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Research paper

The influence of road traffic on birds during autumn period: Implications for planning and management of road network

Jarosław Wiącek[a,*], Marcin Polak[a], Marek Kucharczyk[a], Janusz Bohatkiewicz[b]

[a] Department of Nature Conservation, Institute of Biology and Biochemistry, Maria Curie-Skłodowska University, Akademicka 19, 20-033 Lublin, Poland
[b] Department of Road and Bridge, Faculty of Civil Engineering and Architecture, Lublin University of Technology, Nadbystrzycka 40, 20-618 Lublin, Poland

HIGHLIGHTS

- Road traffic influences woodland birds during their autumn period.
- Reduced abundance and diversity of birds near a noisy road.
- Noise levels below 49 dB did not significantly affect birds.
- Insectivores preferred the proximity of the road.

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ABSTRACT

The main objective of this study was to assess disturbance to birds at stopover sites in the vicinity of roads. We attempted to determine the influence of a busy road on birds during the autumn migration period. To our knowledge this is the first study in Europe carried out during this part of a bird's annual cycle in the context of road noise impact. Individuals were counted using the point method at 36 observation points located at three distances (60 m, 310 m, 560 m) from the road. At each point we determined the habitat parameters and the intensity of noise. In total, 648 individuals from 25 species were recorded on the study plot. The number of birds per point was higher on the second line of points but lower on the last line from the road. Species diversity was lower near the road. The density of the following common species increased with distance from the road: Eurasian jay, great spotted woodpecker, siskin, mistle thrush and nuthatch. Only great tits preferred the proximity of the road. The number and species diversity of birds were correlated with road noise propagation across our study area. Noise levels below 49 dB did not significantly influence the number of birds or species richness. Our results showed that species foraging on invertebrates preferred the neighbourhood of the road. These data may be helpful in planning and managing road environments in the context of bird conservation and protection against road noise.

1. Introduction

In the annual life cycle of birds, migration takes up nearly one third of the year (Sillett & Holmes, 2002). During this period birds spend more time at stopover sites than actually flying (Wikelski et al., 2003). Indeed, foraging and resting may occupy birds for as much as 95% of the migration time (Hedenstrom & Alerstam, 1997; Alerstam, 2003). Some small passerines in particular are not capable of continuous flight during migration, so they stop frequently during their journey to restock the food resources necessary to fuel further flight (Berthold, 2001). During stopovers, birds have to quickly replenish their fat reserves (Moore, Gauthreaux, Kerlinger, & Simons, 1995). To do so, birds feed voraciously and compete for food; at the same time, however, they are exposed to attack from predators, infections and parasites (Hutto, 1985). Human activities are a significant factor affecting the migration of birds and the duration of their stays at stopover sites. Birds usually avoid sites subject to human interference, because this may have an adverse effect on their foraging (Burger & Gochfeld, 1998), territory use (Andersen, Rongstaf, & Mytton, 1990), survival (West et al., 2002) and numbers (Fernández-Juricic, 2002). The march of civilisation is unceasing, and urbanisation is encroaching on to many areas utilised by animals, including birds (Wight, 2002; Christ, Hillel, Matus, & Sweeting, 2003). The losses and degradation of habitats used by migrating birds are also contributing to the fall in numbers of many species (Sauer et al., 2011). The construction of

* Corresponding author. Tel.: +48 081 537 59 71; fax: +48 081 537 59 01.
E-mail address: wiacek@hektor.umcs.lublin.pl (J. Wiącek).

