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How farmland birds react to traffic noise?

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Abstract. The effect of vehicle noise on farmland birds living in the vicinity of very busy roads was investigated. The study was conducted on two plots of crop fields located near national roads Nr. 12 and 19, the most important trunk roads in Poland and the eastern part of the Europe. The results of the current study are of wide relevance because crop fields are the dominant landscape type in both Poland and Europe. The conservation of the animals, including birds, living in such habitats is a priority issue in view of the strong pressure from human activities and the intensification of agriculture. The fieldwork was carried out in monthly from April to June 2020 and included counting birds in three rows of listening-observation points situated at 50, 150 and 250 m from the roads. At each observation point, all farmland and meadow birds seen and heard during a five-minute period were recorded, as was the maximum ambient noise level during this time. With increasing distance from the roads, the level of noise decreased while the number of individual birds and observed species increased. Most of the birds recorded, like skylark, lapwing, whinchat, yellowhammer, meadow pipit, pheasant, and common quail, avoided the vicinity of the roads. In contrast, the abundant yellow wagtail appeared to be insensitive to traffic noise and was evenly distributed over the two study plots. The roads and their associated traffic noise had a negative impact over a distance of about 100 m. At that distance, noise levels above 53–60 dB led to sharp falls in bird densities. Bird mortality due to collisions with vehicles was low because noise combined with the lack of attractive roadside habitats effectively deterred birds from the vicinity of the roads.

Keywords. Birds, farmland, traffic noise.

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Introduction

The unrestricted movement of large groups of people and the transport of goods within this extended infrastructure is expected to make its mark on living organisms (Kociolek *et al.* 2010). The continual expansion of road networks is adversely affecting natural environments (McGregor *et al*. 2008). The most common effects are loss or fragmentation of natural habitats occupied or crossed by new roads and railway lines (Šalek *et al*. 2010; Borda de Agua 2017). Frequent collisions between animals and motor vehicles are another unfortunate consequence of road development (Jack *et al* 2015; Borda de Agua 2017), leading to high levels of animal mortality. Such situations potentially endanger not only the animals themselves but also the humans travelling in those vehicles (Santos *et al*. 2017). In addition, intensive road traffic generates high levels of air pollution, with contaminants entering the roadside soil and atmosphere (Rheindt 2003; Parris & Schneider 2009). Road transport additionally produces other forms of pollution like the noise and lights of passing vehicles (Pocock & Lawrence 2005; Summers *et al*. 2011; Polak *et al*. 2013). Traffic noise has an extremely negative effect on birds: the phantom road experiments performed in the USA by McClure *et al*. (2013) provided compelling evidence of this. Deployed in a forest, loudspeakers emitting traffic noise produced the same effect as the noise generated by heavy traffic travelling along a real road. Birds avoided this phantom road just as if vehicles were actually moving along it.

Noise affects birds in variety of ways. Physiological changes can elicit behavioural changes; birds' hearing organs may be damaged, and their breeding success and breeding density in habitats adjacent to roads may be reduced (Dooling & Popper 2007). Road noise can alter the intensity and frequency of bird song (Rheindt 2003). In such cases, occupying a territory becomes more difficult; attracting a partner, and vocal communication with conspecifics, especially between adults and their young, is hampered (Goodwin & Shriver 2011; Brumm 2013; Nemeth *et al*. 2013).

A straightforward way of assessing the effect of traffic noise on birds is to study the changes in breeding density near a busy road. It has long been known that the numbers and species diversity of birds decrease in the vicinity of roads (Reijnen *et al*. 1995, 1996), although some birds, in line with the edge effect, may occur in larger densities close to transport routes (Kuitunen *et al*. 2003; Benitez Lopez *et al*. 2010), particularly along railway lines (Wiącek *et al*. 2015a, 2019, 2020).

Woodlands adjacent to busy roads have been very thoroughly studied for noise pollution (Kuitunen *et al*. 2003; Halfwerk *et al*. 2011; Polak *et al*. 2013; Wiącek *et al*. 2015a), but anthropogenic habitats somewhat less so (Brumm 2004, 2013; Nemeth *et al*. 2013). Agricultural landscapes including meadows and pastures, have so far received the least attention (Reijnen *et al.* 1996; Waterman *et al*. 2002). Investigating birds in these habitats appears to be important as farmland covers ca 60% of Poland and ca 40% of the European Union (Tryjanowski *et al*. 2009; EUROSTAT 2018) but such landscapes remain poorly studied. In view of the incessant pressure of human civilization and the intensification of farming, assessing the effects of noise pollution on the fauna living in these habitats has become of major significance (Chamberlain *et al*. 2000).

