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BIRDS CROSSING OVER ROADS: SPECIES, FLIGHT HEIGHTS AND INFRASTRUCTURE USE

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Abstract.

How high do birds fly above roads, and how do they use the road infrastructure (bridges, lampposts etc.)? These questions are rarely explored in ecological studies but were addressed by us during research in 2016–2018 in southern Poland. In total, 1665 individual birds belonging to 24 species were recorded. Species differed significantly in the height at which they crossed over roads, but about 30% of all crossings were at heights below 12 m, hence at potential collision heights. The proportion of birds perching on lampposts in the central reservation between carriageways also differed significantly between species. The surrounding landscape and road infrastructure, especially lampposts, modified the species composition associated with roads. This knowledge has practical importance, not only in regard to collisions, but also to much less studied aspects such as plant seed dispersal and/or corrosion of the infrastructure. Lampposts, as a taller component of the infrastructure, may not directly affect vehicle-bird collisions, but a flight to them may be a risky business, and we recommended higher lampposts to discourage low-level flights. This information may need to be incorporated into future studies on road ecology, as well as in mitigation programs.

Key words: road ecology; urbanization; overpasses; infrastructure; lampposts

Introduction

Roads provide humans with a means of mobility between destinations, be it for transportation of goods and services or as a means of connecting with others and are especially important, and occur at high density, in urbanised areas (Beim & Haag 2010; Jones et al. 2015). However, the location of roads, and of the urban locations in which they occur, are not random. For example, they are very often associated with riparian habitats or they pass through fallow areas not used for either agriculture or industry (Jones et al. 2015). Roads can disrupt ecological systems, mainly through collisions with wildlife (Johnson et al. 2017) and isolation of habitats (Forman 1999). Birds are one of the groups of animals seriously negatively affected by roads due to collisions (Erritzoe et al. 2003; Bujoczek et al. 2011). However, roads may benefit migrating birds and are often used as landmarks, helping in navigation, both in the seasonal, as well as the daily, passage of birds (Yosef 2009). Some bird species migrate directly along a road, but the majority of local movements involve crossing over roads, searching for food, avoiding predators or looking for roosts (Johnson et al. 2017; Song et al. 2018). This is related not only to road characteristics, such as the volume of traffic, the type of road surface and width (Morelli et al. 2014), but also to the associated infrastructure such as small bridges and lampposts which often provide many birds with places to sing, rest and perch (Outens 2002; Morelli et al. 2014; Planillo et al. 2015). The use of lampposts by birds as perches can affect the environment. Firstly, birds influence the vegetation around lampposts by nutrient enrichment from excrement and from undigested seeds of plants (Gelmi-Candusso & Hämäläinen 2019). Moreover, of current concern is that defecation by birds encourages metal corrosion (Spennemann & Watson2017), and thus knowledge of the location of lampposts can improve management plans, such as for painting and renovation (Spennemann et al. 2018). Taken together, the above information builds a picture of cross-sector relationships between birds, transport and infrastructure, however is not a very well-studied aspect. It is not known whether lampposts or other infrastructure elements directly affect patterns of vehicle–bird collisions: for instance, lampposts may affect the height at which birds overpass roads (e.g. by influencing the flight trajectory between foraging and perching locations) and flying height can be crucial to understanding collisions (Kociolek et al. 2015; Pell & Jones 2015). However, the literature linking road infrastructure, flight height over roads and collisions is very scarce (cf. Morelli et al. 2014; Kociolek et al. 2015).

The main aims of our study were (1) to collect data on bird species composition and numbers in an urban area and then to answer questions: (2) at what height do birds cross roads? (3) how does the road infrastructure, especially lampposts, affect bird species presence and behaviour; (4) which habitats located close to the roads influence birds in different seasons. Finally, we discuss these findings in the light of better road infrastructure system planning, especially in highly urbanized ecosystems.

Methods

The survey was conducted on three-lane highway no. 902 between Gliwice (50°16'46.1"N 18°43'31.8"E) and Chorzów city (50°17'08.3"N 18°56'23.6"E) in southern Poland. A 16.5 km length of the highway was divided into six survey sections of 2.0–3.7 km each for practical reasons. Lampposts were spaced at exactly 38 m intervals in the central reservation along the entire surveyed length. The route ran between urban buildings, high-rise housing estates, industrial buildings, open areas, water reservoirs and suburban forest. Wide roadsides and embankments, sound-absorbing screens, road infrastructure, gas stations, parallel roads, and industrial buildings directly separated the road from the surrounding landscape. The road was a substantial barrier, clearly distinctive in the landscape.