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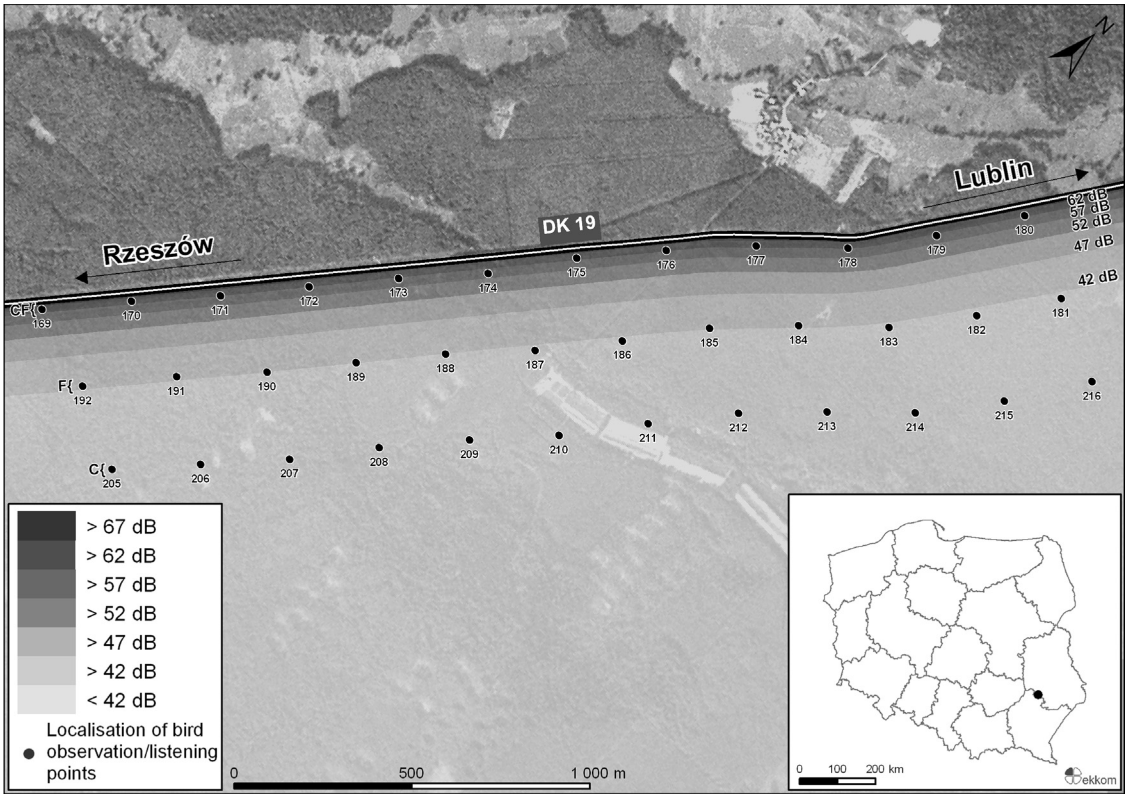

Fig. 1. The study plot with the point-count locations (36 black dots) and noise level isolines during the autumn period near a road in Janów Forest (eastern Poland).

new roads has caused environmental degradation through habitat fragmentation and noise pollution (Šálek, Svobodová, & Zasadil, 2010). The negative impact of road traffic on animals has been reported in the literature (Fahrig, Pedla, Pope, Taylor, & Wegner, 1995; Forman & Sperling, 2003; Fahrig & Rytwinski, 2009) and most papers describe the adverse influence of traffic noise on birds (e.g. Reijnen, Foppen, & Veenbaas, 1997; Kuitunen, Viljanen, Rossi, & Stenroos, 2003; Pescador & Peris, 2007), many of them highlighting the rapid decrease in the density and diversity of birds near roads carrying heavy traffic (Palomino & Carrascal, 2007; Polak, Wiącek, Kucharczyk, & Orzechowski, 2013). Disturbance due to vehicle lights, traffic noise, pollutants in food and the movements of people have been pinpointed by many authors (Pocock & Lawrence, 2005; Wood & Yezerinac, 2006; Slabbekoorn & Ripmeester, 2007; Summers, Cunnington, & Fahrig, 2011). Mortality as a result of collisions with vehicles is the most important negative effect of roads (Orłowski, 2005, 2008). Even so, some species of birds have adapted to an existence near busy roads (Adams & Geis, 1981; Benitez-López, Alkemade, & Verweij, 2010). Although some birds are able to modify their behaviour in a noisy environment (Brumm & Slabbekoorn, 2005), a high level of noise may impair the transmission of sound signals (Kuitunen et al., 2003; Leonard & Horn, 2008; Salaberria & Gil, 2010; Halfwerk, Holleman, Lessells, & Slabbekoorn, 2011).

However, while most papers describing the negative effects of road infrastructure on birds focus on the breeding season, we still know too little about how traffic noise affects avian ecology in the non-breeding period. The "phantom road" experiment, recently carried out during the autumn migration in Idaho, USA, has provided compelling evidence that traffic noise is the main factor impacting adversely on migrating birds near roadways (McClure, Ware, Carlisle, Kaltenecker, & Barber, 2013). In this study the researchers deployed loudspeakers that emitted artificial road noise in a forest. They tested the impact of noise only, avoiding bias from other factors such as light, vehicle movements, pollution or disturbance by humans. The researchers found that the only important factor reducing the density of birds was the noise emitted from loudspeakers.