The principal aim of this study was to determine the response of the different bird species breeding on cultivated land to road noise, and to measure the levels and audibility range of noise at different distances from roads. We test here if there will be a decline in bird numbers close to the road, similar to what is known from forest habitats.

Study plots

The fieldwork was carried out on cultivated fields in eastern Poland. The study plots were located near the two most important national roads in the Lublin region and in Poland. The first one was situated by the main west-east road (No. 12, between German and Ukraine borders) near the village of Anusin, ca 20 km from the town of Chełm (51°17′08″ N, 23°12′78″ E) (study area A). The traffic on this road was 10 300 vehicles per 24 h; 70% were cars, the other 30% included vans and lorries (data from GDDKiA – the General Directorate for National Roads and Motorways). The second study plot (T) was situated along the north-south running road No. 19 (called "Via Carpathia"), near the village of Trzciniec, just south of the town of Lubartów (51°40′57″ N, 22°64′28″ E). There, the intensity of traffic was 7 650 vehicles per 24 h, including about 60% of cars and 40% vans and lorries (data from GDDKiA). Around 65% of study area A was planted with rapeseed, while wheat and rye were grown on 30% of this area. The remaining 5% consisted of meadows and farm tracks. There was an avenue of trees alongside road

No. 12 on the border of this study plot. Study plot T consisted mostly of fields with spring and winter cereals (85% of the area), criss-crossed by strips of fallow land and farm tracks (ca 15%), and lacking trees along the border with road No. 19. There were single trees on both study areas; although these were growing at some considerable distance from one another, they were fairly evenly spaced at the three studied distances from the roads (50, 150, 250 m).

Methods

The fieldwork, carried out with permission of the landowners, was monthly carried out from April to June 2020 with three counts per study plot. Beforehand, the study plots were carefully selected for habitat homogeneity. This was not difficult, as most of the crops in the fields were monocultures. At each observation/listening point, the height of the vegetation was measured to the nearest 1 cm (and the average of 5 random measurements made within 5 m of the point calculated). The number of different plant species was also counted within this 5 m radius, and the presence of trees and shrubs noted within 50 m of the point. The dominant type of crop around each point was recorded (rapeseed, cereal, fallow land) as well. The differences in vegetation height on study plot T were due to different rates of growth of the winter and spring cereals. Apart from the latter parameter, the study plots were uniform. The rows of observation/listening points, set up with the aid of a GPS, ran parallel to the roads at three distances from, i.e., 50 m, 150 m and 250 m, and the points along the rows were 100 m apart. On study plot A, there were 42 points in total (14 in each row) and on plot T 33 points (11 in each row). The fieldwork was carried out during the birds' peak morning activity, between 05:30 and 09:30 hrs. All the farmland and meadow birds seen/heard during a 5-minute period within a radius of 50 m of the point were recorded at each observation/listening point. Species migrating, flying past or not being associated with these habitats were ignored. The observer was highly experienced in bird censusing and used the same counting method as in studies on other habitats (Wiącek *et al*. 2015a, 2015b, 2019, 2020). Birds were with great care, while moving slowly from one point to the next so as not to record the same birds twice at consecutive points. During each inspection, roadsides were searched for victims of collisions with vehicles. The maximum ambient noise level was measured during the same 5-minute period at each point using a CHY 650 sound level meter. The statistical computations were carried out using Statistica 12 (STATSOFT 2014) and Canoco 4.0 (ter Braak & Smilauer 1998). An ANOVA was used to assess noise propagation over the study plots and to define the number of species and individuals seen/heard at the three distances from the road. Redundancy analysis (RDA) was used to define the preference of particular bird species near roads or for avoiding them. A Monte Carlo test with 500 permutations was applied to define the significance of the principal axes.

The applied methodology was non-invasive regarding the studied birds and complied with Polish Nature Conservation laws, so no special permits were required.

Results

Anusin (study plot A)

The three counts on the study plot at Anusin (A) yielded a total of 237 birds from 11 species. The most numerous were skylark *Alauda arvensis* (65% of this bird assemblage) and yellow wagtail *Motacilla flava* (ca 30%). The other nine species occurred in very small numbers (Table 1). Analysis of the six most numerous bird species recorded on this study plot revealed two significantly different preferences for either being close to the road or distant from it. (Monte Carlo test of the significance of the first axis, F ratio = 72.715; P=0.002. Monte Carlo test of the significance of all axes, F ratio=41.962, P=0.002.). Among the dominant birds on this plot, skylarks clearly avoided the road whereas yellow wagtails were distributed evenly at all the distances from the road (Fig. 1). Other bird species such as yellowhammer

TABLE 1

Study plot “Anusin” – numbers of recorded bird species and individual birds per species.
Row A is situated 50 m from the road, row B 150 m and row C-250 m.