In total, 73 counts were made between 22 April 2016 and 20 June 2018. Birds were counted from 8:00 to 9:00 in the morning, from a moving car (Hewitt 1967; Wuczyński 2001) by a single experienced observer (J.B.). To avoid a weekend effect associated with lower traffic volume, and consequent responses of birds (Bautista et al. 2004), all counts were made on working days. Counts were made in all months of the year except August; the monthly distribution of counts is shown in Supplementary Material 1. Counts were carried out while driving at an average speed of 90–100 km/h. Bird species were identified by the driver, and the number of birds, their position and height above the road were recorded directly onto a voice recorder.

Flight heights

The estimation of flying heights was made with reference to lampposts which were 12 metres tall (information from the local Department of Municipal infrastructure). Flight heights were categorised as either below or above this height. The lower height category (below 12 m) was considered a potential collision space, not only directly with cars and lorries, but also because passing lorries generate eddies affecting insects, small birds and bats (see Pons 2000; Myczko et al. 2017). Normally, collision height is only up to 5 metres but generated air vortices may also affect small insectivorous birds such as swifts or swallows (Myczko et al. 2017). To test which of the most commonly recorded bird species showed the greater collision risk the data from below and above 12m were compared using Fisher's Exact Test for count data with simulated p-value based on 1,000,000 replicates. To compare flight height between the most commonly recorded species we used pairwise Fisher's Exact Tests with Bonferroni corrections for multiple comparisons.

Perching preferences

During the counts we recorded if birds flew over the road or perched on lampposts. We then compared flight versus perching numbers using Fisher's Exact Test with simulated p-value based on 1,000,000 replicates. To compare perching preference between the most commonly recorded species we used pairwise Fisher's Exact Tests with Bonferroni corrections for multiple comparisons.

Environmental data and bird preferences

We measured the habitat data around the six transects in 250 m radius buffers. All measurements were made using Quantum GIS software version 3.6.3 on ortho-images. The landscape composition of these buffers was characterized by five variables measuring the percentage cover of roads, forests, buildings, water reservoirs, and fallow areas. We also added a dummy independent variable indicating whether the count was made in the breeding season (April–July) or non-breeding period (other months).

Statistical analyses

We used Canonical Correspondence Analysis (CCA) in the "vegan" package (Oksanen et al. 2015) in R software (R Development Core Team, 2018) to test the relationship between environmental variables and the abundance of the most commonly recorded species. This multivariate technique tests for the importance of each environmental variable on species response variables. It allows the creation of ordination diagrams, where the length of vector arrows represents the importance of an environmental variable linked to axes. We chose the final CCA model by stepwise forward model building using permutation tests (F-statistic with a Monte Carlo Permutation Test with 20,000 replicates).

We tested the significance of axes by separate tests for each constrained axis (all previous constrained axes were used as conditions). Each environmental variable was tested by an F-statistic with a Monte Carlo Permutation Test with 20,000 replicates and was performed as a separate significance test for each marginal term in a model containing all other terms.

Results

In total, 1665 individuals belonging to at least 24 different species (5 small passerines were unidentified to species level) were recorded (Supplementary Material 1). The most common species was Feral Pigeon (35.3% of all observed birds).

Flight distribution

For the 11 most abundant species the height distribution is given in Table 1. Black-headed Gull and Hooded Crow flew at the greatest heights, while Starling flew at the lowest heights. Flight heights differed significantly between species ($p < 0.001$). Starling flight heights differed significantly from Rook, Pigeon, Collared Dove, Common Swift, Jackdaw, Magpie, Black-headed Gull and Hooded Crow (all cases $p < 0.01$). For all other comparisons there were no significant differences ($p > 0.05$).

Perching preferences

The proportion of observations of birds perching on lampposts relative to flight (Table 2) and *post-hoc* analyses allowed us to group species into several categories. The first group (observed mainly perching) comprised Kestrel, and this species differed significantly from the other 11 species considered (all $p < 0.006$). The second group (observed very often perching) included Wood Pigeon, Black-headed Gull, Magpie, Hooded Crow and Starling. These species were seen significantly more often perching on lampposts than Feral Pigeon, Collared Dove, Common Swift, Jackdaw and Jay (all $p < 0.001$). Hooded Crow were seen significantly more often perching on lampposts than Swift, Jackdaw and Jay (all $p < 0.001$). The third group (often perching) comprised Collared Dove which perched significantly more often on lampposts than Common Swift ($p < 0.001$). In

Table 1. Distribution of flight heights of the 11 most abundant bird species in 2016-2018.