The principal objective of the present work was therefore to determine the effect of traffic noise on the numbers, species richness and spatial distribution of birds during the autumn migration period. The null hypothesis to be tested was the assumption that the utilisation of a road by vehicles would not cause the numbers and species richness of birds in the vicinity of that road to drop. In the alternative hypothesis we assumed that, in connection with the negative influence of the road, we should expect changes to the distribution pattern and numbers of birds in the zone directly exposed to such an influence. Moreover, we assessed the influence of traffic noise in the vicinity of the road for habitat utilisation by birds from different feeding guilds (insectivores or granivores). We expected that uneven food resources in the vicinity of the road, human disturbance and anthropogenic food might be reasons for the different locations of the various groups of birds in relation to the road.

2. Methods

2.1. Study area

The field work was conducted in the Janów Forest in south-eastern Poland (N50°41′-27′ E22°17′; Fig. 1). This extensive, closed-canopy forest complex lies on flat terrain, but there are dune hillocks in places. The habitats are mostly coniferous woodland, but alder woods grow in the depressions and river valleys. The principal tree species is scots pine (*Pinus sylvestris*), and to a lesser extent silver birch (*Betula pendula*), oak (*Quercus* sp.), spruce (*Picea abies*) and fir (*Abies alba*). The study was done along the two-lane national road No. 19 between Janów Lubelski and Łążek Ordynacki; the roadway is relatively wide and carries a high level of traffic in comparison with other roads in eastern Poland (Fig. 1). According to data from a 2005 study by the General Administration for National Roads and Motorways, traffic intensity in the Janów Forest was 8738 vehicles per 24 h, including 6842 cars and minibuses, 1739 lorries, 131 buses/coaches and 26 motorcycles. There is a speed limit of 90 km/h along this stretch.

2.2. Numbers of birds

The numbers and distribution patterns of woodland birds were determined using the point-count method (Bibby, Burgess, & Hill, 1992). The study was done at 36 observation/listening points located along three lines running parallel to the road (Fig. 1). All the points were established and recorded on GPS receivers in March 2011 before the start of the actual counting. The first row of 12 points (referred to as CF-points) lay 60 m from the road, the next row of 12 points (F-points) was situated 310 m from the road, and the last row of 12 points (C-points) ran at a distance of 560 m from the road. All the points were 250 m apart from one another. Counting at each point lasted for 5 min. All the birds seen and heard within a radius of 100 m were recorded, but birds flying over the study plot were disregarded. Three counts were done at each point—on 25 September 2012, 18 October 2012 and 20 November 2012. All the counts were done on comparatively short autumn days from morning (07:00 h) to early afternoon (14:00 h). The limiting factor in this type of study was the fact that the observers themselves sometimes had difficulty in hearing the birds above the traffic noise, so some will undoubtedly have gone unrecorded (Rheindt, 2003; Summers et al., 2011). Nevertheless we were aware of these limitations during our point counts and tried to minimise them. Our task was made a little easier because the traffic along the road was not continuous, and we were able to record the birds' vocal activity in the quieter gaps. The counts at all the points on one day were performed by two experienced observers (MP and JW). In order to limit the time-of-day effect, counting on each day was done in a different order, so that the next count began at the point where the previous one had ended. The counting route was S-shaped and the observation points were visited in the order CF, F, C, C, F, CF, CF and so on. We divided the birds into feeding guilds: this was done on the basis of the publications by Tomiałojć, Wesołowski, and Walankiewicz (1984) and Polak et al. (2013)

2.3. Environmental parameters

Before the counts began, the study plot was selected very carefully in order to reduce to an absolute minimum the effect of environmental parameters on bird clustering. To minimise the edge effect the plot was located in the depths of a large, dense forest complex. The structure of the vegetation at every listening point was assessed using a set of environmental parameters. The age of the tree stand at the point-count location was obtained from current forest maps. The canopy and bush cover were determined in eleven categories: 0—0%; 10—1–10%; 20—11–20%; 30—21–30%; 40—31–40%; 50—51–60%, 60—61–70%, 70—71–80%, 80—81–90%, 90—91–99%, 100—100% within a circle of radius 30 m. Tree heights were measured with a Silva CM 1015/2025 PA (Silva Sweden AB) clinometer accurate to 25 cm (for trees up to 20 m above ground level) and to 50 cm (trees < 20 m). At each observation point the mean height of 5 trees growing within the circle (radius 30 m) was measured. The number of tree species among the 30 nearest trees with DBH >20 cm was counted. Likewise, the number of deciduous trees among the 30 nearest trees with DBH >20 cm was counted. The number of dead trees that were >20 cm diameter at breast height was estimated within a circle of radius 50 m. The number of species of shrubs or young trees (with DBH <20 cm) was counted within a 30 m radius of the observation point. None of these parameters were strongly correlated with each other (Spearman's correlation: $r < 0.6$).