	Species		April	May	June	Row A	Row B	Row C	Total
1	Skylark	*Alauda arvensis*	45	60	49	6	59	89	154
2	Yellow wagtail	*Motacilla flava*	16	16	38	21	33	16	70
3	Whinchat	*Saxicola rubetra*	2	0	0	1	1	0	2
4	Yellowhammer	*Emberiza citrinella*	1	0	1	1	0	1	2
5	Garden warbler	*Sylvia borin*	0	0	2	2	0	0	2
6	Chaffinch	*Fringilla coelebs*	0	1	1	2	0	0	2
7	Corn bunting	*Emberiza calandra*	1	0	0	1	0	0	1
8	Goldfinch	*Carduelis carduelis*	1	0	0	1	0	0	1
9	Blackcap	*Sylvia atricapilla*	0	1	0	1	0	0	1
10	Montagu’s harrier	*Circus pygargus*	1	0	0	0	0	1	1
11	Common quail	*Coturnix coturnix*	0	1	0	1	0	0	1
	Total		67	79	91				237

Emberiza citrinella, garden warbler *Sylvia borin* and chaffinch *Fringilla coelebs* were observed by the roadside.

During all three study periods (April, May, June) on plot A, the mean noise levels decreased significantly with increasing distance from the road ($F(6.74)=27.43$, $p=0.000$) (Fig. 2). At the first row of observation points (50 m from the road), 63.15 dB ($SD=5.37$, $n=42$) was recorded. Along the second row (150 m), 53.35 dB ($SD=4.06$, $n=42$) were observed and at the third row (250 m), –49.92 dB ($SD=4.13$, $n=42$). On this plot, the noise level decreased with distance from the road.

During all three study periods (April, May, June) on plot A, the mean numbers of individual birds increased with distance from the road ($F(6.74)=14.771$, $p=0.000$) (Fig. 3). At the first row of observation points, an average of 0.9 individuals were recorded ($SD=0.77$, $n=42$), along the second row, an average of 2.2 ($SD=0.96$, $n=42$) and at the third row, an average of 2.5 ($SD=0.83$, $n=42$). During all three study periods, the mean numbers of bird species increased with distance from the road $F(6.74)=5.0137$,

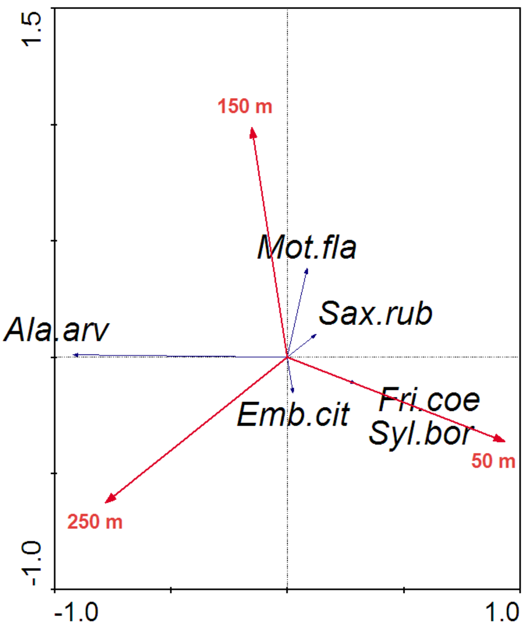

Figure 1 – Preferences of the most abundant bird species to stay at different distances from the road in study plot A. Species names of birds are abbreviations of the first three letters of the name in Latin (*Ala.arv* – *Alauda arvensis*, *Mot.fla* – *Motacilla flava*, *Sax.rub* – *Saxicola rubetra*, *Emb.cit* – *Emberiza citrinella*, *Syl.bor* – *Sylvia borin*, *Fri.coe* – *Fringilla coelebs*).

p=0.0002. (Fig. 4). The average number of the bird species increased from 0.8 species (SD=0.64, n=42) at the first row to an average of 1.4 (SD=0.49, n=42) at the second row and 1.36 species (SD=0.53, n=42) at the third row. Only one victim of a collision with vehicles was found during the three field inspections (a yellowhammer).