Flight height category	Abundance		Percentage	
	≤ 12 m	> 12 m	≤ 12 m	> 12 m
Feral Pigeon (*Columba livia*)	75	350	17.6	82.4
Wood Pigeon (*Columba palumbus*)	9	34	20.9	79.1
Collared Dove (*Streptopelia decaocto*)	6	6	50.0	50.0
Common Swift (*Apus apus*)	17	46	27.0	73.0
Black-headed Gull (*Chroicocephalus ridibundus*)	2	26	7.1	92.9
Eurasian Jay (*Garrulus glandarius*)	5	7	41.7	58.3
Eurasian Magpie (*Pica pica*)	15	44	25.4	74.6
Eurasian Jackdaw (*Corvus monedula*)	18	54	25.0	75.0
Rook (*Corvus frugilegus*)	2	10	16.7	83.3
Hooded Crow (*Corvus cornix*)	0	9	0.0	100.0
European Starling (*Sturnus vulgaris*)	126	48	72.4	27.6

Table 2. Lamppost perching preference of the 12 most abundant bird species in 2016-2018 observed in Southern Poland.

	Abundance		Percentage	
Perching on lamppost vs flight	**perch**	**flight**	**perch**	**flight**
Feral Pigeon (*Columba livia)*	152	435	25.9	74.1
Wood Pigeon (*Columba palumbus*)	106	48	68.8	31.2
Collared Dove (*Streptopelia decaocto*)	11	14	44.0	56.0
Common Swift (*Apus apus*)	0	63	0.0	100.0
Black-headed Gull (*Chroicocephalus ridibundus*)	34	29	54.0	46.0
Kestrel (*Falco tinnunculus*)	45	2	95.7	4.3
Jay (*Garrulus glandarius*)	0	12	0.0	100.0
Magpie (*Pica pica*)	77	60	56.2	43.8
Jackdaw (*Corvus monedula*)	8	75	9.6	90.4
Rook (*Corvus frugilegus*)	3	9	25.0	75.0
Hooded Crow (*Corvus cornix*)	15	12	55.6	44.4
Starling (*Sturnus vulgaris*)	239	177	57.5	42.5

the fourth group (low frequency of perching) we included Feral Pigeon and Rook. For Feral Pigeon, we found that it perched significantly more often than Common Swift, Jackdaw and Jay (all $p < 0.001$). In the rarely perching group we only included Jackdaw, and in the no perching group Common Swift and Jay.

Environmental data and bird preferences

The final CCA model included four explanatory variables: breeding season, water reservoir, buildings, and fallow areas. All canonical axes explained 10.7% of the total variance (first axis 7.7%, second axis 1.5%, third axis 0.9% and fourth axis 0.6%). Permutation tests showed that all axes were statistically significant (first, second and third: all $p < 0.001$, fourth: $p = 0.04$). We found that all four explanatory variables selected in the final model were significant (all $p < 0.001$). In the ordination, the first axis shows a gradient from breeding season birds to birds in water reservoirs in the non-breeding period (Fig. 1). The second axis is from buildings to fallow areas (Fig. 1).

Discussion

In this study we have shown differences in the height at which bird species cross over roads and how frequently they perch on lampposts, an important part of the transport infrastructure. Obviously, due to limitations of the methods used – counts made whilst driving – the number of observed bird species is probably underestimated, especially for small birds, and this was the reason for the non-identification to species level of five individual passerines. Small birds are simply less detectable from a moving car. This has been noted by other authors, but a similar observation method has been used to count pest birds (the size of Blackbird) in agriculture (Hewitt 1967), and especially raptors (Wuczyński 2001; Bautista et al. 2004). The method is imperfect, however, with constant and repetitive error, but is reliable, especially when carried out by experienced observers (Hewitt 1967; Wuczyński 2001; Bautista et al. 2004).