2.4. Level of traffic noise

Two different approaches were applied to determine the model of noise propagation across our study area: (1) direct measurements of sound levels during counts, (2) acoustic map (see Fig. 1). Only the data obtained by direct measurement at listening/observation points were used in the statistical analyses. The level of road noise was measured at all the points during every count in September, October and November using a CHY 650 digital sound level meter (IEC 651-1979 Type 2, ANSI S1.4-1983 Type 2, JIS C 1502). During each measurement the frequency weighting was set to A and the time weighting to SLOW. The noise level at the centre of each point was measured for 5 min at a height of 1.5 m above the ground and the maximum level recorded. Traffic noise was measured on weekdays in comparable and stable weather (no rain or high winds). In addition, the propagation of traffic noise in the study area was modelled to produce an acoustic map (Fig. 1). The acoustic modelling was done using the following measurement instruments: sound level meters (SVAN 945A, SVAN 955 (Svantek) and 2238 (Brüel and Kjaer), microphones (40AN, ACO 7052A and 4188 (Brüel and Kjaer) and an acoustic calibrator (NC-74 (RION). Measurements were made at six points, two each at each distance class from the road, from which the noise level at each observation point was calculated. The field studies were done using the sampling method, carrying out three 5-min measurements at each point, which were then averaged logarithmically. The measurements were made in good weather without rainfall or wind speeds in excess of 3.0 m/s. For calculating the noise of road traffic we used the French national method of calculation (1995). With regard to input data regarding emissions, these documents refer one to "Guide du bruit des transports terrestres, fascicule prévision des niveaux sonores, CETUR 1980". This method is the standard way of measuring traffic noise in Poland and other EU countries. However, this method of calculation takes no account of propagated sound being absorbed by vegetation. In view of this, sound propagation was calculated according to the Polish standard PN-ISO 9613-2:2002 Acoustics. "Attenuation of sound during propagation in an open space—a general method of calculation". This method takes only two types of vehicle into account: (1) light vehicles weighing less than 3.5 t, (2) heavy vehicles with a weight of more than 3.5 t. For the model calculations we used the SoundPLAN program, version 7.2.

2.5. Statistical analyses

For the present analyses we applied parametric tests after having checked whether the distribution was consistent with the normal distribution (Kolmogorov–Smirnov test; $P > 0.05$); in other cases we applied a non-parametric test (Kruskal Wallis test). A bilateral critical region was assumed in the tests, and results were deemed significant if the probability of committing an error of the first kind was equal to or less than 0.05. Redundancy analysis (RDA) was used to analyse the relationship between the numbers of particular bird species and distance from the road—this parameter was used as the environmental variable. The significance of canonical axes was determined using the Monte Carlo test with 500 permutations. Only species with abundance ≥10 individuals were included in RDA. Analysis of variance (ANOVA) was used to assess the propagation of noise over the study area and to determine the differences in species richness and numbers in specified categories of observation points. The measure of species richness was taken to be the sum of all species come across during the three counts, and the number

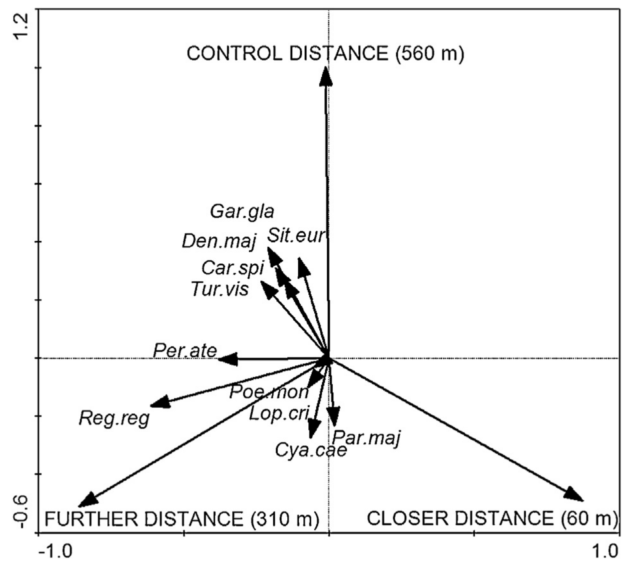

Fig. 2. Ordination diagram of redundancy analysis (RDA) with 11 of the most common bird species recorded in Janów Forest (eastern Poland) explained by the point-count locations in relation to distance from the road. Abbreviations of species names include the first three letters of the genus and specific names.