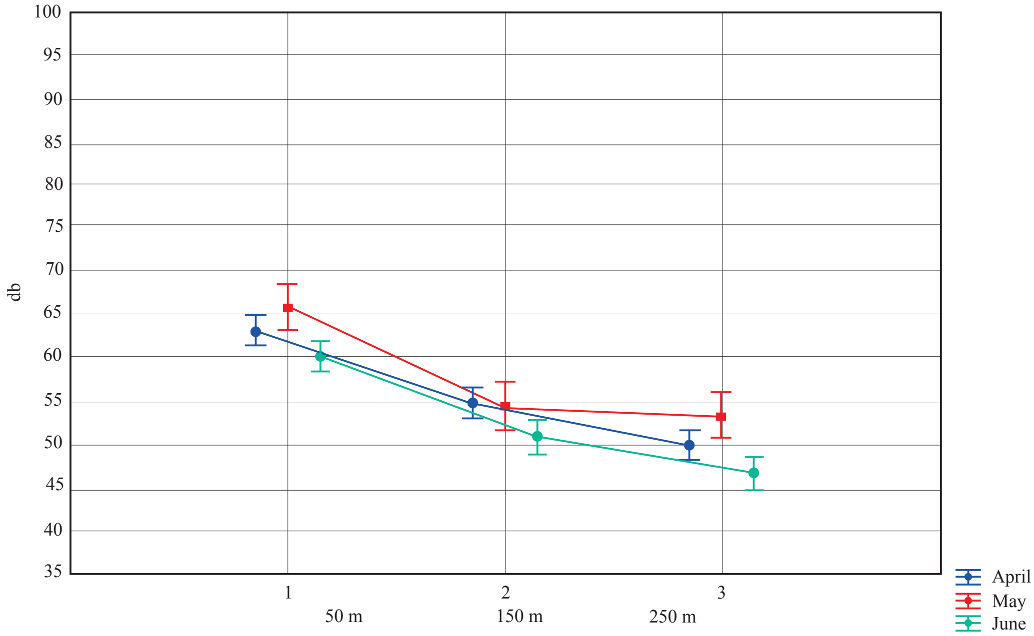

Figure 2 – Average road noise levels in dB recorded at each observation point at different distances from the road in April, May and June for study plot A.

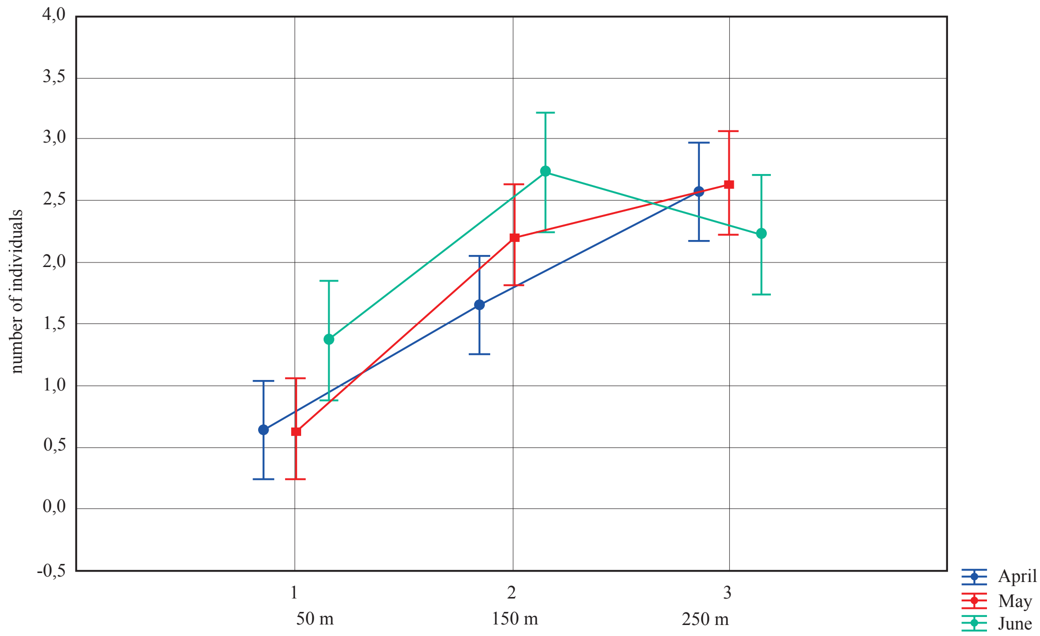

Figure 3 – The mean number of individual birds observed at each observation point at different distances from the road in April, May and June for study plot A.