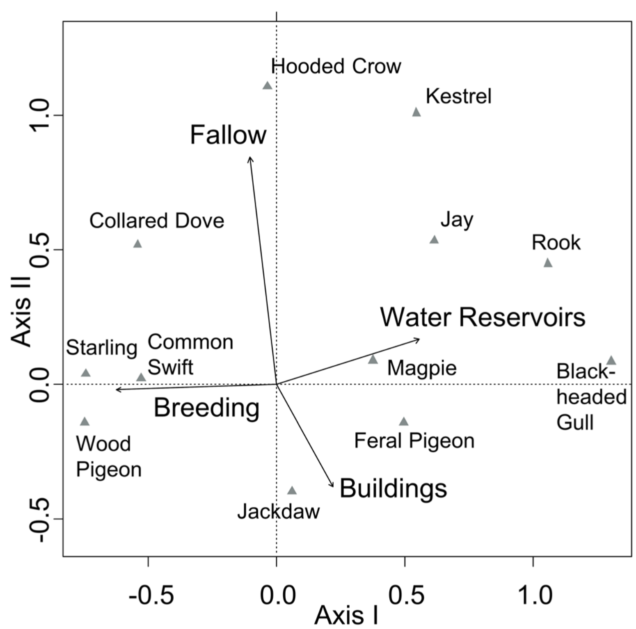

Figure 1. Canonical Correspondence Analysis ordination diagram of the bird species in relation to environmental variables in Southern Poland. The length of the vector arrows indicates the relative effect.

The recorded bird species are common in urban areas of southern Poland and characteristic of most cities and towns (Betleja et al. 2007; Soska & Beuch 2016), with a strong dominance by Feral Pigeon. It is difficult to make a comparison with other studies because, to the best of our knowledge, none has focused on both crossing over roads and on infrastructure use. For example, in emphasizing the positive value of road infrastructure to birds, it has been stated that lampposts are especially attractive perching posts for many bird species, especially raptors (e.g. Morelli et al. 2014; Planillo et al. 2015). In our study, this was especially so for Kestrel, a common raptor species. Kestrel is known to be a sit-and-wait predator and perching places are important for improving their foraging efficiency (Pettifor 1983). Other species, especially pigeons, some corvids and Starling, also used lampposts for perching. Therefore, the height of lampposts might affect passage height and also the intensity of road crossing in a similar way to road embankments with vegetation (Pons 2000) or other structures, both natural, such as trees and bushes, and artificial, such as fences and plastic noise barriers (Johnson et al. 2017; Song et al. 2018). However, it is worth noting that sometimes the infrastructure, such as noise barriers, may produce a higher mortality in birds than collisions with vehicles (Mitrus & Zbyryt 2018), but we do not know how the use of lampposts may affect this process and this aspect is worthy of further study. Some species, in the case of our study, Common Swift and Jay, were never seen perching on lampposts. This is easy to explain for Common Swift, a strongly aerial species spending nearly its whole life in the air (Hedenström et al. 2016), but Jay often perch on other structures, but typically on natural ones such as trees and bushes (pers. obs.). It is worth noting that during our research we did not find any information on collisions with birds flying between foraging and resting perches (lampposts). This is probably due to the height of the lampposts, which encourages higher overflying by birds above collision heights (normally only up to 12 m) with moving vehicles (Kociolek et al. 2015; Pell & Jones 2015).

The effect of the landscape close to the road, although significant, did not have a strongly visible effect on species and numbers of birds crossing over roads. Obviously, the situation differed between breeding and non-breeding seasons, and between habitats offering foraging areas (mainly water reservoirs, fallow areas) to particular groups of species, especially gulls and corvids (Meissner et al. 2012). This aspect is probably worth further investigation, but requires not only counts from cars, but also parallel bird surveys in other habitats, located adjacent to the study roads. Potential problems associated with birds using the infrastructure appear interesting, because their excreta, mainly in terms of acidity, differ between species, season and food sources used and consequently in corrosion processes (Spennemann & Watson 2018). In addition, perching birds on infrastructure probably modify the ground vegetation and soil mineral components. However, the importance of that process has not been studied, but knowledge on species composition of birds using particular parts of the road infrastructure is crucial for effective protection and prevention (Pike et al. 2017).

Although we did not monitor bird collisions with vehicles, among the recorded birds there was a lack of rare species, so vehicle-bird collisions are unlikely, in urban areas, to limit their population size. Moreover, among recorded species only corvids and pigeons are identified as common victims of collisions (Erritzoe et al. 2003). Fortunately, and in contrast to those with larger mammals, such collisions with birds are rarely dangerous to car drivers (Vanlaar et al. 2019). This information may need to be incorporated into future studies on road ecology, as well as in mitigation programs. For example, the modification of lampposts is probably very costly, but new technologies (e.g. solar panels on lamps) are changing the economic arguments, and we simply recommend higher lampposts in order to reduce the number of low level flights between foraging places and perches. The tall lampposts (12 m) used in our study area are probably appropriate for this. However, planning for birds is probably marginal compared to other aspects of road safety (light intensity and colour), as well as to general landscape urban planning.