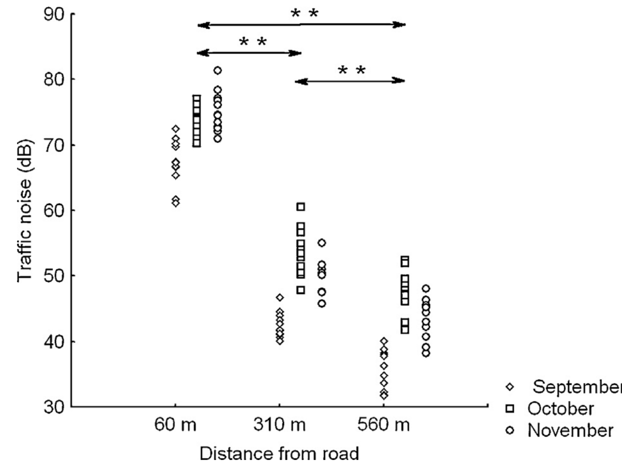

Fig. 3. Relationship between A-weighted traffic noise (dB) at point-count locations and distance from the road in September, October and November. The arrow shows significant differences between points (Tukey's test, ** $P < 0.0005$).

of birds was the sum total of all individuals discovered during all three counts. The impact of the eight environmental parameters on the density and species richness was tested with multiple regression analysis. Variation in avian ecological groups at points located in different distance from road was tested using multivariate analysis of variance (MANOVA). The means are given together with their standard deviations ± SD. The computations were performed using the STATISTICA 6.0 program (Statsoft Inc., 2001) and the Canoco 4.0 program (ter Braak & Smilauer, 1998).

3. Results

During the three counts a total of 648 individual birds belonging to 25 species (Table 1) were recorded. The most numerous species was goldcrest *Regulus regulus*, which made up 29% of the birds counted in the study area. Seven other species dominated the study site: great tit (*Parus major*), Eurasian jay (*Garrulus glandarius*), great spotted woodpecker (*Dendrocopos major*), siskin (*Carduelis spinus*), crested tit (*Lophophanes cristatus*), coal tit (*Periparus ater*) and mistle thrush (*Turdus viscivorus*). There were no significant differences between the mean bird abundance (all individuals/point) in September: 5.5 ± 4.0 (range 0–17; $n = 36$), October: 7.1 ± 5.3 (range 0–21; $n = 36$) and November: 5.5 ± 4.4 (range 0–19; $n = 36$; ANOVA; $F_{2,105} = 0.67$; $P = 0.51$). A similar pattern was obtained for the mean numbers of species per counting point. These were: September—3.7 ± 2.1 (range 0–8; $n = 36$), October–4.0 ± 2.2 (range 0–8; $n = 36$) and November—3.1 ± 1.6 (range 0–6; $n = 36$; ANOVA; $F_{2,105} = 0.56$; $P = 0.58$).

Numbers of the most common birds (>10 inds.) differed widely in relation to distance from the road (Fig. 2; Monte Carlo test of the significance of the first axis; F ratio = 4.318; $P < 0.01$; Monte Carlo test of the significance of all axes; F ratio = 3.454; $P < 0.01$). The abundance of the following species increased with distance from the road: Eurasian jay, great spotted woodpecker, siskin, mistle thrush, nuthatch (*Sitta europaea*). Great tits preferred the proximity of the road, whereas numbers of the other common species were the highest along the middle row of points. The mean noise intensity during the counts at CF-points was 72.1 ± 4.5 dB (range 61.2–81.4 dB; $n = 36$), at F-points 48.6 ± 5.4 dB (40.1–60.6 dB; $n = 36$) and at C-points 42.1 ± 6.1 dB (31.7–52.4; $n = 36$). There were significant differences in noise propagation between the point categories during the counts in September (ANOVA; $F_{2,33} = 318.84$; $P < 0.001$), October (ANOVA; $F_{2,33} = 247.00$; $P < 0.001$) and November (ANOVA; $F_{2,33} = 295.13$; $P < 0.001$; Fig. 3).