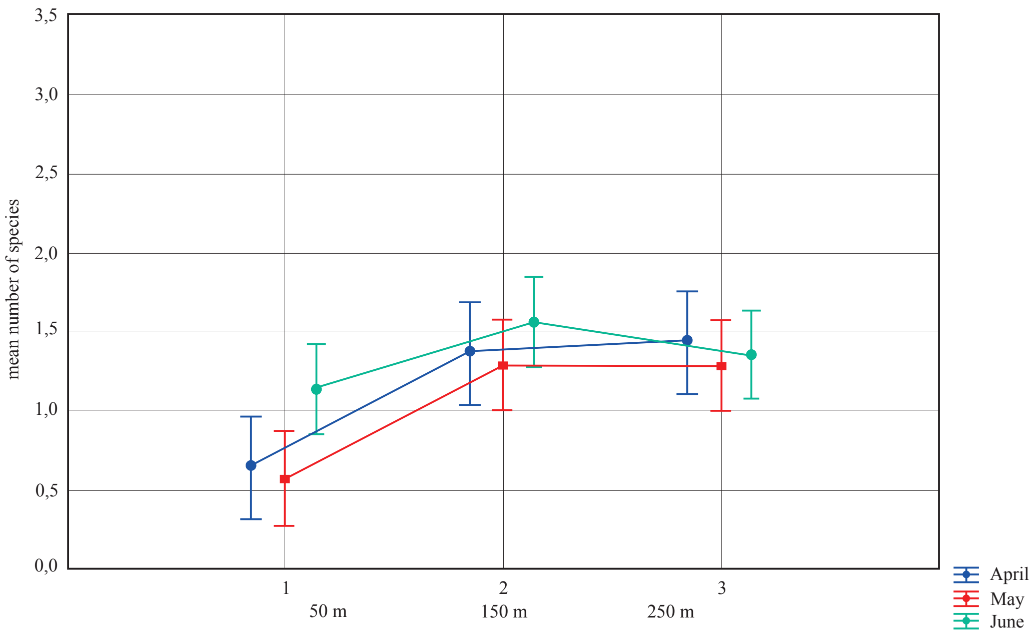

Figure 4 – The mean number of bird species observed at each observation point at different distances from the road in April, May and June for study plot A.

Trzciniec (Study plot T)

The three counts on the study plot at Trzciniec (T) yielded a total of 173 birds from 17 species (Table 2). The most numerous were skylark (> 53%), whinchat *Saxicola rubetra* (15%) and lapwing *Vanellus vanellus* (7.5%). The abundance of the other species did not exceed 5% of the total assemblage on this plot. Analysis of the eight most numerous species showed that all of them were significantly absent from the vicinity of the road (Fig. 5). Monte Carlo test of the significance of the first axis, F ratio = 13.548; P = 0.002. Monte Carlo test of the significance of all axes, F ratio = 7.004, P = 0.002.

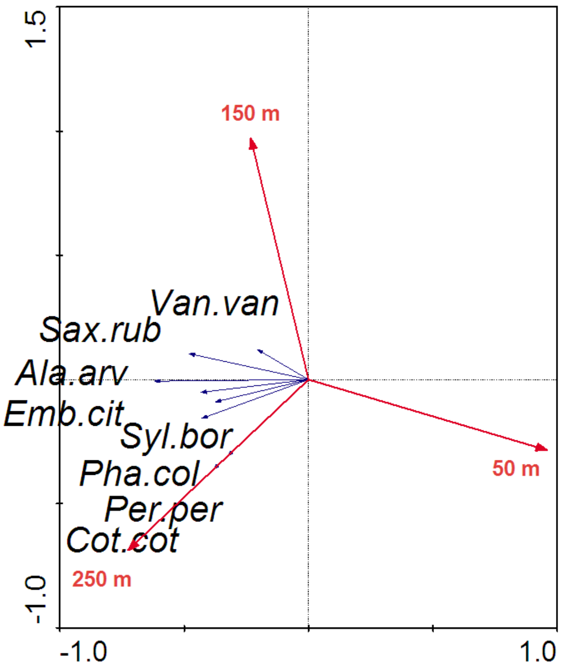

Figure 5 – Preferences of the most abundant bird species to stay at different distances from the road in study plot T. Species names of birds are abbreviations of the first three letters of the name in Latin (*Van.van* – *Vanellus vanellus*, *Sax.rub* – *Saxicola rubetra*, *Ala.arv* – *Alauda arvensis*, *Emb.cit* – *Emberiza citrinella*, *Syl.bor* – *Sylvia borin*, *Pha.col* – *Phasianus colchicus*, *Per.per* – *Perdix perdix*, *Cot.cot* – *Coturnix coturnix*).

TABLE 2

Study plot “Trzciniec” – number of recorded birds species and individuals per species.
Row A is situated 50 m from the road, row B 150 m and row C-250 m.

