectively. The surface of trees and number of garbage cans were the most important variables predicting the corvids community in winter (Fig. 6, Supplementary material: Table A3).

We also found statistically significant positive correlations between the abundances of hooded crows, rooks, jackdaws, and magpies, as summarised in Table 4. Selected relationships between abundances of birds are presented in Fig. 7.

Discussion

In this paper, we showed that different species of birds from one family use different habitats within the urban ecosystem during a crucial time for survival, i.e. the winter. Although their prime habitat preferences differ significantly, they share the same environments in urban conditions. Urban greenery, together with the blue infrastructure are areas in cities with the highest avian species richness (Chamberlain et al. 2007). It is consistent with the results of our study since we found a positive relationship between the surface of the water bodies and the abundance of hooded crow, rook and jackdaw and between the surface of parks and the abundance of a hooded crow. River valleys are considered a natural habitat of the hooded crow (Zduniak and Kuczynski 2003). Crustaceans and molluscs constitute an essential part of its diet (Gołdyn

Fig. 4 Relationship between jackdaw abundance and statistically significant habitat features. Black line represents linear regression, gray filling is standard error
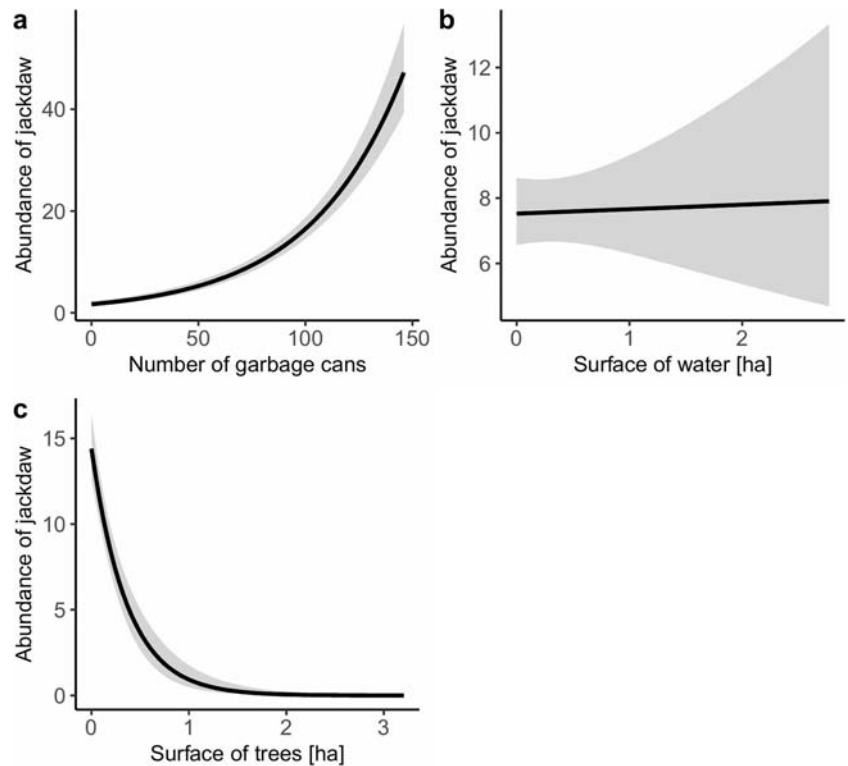
et al. 2016); thus, the greater abundance of this species in proximity to water is not surprising. However, we found no relationship between the abundance of this species and distance from the river valley in the urban environment. On the

other hand, we found a negative relationship between small watercourses and rook abundance. Watercourses were especially abundant in research sites covered by forest, in open areas more distant from the city centre and housing estates