The number of individual birds per point was significantly lower near the road (ANOVA; $F_{2,33} = 13.16$; $P < 0.001$; Fig. 4). The mean number of birds at the CF-points was 11.5 ± 5.8 (range 1–21; $n = 12$) and was significantly different from the numbers at the F-points (22.3 ± 6.0; 8–32; $n = 12$) and the C-points (20.3 ± 4.5; 13–29; $n = 12$). Detailed analysis of the environmental parameters showed that the study area was homogeneous with respect to habitat (Table 2). Only one of the habitat parameters differentiated the study area: the shrub cover decreased with the distance from the road. Multiple regression analysis indicated that among the set of environmental parameters (in all cases $P > 0.119$), the only one influencing abundance (all individuals/point) was traffic noise ($B = -0.322$; $SE = 0.074$; $P < 0.01$). The data showed that noise levels below 49 dB did not significantly influence numbers of birds or species diversity in the study area. Species richness was lower near the road (ANOVA; $F_{2,33} = 6.29$; $P < 0.01$; Fig. 5). The mean number of species at the CF-points, lying closest to the road, was 5.6 ± 2.1

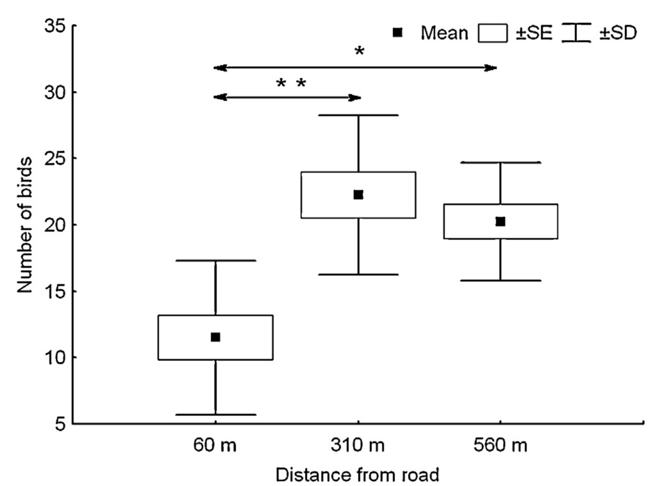

Fig. 4. Relationship between bird abundance at point-count locations and distance from the road. The arrow shows significant differences between points (Tukey's test, * $P < 0.001$, ** $P < 0.0005$).

Table 1
Forest bird community composition in relation to distance from road (CF-points—60 m, *F*-points—310 m, *C*-points—560 m) in eastern Poland. The explanation of bird classification according to foraging guilds: G—Granivorous–insectivorous; I—Insectivorous. The percentages are shown in parentheses.

Species	Foraging guild	Total number	Number of individuals (%)		
			CF-points ($n = 12$)	F-points ($n = 12$)	C-points ($n = 12$)
Regulus regulus	I	186	39 (21)	93 (50)	54 (29)
Parus major	I	94	36 (38)	35 (37)	23 (25)
Garrulus glandarius	G	58	10 (17)	19 (33)	29 (50)
Dendrocopops major	G	54	11 (20)	18 (33)	25 (47)
Carduelis spinus	G	52	2 (4)	17 (33)	33 (63)
Lophophanes cristatus	I	46	15 (32)	18 (39)	13 (29)
Periparus ater	I	45	8 (18)	22 (49)	15 (33)
Turdus viscivorus	G	37	4 (11)	14 (38)	19 (51)
Sitta europea	I	18	3 (17)	5 (28)	10 (55)
Poecile montana	I	10	3 (30)	4 (40)	3 (30)
Cyanistes caeruleus	I	10	4 (40)	5 (50)	1 (10)
Poecille palustris	I	5	2 (40)	3 (60)	0
Pyrrhula pyrrhula	G	5	1 (20)	0	4 (80)
Turdus pilaris	I	4	0	3 (75)	1 (25)
Corvus corax	G	4	0	3 (75)	1 (25)
Dryocopus martius	I	3	0	1 (33)	2 (67)
Certhia familiaris	I	3	0	2 (67)	1 (33)
Erithacus rubecula	I	3	0	1 (33)	2 (67)
Fringilla coelebs	G	2	0	2 (100)	0
Troglodytes troglodytes	I	2	0	1 (50)	1 (50)
Aeghitalos caudatus	I	2	0	0	2 (100)
Phylloscopus collybita	I	2	0	0	2 (100)
Certhia brachydactyla	I	1	0	1 (100)	0
Turdus merula	I	1	0	0	1 (100)
Phylloscopus trochilus	I	1	0	0	1 (100)
Total		648	138	267	243

Table 2
Vegetation at the point-count locations in relation to distance from the road (CF-points—60 m, F-points—310 m, C-points—560 m). Median values, with 25% and 75% quartiles in parentheses are show. Differences between points were tested by Kruskal–Wallis test.