	Species		April	May	June	Row A	Row B	Row C	Total
1	Skylark	*Alauda arvensis*	29	34	29	11	36	45	92
2	Whinchat	*Saxicola rubetra*	4	14	8	1	12	13	26
3	Lapwing	*Vanellus vanellus*	9	2	2	1	5	7	13
4	Yellowhammer	*Emberiza citrinella*	2	3	3	0	2	6	8
5	Pheasant	*Phasianus colchicus*	3	1	3	0	2	5	7
6	Garden warbler	*Sylvia borin*	0	4	2	0	1	5	6
7	Common quail	*Coturnix coturnix*	0	0	4	0	0	4	4
8	Meadow pipit	*Anthus pratensis*	2	2	0	0	1	3	4
9	Grey partridge	*Perdix perdix*	1	0	2	0	0	3	3
10	Chaffinch	*Fringilla coelebs*	0	0	2	0	0	2	2
11	Yellow wagtail	*Motacilla flava*	0	1	1	0	1	1	2
12	White wagtail	*Motacilla alba*	0	0	1	0	1	0	1
13	Blackcap	*Sylvia atricapilla*	0	0	1	0	0	1	1
14	Willow warbler	*Phylloscopus trochilus*	1	0	0	0	0	1	1
15	Common chiffchaff	*Phylloscopus collybita*	0	1	0	0	0	1	1
16	Wheatear	*Oenanthe oenanthe*	1	0	0	0	1	0	1
17	Red-backed shrike	*Lanius collurio*	0	1	0	0	1	0	1
	Total		52	63	58				173

During all three study periods (April, May, June) on plot T, the mean noise levels decreased with distance from the road F(6.56)=31.752, p=0.0000) (Fig. 6). At the first row (50 m from the road), an average noise level of 70.7 dB (SD=13.93, n=33) was recorded. Along the second row (150 m), an average of 60.75 dB (SD=11.76, n=33) was observed and at the third row (250 m), an average of 54.93 dB (SD=114, n=33).

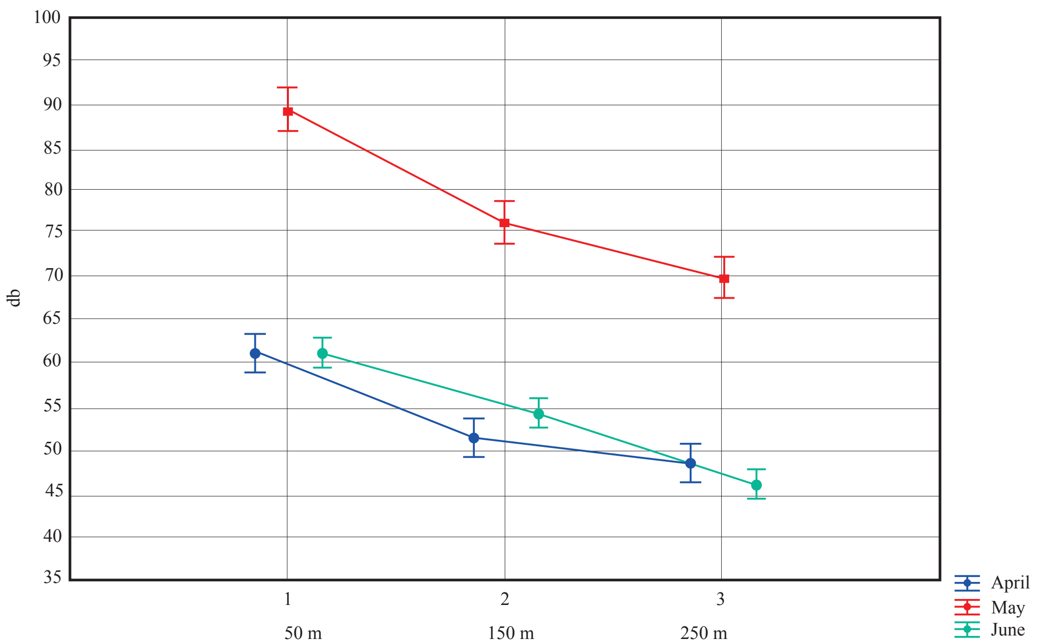

Figure 6 – Average road noise levels in dB recorded at each observation point at different distances from the road in April, May and June for study plot T.

During all three study periods (April, May, June), the mean numbers of individual birds increased with distance from the road (F(6.56)=16.496, p=0.0000) (Fig. 7). At the first row, an average number of 0.4 (SD=0.49, n=33) individuals were found, which increased to an average of 1.9 (SD=0.59, n=33) along the second row and 2.8 (SD=0.93, n=33) at the third row. As in the other plots, the mean numbers of bird species increased with distance from the road F(6.56)=14.291, p=0.0000 (Fig. 8) during the entire study period.