To conclude, our findings show a high number of species crossing over roads at varying heights, and we suggest that road infrastructure, such as street lampposts, could modify this effect, with potential consequences not only for urban planning in the future, but also currently via impacts on vegetation, soil and material corrosion.

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Supplementary material

Supplementary material 1. Monthly totals and means for bird species according to overall mean abundance. Σ – total number of birds counted in the given month, *m* – mean number of birds per count.

Species	Jan		Feb		Mar		Apr		May		Jun		Jul	
	Σ	*m*	Σ	*m*	Σ	*m*	Σ	*m*	Σ	*m*	Σ	*m*	Σ	*m*
Mallard									2	0.2	3	0.3		
Feral Pigeon	38	6.3	9	1.1	22	7.3	94	6.7	86	6.6	38	4.2	13	4.3
Wood Pigeon					9	3.0	39	2.8	44	3.4	34	3.8	12	4.0
Collared Dove	1	0.2					12	0.9	6	0.5	2	0.2	2	0.7
Common Swift									29	2.2	34	3.8		
Black-headed Gull							8	0.6	3	0.2	3	0.3		
Common Gull														
Caspian Gull							1	0.1						
Great Cormorant					1	0.3								
Sparrowhawk														
Common Buzzard	1	0.2									1	0.1		
Great Spotted Woodpecker									3	0.2	1	0.1		
Kestrel	3	0.5	5	0.6	1	0.3	5	0.4	7	0.5	4	0.4		
Unidentified passerines									5	0.4				
Jay	1	0.2					1	0.1	3	0.2	1	0.1		
Magpie	7	1.2	16	2.0	4	1.3	20	1.4	20	1.5	20	2.2	8	2.7
Jackdaw	2	0.3			7	2.3	23	1.6	20	1.5	11	1.2		
Rook	1	0.2	3	0.4										
Hooded Crow	1	0.2	3	0.4	1	0.3	9	0.6	9	0.7	3	0.3		
Great Tit							1	0.1						
Barn Swallow							1	0.1						
Starling					22	7.3	140	10.0	136	10.5	49	5.4	4	1.3
Blackbird	1	0.2			1	0.3			2	0.2	4	0.4		
Fieldfare									1	0.1	1	0.1		
House Sparrow							1	0.1						
Total	**56**	**9.3**	**36**	**4.5**	**68**	**22.7**	**355**	**25.4**	**376**	**28.9**	**209**	**23.2**	**39**	**13.0**
Number of counts		**6**		**8**		**3**		**14**		**13**		**9**		**3**

Supplementary material 1. Monthly totals and means for bird species according to overall mean abundance. Σ – total number of birds counted in the given month, *m* – mean number of birds per count.

Species	**Sep**		**Oct**		**Nov**		**Dec**		**Overall**	
	Σ	*m*	Σ	*m*	Σ	*m*	Σ	*m*	Σ	*m*
Mallard			1	0.5					6	0.08
Feral Pigeon	31	10.3	100	50.0	65	21.7	91	10.1	587	8.04
Wood Pigeon	16	5.3							154	2.11
Collared Dove	2	0.7							25	0.34
Common Swift									63	0.86
Black-headed Gull	8	2.7	10	5.0	17	5.7	14	1.6	63	0.86
Common Gull	1	0.3					1	0.1	2	0.03
Caspian Gull	1	0.3			1	0.3			3	0.04
Great Cormorant									1	0.01
Sparrowhawk							1	0.1	1	0.01
Common Buzzard									2	0.03
Great Spotted Woodpecker									4	0.05
Kestrel	1	0.3	5	2.5	3	1.0	13	1.4	47	0.64
Unidentified passerines									5	0.07
Jay	2	0.7	1	0.5	2	0.7	1	0.1	12	0.16
Magpie	2	0.7	5	2.5	5	1.7	30	3.3	137	1.88
Jackdaw	6	2.0	7	3.5	2	0.7	5	0.6	83	1.14
Rook			3	1.5	2	0.7	3	0.3	12	0.16
Hooded Crow			1	0.5					27	0.37
Great Tit									1	0.01
Barn Swallow	1	0.3							2	0.03
Starling	64	21.3	1	0.5					416	5.70
Blackbird							1	0.1	9	0.12
Fieldfare									2	0.03
House Sparrow									1	0.01
Total	**135**	**45.0**	**134**	**67.0**	**97**	**32.3**	**160**	**17.8**	**1665**	**22.81**
Number of counts		**3**		**2**		**3**		**9**		**73**