Variable	CF-points	F-points	C-points	$H_{2,36}$	P
Canopy cover (%)	50 (40–60)	50 (40–52.5)	45 (30–50)	2.270	ns
Tree height (m)	15.3 (14.5–16.8)	18.6 (14.9–19.7)	16.1 (15.5–18.8)	2.113	ns
Number of tree species	4 (3–5)	4 (3.8–5)	4 (3.8–5)	0.262	ns
Number of deciduous trees	6.5 (3.8–9.3)	5.5 (1–9)	4 (2–7.3)	0.850	ns
Number of dead trees	0 (0–0.3)	1 (0–2)	1.5 (0–2.3)	4.628	ns
Number of shrub species	5.5 (4–7)	6 (5–6)	6 (5–6)	0.047	ns
Shrub cover (%)	40 (40–55)	40 (37.5–52.5)	30 (20–32.5)	9.918	<0.01

species ($n = 12$) and differed significantly from the number at the F-points (7.8 ± 2.1; $n = 12$) and C-points (8.2 ± 1.6; $n = 12$). The only environmental factor (multiple regression; in all cases $P > 0.119$) to influence species diversity was traffic noise ($B = -0.087$; $SE = 0.025$; $P < 0.01$). We thus used MANOVA to test for the effects of the road on the proportion of individuals in different ecological groups. Species foraging on invertebrates preferred the proximity of the road (MANOVA; $F_{2,66} = 11.46$; $P < 0.001$; Fig. 6).

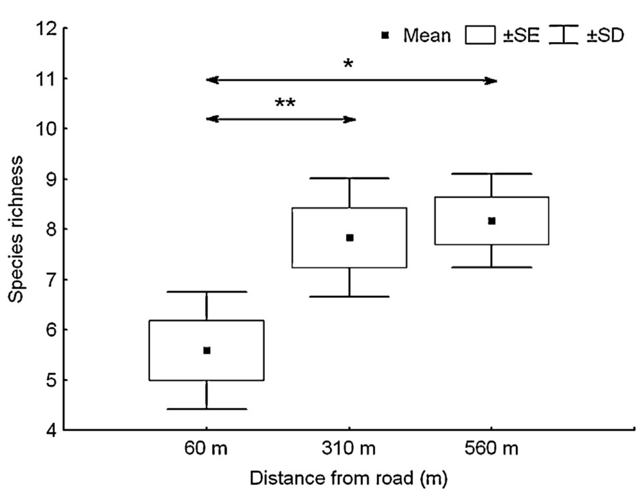

Fig. 5. Relationship between bird species richness at point-count locations and distance from the road. The arrow shows significant differences between points (Tukey's test, * $P < 0.001$, ** $P < 0.0005$).

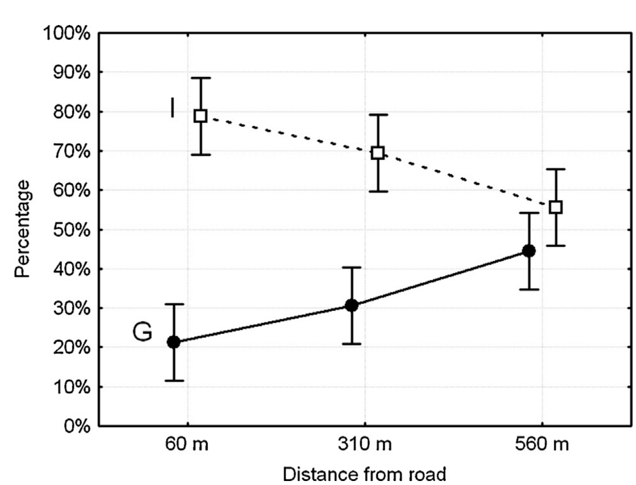

Fig. 6. Foraging (G—Granivorous–insectivorous; I—Insectivorous) guilds in relation to the distance from road. Vertical lines indicate 95% confidence intervals.