Fig. 5 Relationship between magpie abundance and statistically significant habitat features. Black line represents linear regression, gray filling is standard error
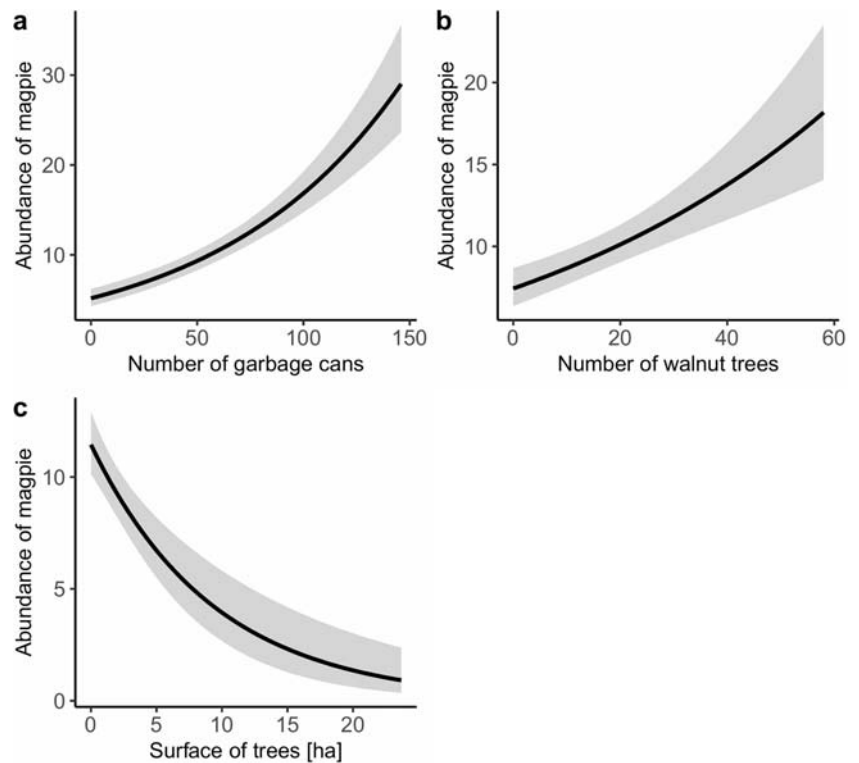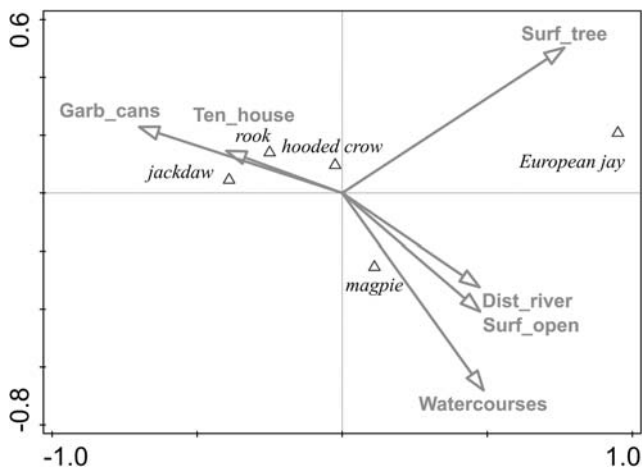
Fig. 6 Results of canonical correspondence analysis (CCA) results – environmental factors that significantly predicted the corvids community in the urban environment in the winter period (variables: number of garbage cans, surface of tenement houses, surface of trees, distance from the research site to Warta river, surface of open areas and length of watercourses)

areas. As shown in CCA, the rook is strongly linked with habitats transformed by humans. Thus, the negative link between rook and watercourses may be a side effect of rook avoiding forests and open areas. Since it is assumed that populations of the hooded crow are relatively sedentary (Holyoak 1971), our results are consistent with data from other European cities showing that municipal parks create the most important habitats for breeding individuals (Vuorisalo et al. 2003; Zduniak 2005; Kövér et al. 2015). Many people visiting parks feed birds with leftover food (mostly bread), especially during the cold part of the year (Chosińska et al. 2012), which may be one of the factors attracting hooded crow to parks.