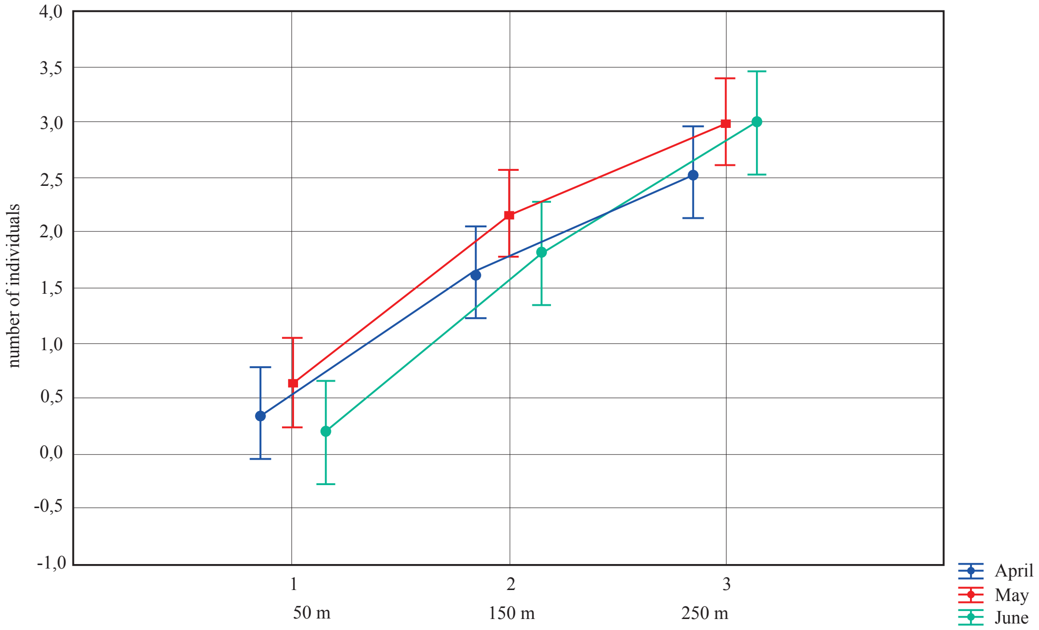

Figure 7 – The mean number of individual birds observed at each observation point at different distances from the road in April, May and June in study plot T.

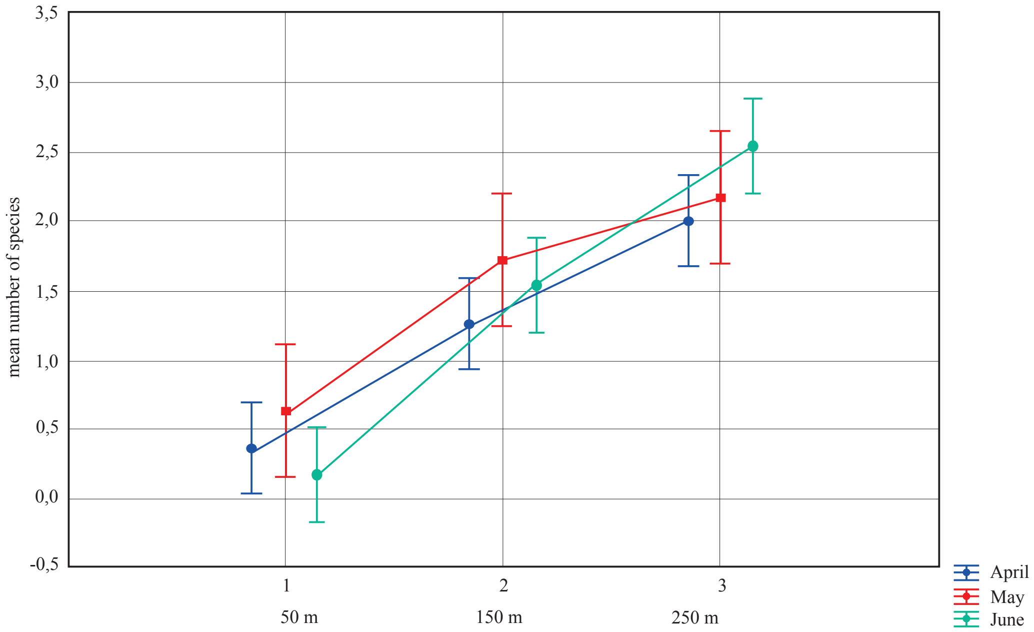

Figure 8 – The mean number of bird species observed at each observation point at different distances from the road in April, May and June for study plot T.

At the first row, we found an average of 0.4 (SD=0.49, n=33) bird species. This value increased to 1.5 (SD=0.56, n=33) at the second row and was with 2.2 (SD=0.83, n=33) even higher at the third row. No victims of possible vehicle collisions with birds of agricultural habitat were found during field inspections performed.