4. Discussion

Our study showed that the number of birds and species diversity were lower in the vicinity of the road. We observed that some species clearly avoided the "danger zone" in roadside habitats. This is in agreement with the "phantom road" experiment carried out in the autumn (McClure et al., 2013). The results of our study, performed under natural conditions near a quite heavily trafficked road, and those of the "phantom road" experiment, yielded very similar results. We found that nearly one quarter of the avian species avoided the vicinity of the noise polluted area. Preliminary results of other research carried out during the autumn migration period have demonstrated that birds experiencing stress as a result of exposure to traffic noise do not increase their body mass at stopover sites (Ware, McClure, & Barber, 2013). Analysis of recent papers focusing on the influence of negative factors affecting birds in the neighbourhood of roads reveals that the most important factor is excessive traffic noise; other factors, such as mortality due to collisions with vehicles, optical disturbances, human penetration or pollutants emitted by cars, stressed by some authors (Reijnen, Foppen, ter Braak, & Thiessen, 1995; Pocock & Lawrence, 2005; Summers et al., 2011), are probably of lesser significance (McClure et al., 2013).

The results presented in this work show that only anthropogenic noise affected species abundance and richness, but we cannot rule out the influence of other factors that we did not assess in our study and which could have modified our picture of the distribution and numbers of birds. The most important factor distorting the results of this research could have been the differentiation of habitat parameters (Reijnen et al., 1995). Therefore we carried out our study in a carefully selected plot in the forest where the habitat was homogeneous. Structurally, the habitat was quite uniform, which helped to minimise the modifying influence of habitat on bird distribution (Šálek et al., 2010; Halfwerk et al., 2011). Of all the environmental variables analysed, only shrub cover was a distinguishing feature of the study plot. The value of this parameter decreased with distance from the road (Table 2). It probably did not have any significant influence on the distribution of birds in the study area, because the numbers of individuals and the numbers of species were higher in the forest interior. The greater shrub cover in the vicinity of the road was the result of deliberate plantings by the roadside (Polak et al., 2013) and other factors related to the edge effect, such as temperature and light intensity (Delgado, Arroyo, Arevalo, & Fernandez-Palacios, 2007). On the other hand, we could not control all the factors affecting the autumn assemblage of birds in the study area. Competition and predation, together with other factors related to the edge effect, can modify the pattern of bird distributions (McCollin, 1998).

Some research has shown that not all bird species avoid traffic noise (Reijnen et al., 1995). During our study great tits displayed a distinct preference for the proximity of the road, as was the case during the breeding season (Polak et al., 2013). In spite of the noise and increased pressure from raptors along roads, some species decide to forage or nest in their vicinity (Kuitunen & Helle, 1988; Ratti & Reese, 1988; Kuitunen et al., 2003). Some individuals perish in collisions with vehicles (Orłowski, 2008), but this is the cost they bear in return for access to a more abundant food supply (Massemin, Maho, & Handrich, 1998). Indeed, this better supply of food along the edge of roads is the basic reason for such behaviour (Helle & Muona, 1985; Huhta, Jokimäki, & Rahko, 1999; Kuitunen et al., 2003). It may be that the higher temperature of the black road surface compared to the surroundings attracts certain species of invertebrates (Kriska, Horvath, & Andrikovics, 1998). Moreover, roads running through woodland and their immediate surroundings receive more insolation and have a warmer microclimate, which could be a significant factor, especially in autumn (McCollin, 1998). Anthropogenic food, available as roadside litter, may also be consumed. As a result of the edge effect created by roads, the present study indicated that insectivorous birds preferred the proximity of the road during the autumn migration period as opposed to the breeding period, when granivorous birds preferred the nearness of the road (Polak et al., 2013).

5. Conclusions

To the best of our knowledge, this is the first non-experimental fieldwork carried out at stopover sites during the autumn period in the context of the impact of traffic noise on woodland birds. Our observations have shown that roads carrying heavy traffic can modify the distribution and species diversity of woodland birds during the autumn to a significant extent. This study indicates that noise levels above 49 dB significantly influence the number of birds and species diversity in the study area. The number of individuals per point and species richness was lower near the road. In accordance with this pattern the density of five species increased with distance from the road. However, we also observed the opposite trend: species foraging on invertebrates, great tits in particular, preferred the proximity of the road. The habitat requirements of birds on migration are not exactly known (Bonter, Gautheraux, & Donavan, 2008). Hence, there is a need for further studies of the anthropogenic factors impairing migration and disturbing the sojourn of birds at stopover sites. One of these important factors is noise pollution due to road traffic. The data presented here may be helpful in the planning and management of road verges in the context of bird conservation and protection against road noise.

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