Corvids, as omnivorous with the ability to use new food resources supplied in the urban landscape like food leftovers in garbage cans or walnut trees profit from human proximity. Abundant garbage cans with leftover food, along with easily accessible bird feeders (Chosińska et al. 2012), may constitute factor inviting birds to forage near buildings. In this study, we found that rooks, jackdaws, and magpies were mainly affected by garbage cans. The supplementary food source is particularly important in the winter season when snow cover prevents effective foraging (Brittingham and Temple 1988; Robb et al.

Table 4 Spearman's rank correlation coefficient between abundances of studied species (*p < 0.05, **p < 0.01, ***p < 0.001)

	Hooded crow	Rook	Jackdaw	Magpie	Jay
Hooded crow	1.00	0.62***	0.49**	0.52**	−0.02
Rook	0.62***	1.00	0.82***	0.75***	−0.06
Jackdaw	0.49**	0.82***	1.00	0.56**	−0.30
Magpie	0.52**	0.75***	0.56**	1.00	−0.16
Jay	−0.02	−0.06	−0.30	−0.16	1.00

2008). The phenomenon of the urban heat island may be additionally advantageous for wintering birds. Higher ambient temperatures cause thinner snow cover, which makes foraging easier and therefore birds may save energy (Møller 1983). Both latitude and longitude negatively influence the abundance of birds, but this relationship is less visible in highly urbanized areas which buffer the effect of severe winters on the north and east (Jokimäki et al. 2002; Tryjanowski et al. 2015). One of the significant predictors of the occurrence of rook and magpie was the number of walnut trees in a given plot. These trees are quite abundant in backyard gardens in housing estates, but also wastelands. As shown by Lenda et al. (2012), not only do corvids profit from caloric seeds such as walnuts but, by caching them, they contribute to the spread of walnut trees in abandoned agricultural areas. Corvids are smart enough to crack the hard shells of walnuts by dropping them from the air to the ground.

Although it is usually assumed that anthropogenic barriers such as railways have an adverse effect on animal populations (Santos et al. 2017), it turns out that some species can benefit from them (Li et al. 2010; Morelli et al. 2014). For example, several species of birds use railways as attractive foraging areas, sources of gastroliths, or sand-bathing locations where they can clean their feathers (Morelli et al. 2014; Lucas et al. 2017). In this study, we found a positive relationship between the length of tram tracks and the abundance of a hooded crow. Despite numerous papers showing the influence of railways on birds, to the best of our knowledge, there have been no studies concerning the impact of tram tracks in an urban landscape, which makes it more difficult to predict how a tram network may affect birds. Tram tracks with broken stone may constitute an attractive foraging area, especially during severe winters when crop fields in the farmlands and lawns in the cities are covered with layers of snow that impedes the foraging process. Dark stone aggregate beneath tracks quickly absorbs the rays of the sun. Also, the heat of passing trams and friction between tram wheels and rails raise the temperature of the substratum, resulting in thinner snow cover. Kaczmarski and Kaczmarek (2016) observed that tram tracks constitute a humid and prey-rich autumn and winter habitat for an urban population of smooth newts *Lissotriton vulgaris*. Therefore, corvids, as generalist foragers, may prey on small animals hiding or hibernating under rails. Since corvids living in an urban environment commonly forage on roadkill (Schwartz et al. 2018), they can profit equally from the carcasses of animals killed in collisions with trams. Corvids are known to cache seeds for use when food availability is low (Waite 1985; Cristol 2005; Castro et al. 2017). They can use tram tracks or railways with broken stones to hide, e.g. walnuts, to be retrieved when needed (Waite 1985). Further investigations are needed in order to understand better whether – and if so, how – tram tracks can influence the behaviour of wintering corvids and birds in general.
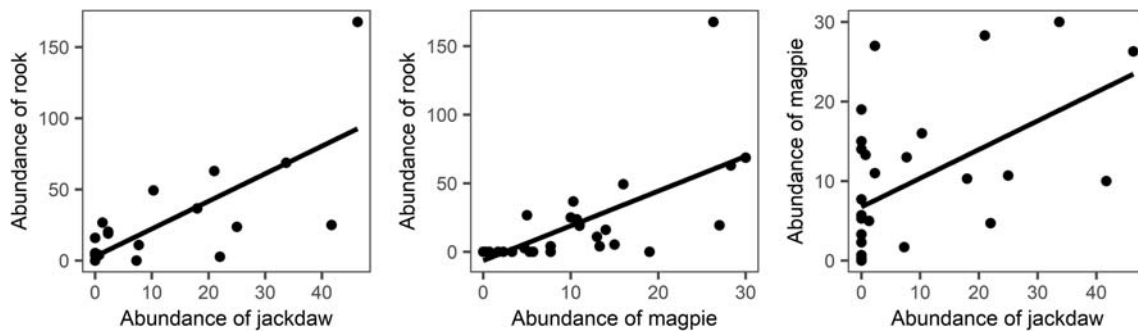
Fig. 7 Interspecific correlations between abundances of rook (*Corvus frugilegus)* and jackdaw (*Corvus monedula)* (r = 0.82, *p* < 0.001), rook and magpie (*Pica pica)* (r = 0.75, p < 0.001) and between jackdaw and magpie (r = 0.56, *p* < 0.01)