Discussion

The impact of noise on animals in the vicinity of tarred roads and railway lines is an extremely interesting research question that biologists have been addressing in many European countries and on other continents (Reijnen & Foppen 2006; Brumm 2013; Borda de Agua 2017). Most of their results point to the adverse consequences of road traffic and the noise it emits on animals, primarily birds; they are corroborated by the results of the present study (Reijnen *et al*. 1996; Rheindt 2003; Brumm & Slabbekorn 2005; Parris & Schneider 2009). Exceptionally, field studies carried out along railway lines passing through large forests have shown that bird densities increase along their margins near the tracks. This is due both to the edge effect and to the point nature of the noise emitted by fast but relatively infrequently passing trains (Wiącek *et al*. 2015b, 2019, 2020). In contrast, all studies of this kind relating to tarred roads have shown that birds are negatively impacted by traffic noise (Reijnen & Foppen 2006; Polak *et al*. 2013; Wiącek *et al*. 2015a). Most of these field experiments were carried out in woodland environments (Reijnen & Foppen 2006; Dooling & Popper 2007; Goodwin & Shriver 2011; Polak *et al*. 2013; Wiącek *et al*. 2015a). In contrast, investigations of this type conducted in farming landscapes are still relatively scarce, yet their results are highly insightful (Reijnen *et al*. 1996; Waterman *et al*. 2002).

The present study, carried out on cultivated fields in eastern Poland, provides compelling evidence that birds avoid the immediate vicinity of busy roads with very high noise levels. The number and diversity of species inhabiting cultivated fields increased with distance from roads. Similar relationships were obtained in Dutch meadows, where the great majority of bird species investigated clearly avoided the close neighbourhood of roads (Reijnen *et al*. 1996). As in the present study, lapwings and skylarks in the Netherlands kept well away from roads. In contrast, yellow wagtails in the farm landscapes of both eastern Poland and the Netherlands appeared to remain unaffected by the noise and movements of motor vehicles. Moreover, birds inhabiting meadowlands in western and northern Holland also avoided the immediate vicinity of railway lines (Waterman *et al*. 2002). The present study in eastern Poland showed that the noise produced by passing road vehicles had a distinctly negative impact on many species of meadow birds,. In the present study, the threshold above which numbers of noise-sensitive bird species began to fall sharply was 53 dB on study plot A (Anusin) and 60 dB on plot T (Trzciniec). The noise levels recorded in Poland were higher than those measured near railway tracks in the Netherlands, where the critical level was ca 42 dB for skylarks (Waterman *et al.* 2002), but very similar to the average levels measured near tarred roads (ca 59 dB) (Reijnen *et al*. 1996).

In eastern Poland, diminished abundances of species like skylark and lapwing were recorded at distances of 100 m from the roads in both study plots. These results are comparable with those from Holland for roads with traffic intensities of ca 5000 vehicles per 24 h (Reijnen *et al*. 1996). There, decreases in bird abundance were recorded at average distances of 100–200 m from roads. At higher traffic intensities (50 000 vehicles per 24 h), the zone of negative interaction extended to 490–560 m from the road.

As discussed above, vehicle noise caused skylarks to avoid roads. But this species has also been found to avoid habitats containing clumps of trees in fields or rows (avenues) of trees (Chamberlain & Gregory 1999; Tryjanowski *et al*. 2009). At the study site Anusin, there was an avenue of trees along the road, separating it from plot A, whereas at Trzciniec, the road was immediately adjacent to plot T. Nevertheless, the reaction of the skylarks to traffic noise was identical for both plots, which may indicate that vehicle noise alone is the main factor causing road avoidance while the presence of trees may be less important.

Mortality of birds caused by collisions with vehicles was very low, probably because the impact of noise and passing vehicles effectively kept birds from the vicinity of the road. In such a situation, the presence of a line of trees along the plot in Anusin was not attractive for birds although hedgerows and trees along roads are usually the cause of increased mortality for different animals, including birds (Orłowski 2008). It can be proposed that the noise in both plots and the lack of a tree line in the second study plot influenced the low mortality rates of birds by collisions with vehicles. However, it must be taken into account that not all collision victims were found as predators could have removed killed birds before the next (monthly) study period and the actual mortality may in fact have been higher (Loss *et al*. 2015).

Conclusions

This study on the impact of traffic noise on farmland birds has shown that most bird species clearly avoid the close vicinity of busy roads, including skylark, lapwing, whinchat, yellowhammer, meadow pipit, pheasant and partridge. Both the number of individual birds and the number of bird species increased with increasing distance from the roads. One only bird species, the yellow wagtail, appeared to be undisturbed by road vehicles. Traffic noise negatively affected birds up to a distance of 100 m from the road, and noise levels from 53 to 60 dB reduced bird densities. At higher noise levels, the abundance of sensitive species fell sharply.

Studying birds in agricultural landscape is particularly important for the conservation of biodiversity in habitat-poor agrocenoses. The results of the current study provide evidence for additional negative effects of transport infrastructures in such agricultural landscapes on birds and are useful for developing suitable measures for the conservation of birds and other taxa in Europe.

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