Canonical correspondence analysis revealed that the most important habitat variables predicting the winter corvids community in the city are: the surface of tree and number of garbage cans. Species differed in response to habitat features with European jay as the most outstanding species. According to Mazgajski et al. (2008) and Tzortzakaki et al. (2018), European jays occur in the woods on the peripheries of cities. Currently, in the phase of colonising urban habitats, they are encountered more and more frequently in urban green areas. However, further statistical analysis showed no statistically significant relationship between European jay occurrence and the surface of trees nor the surface of parks. On the other hand, there are hooded crow, rook and jackdaw that are more linked with the landscape transformed by humans and magpie connected with open areas and small watercourses. The similarity of the variables influencing the abundances of these four species is in accordance with statistically significant correlations between them.

During the winter, hooded crows, rooks, jackdaws, and magpies often forage in mixed flocks in abundant aggregations. According to Waite (1984b), although their foraging areas overlap, competition, because of dietary diversification, is not intense. While the prey of (in this case) carrion crow and rooks in grasslands consists mostly of earthworms and invertebrates from within the soil, jackdaws and magpies forage on these animals on the surface. Rooks may even benefit from foraging in dense flocks, as other birds dislodge earthworms that are then easier to catch. Conversely, larger earthworms eaten by carrion crows became unavailable when disturbed, then they tend to avoid foraging with large flocks of other birds. Individual magpies usually forage separately on the edges of corvids assemblages (Waite 1984b) and apparently do not join their flocks (e.g. do not fly away with the other birds). Since magpies do not migrate for winter, adults are strongly bonded to their territory. At the same time, non-breeders (birds in the first and second year of life and adults that have lost their territories) forage in monospecific flocks within a larger area in which they also spend the night (Busse 1963; Eden 1989). Wintering rooks, jackdaws and hooded crows do not hold territories but make daily flights between roosts where they spend the night and their foraging areas, using regular air corridors (Jadczyk 1994). Moreover, interspecific

correlations may result from similar habitat preferences. As shown in this paper, hooded crows, rooks and jackdaws are linked with the water, garbage cans attract both rooks and jackdaws, and both rooks and magpies exhibit selectivity in favour of walnuts.

In the end, we need to highlight that since our fieldwork was performed only during one season (in the winter), then the results of this study are limited. However, the weather during three months of the fieldwork was rather typical for Polish winter.

Conclusion

Cities constitute attractive winter habitats for corvids. However, different species use different elements of the urban landscape. Therefore, a kind of mosaic of green areas (grasslands and ploughed lands) interspersed with aggregations of trees may be an attractive combination for wintering corvids. Jokimäki and Suhonen (1998) suggested that knowledge of the habitat features that influence the occurrence of birds is essential for urban planners, who could thus make cities more attractive for birds in order to better conserve declining species. Although corvids are generalists, with a high degree of behavioural plasticity, enabling them to easily adapt to changes in the environment (Seed et al. 2009), they will benefit from urban greening. Plans for the cityscape should account for these areas as elements of sustainable development.

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