LETTER

A Paradox for Conservation: Electricity Pylons May Benefit Avian Diversity in Intensive Farmland

Piotr Tryjanowski[1], Tim H. Sparks[1,2,3], Leszek Jerzak[4], Zuzanna M. Rosin[5], & Piotr Skórka[1]

[1] Institute of Zoology, Poznań University of Life Sciences, Wojska Polskiego 71C, 60–625, Poznań, Poland
[2] Fachgebiet für Ökoklimatologie, Technische Universität München, Hans-Carl-von-Carlowitz-Platz 2, 85354 Freising, Germany & Institute for Advanced Study, Technische Universität München, Lichtenbergstrasse 2a 85748, Garching, Germany
[3] Sigma, Coventry University CV1 5FB, UK
[4] Faculty of Biological Sciences, University of Zielona Góra, Prof. Z. Szafrana Street 1, 65-561, Zielona Góra, Poland
[5] Department of Cell Biology, Faculty of Biology, Adam Mickiewicz University, Umultowska 89, 61–614, Poznań, Poland

Keywords
Birds; electricity; farmland; nesting; Poland; power line; pylon.

Correspondence
Piotr Tryjanowski, Institute of Zoology, Poznań University of Life Sciences, Wojska Polskiego 71C, 60-625 Poznań, Poland.
Tel: + 48 61 8487656;
fax: + 48 61 8487649.
E-mail: piotr.tryjanowski@gmail.com

Received
12 December 2012
Accepted
3 March 2013

Editor
Andras Baldi

doi: 10.1111/conl.12022

Abstract

Over the past century, electricity power lines have been a conspicuous part of the European landscape. These structures are generally known to cause fatalities to birds. However, some bird species use electricity poles as nesting structures, song posts, or for perching. Other, but not-acknowledged, benefits probably include the marginal habitats around the base of pylons. We tested differences in breeding bird communities under pylons, under electricity high-voltage power lines, and in adjacent open fields. Birds were counted twice during the 2011 breeding season in a total of 91 study plots located in the intensive farmland of western Poland. Both species number and bird abundance were significantly higher under pylons and under power lines at control points than in open fields, especially where there were shrubs under the pylons. Pylons and power lines locally may play a positive role for the avian community in intensive farmland, especially if vegetation succession under pylons is allowed to develop to the shrub stage.

Introduction

For the past century, electricity power lines have been a conspicuous part of the landscape in Europe. These lines and their support structures are known to cause wildlife fatalities, particularly in birds, through collision (Bevanger 1998; Savereno *et al.* 1996) or electrocution (Janss 1998, 2000; Infante & Peris 2003). Moreover, birds may be affected not only directly by contact with power lines, but also by their electromagnetic fields (Balmori 2005; Fernie & Reynolds 2005). On the positive side, poles/pylons are used as nest platforms by corvids, raptors, and especially White Storks *Ciconia ciconia* (Janss 1998; Garrido & Fernandez-Cruz 2003), and as song posts, resting and perching places (Bevanger 1994; Janss 2000; Haas & Nipkow 2006). Irrespective of their influence on birds, power lines are generally negatively perceived by humans, who consider both the impacts on birds as well as the aesthetic impact on landscape, even referring to electricity lines and pylons as pollution (Soini & Aakkula 2007; Clarke & White 2008; Naugle *et al.* 2011).

High-voltage electricity pylons also create new habitat islands at their base, which in arable fields could be recognized by birds as margin habitat. It is well known that bird species composition and numbers in farmland are strongly positively related to the number of microhabitats, such as hedges, field margins, small water bodies, and mid-field forests (Tryjanowski 1999; Walker *et al.* 2005; Wuczyński *et al.* 2011), and consequently heterogeneity is suggested as a key element to explain diversity in farmland (Benton *et al.* 2003; Báldi *et al.* 2005). So, paradoxically, in intensive farmland widespread across Europe, electricity pylons and especially the small patches of habitat at their base may benefit bird species in farmland habitats. As far as we are aware, this potential benefit of pylons has not yet been investigated. Therefore, in this article, we tested whether electricity pylons with their basal habitats and power lines were valuable to avian species in intensive farmland and could thus add to the diversity of the farmland bird community.

Materials and methods

The study was conducted during the 2011 breeding season in the Wielkopolska province, western Poland (centered on: 52°N, 16°E). The main crops were cereals, maize, and sugar beet (for further details, see Tryjanowski 1999), and two types of power lines (110 and 220 kV) were common throughout the farmland habitat.

We randomly chose 91 study plots (27 of 110 kV and 64 of 220 kV steel lattice transmission pylons) located at least 1 km apart. Within each plot, birds were counted from three habitats: (1) from the base of the pylon; (2) in the field under power lines at least 200 m from a pylon; and (3) in the open fields 200 m perpendicular to the power lines. We used a point count method with radius 50 m and time duration of 5 min for each habitat (Bibby *et al.* 1992; Surmacki & Tryjanowski 1999). We chose the same radius for practical reasons, because unfarmed patches under pylons differed significantly by size between 110 and 220 kV power lines (respectively, mean ± SD 15.7 ± 6.4 m^2 vs. 45.4 ± 44.2 m^2, $n_1 = 27$ and $n_2 = 64$, Kruskal–Wallis $H = 18.99$, $P < 0.001$). Each point was counted twice in the breeding season; the first census was conducted between 15 and 25 April, and the second between 20 and 30 May. However, it should be noted that only some of the observed bird species nested on or below pylons. We also recorded individuals that visited pylons/lines to rest or hunt; thus, the results relate to both breeders and nonbreeders. All counts were made during the first 5 hours after sunrise in fair weather. We censused the three habitats per study plot on the same morning, varying the order of census at random. It is not possible to exclude any effect there may have been of the presence of the observer on the number of counted birds. However, all counts started with a few minutes of initial settling time (Bibby *et al.* 1992; Gregory *et al.* 2004) and were conducted by one observer (PT); thus, any effect of human disturbance was similar between the study points. As in other simple bird counting methods, the larger of the two counts was used in subsequent summaries and analyses (Gregory *et al.* 2004; Elphick 2008). However, analyses made on means of the two counts also gave similar results.

All study plots were located in large open fields at least 200 m from field margins, forest edges, and roads. Under pylons, the patches were managed (or, in fact, were unmanaged) by electricity companies (or illegally by farmers) in different ways. The vegetation cover of pylon patches was divided into three categories: 1) grass—if the area under the pylon was covered only by grass and herbaceous plants; 2) mixed—if at least one shrub occurred, but less than 75% of the area was occupied by shrubs/trees; 3) shrub—if over 75% of the patch area was covered by shrubs/trees. Among shrubs, blackthorn (*Prunus spinosa* L.) and elder (*Sambucus nigra* L.) dominated. In addition, the basal area of the pylon patch was recorded.

We have used a significance threshold of $P = 0.05$ and all calculations were conducted using the SPSS for Windows and Minitab packages. Numbers of bird species and of individuals were the two dependent variables. Because of nonnormality in residuals, all analyses were based on nonparametric methods; Spearman rank correlation for relationships, Kruskal–Wallis for one-way ANOVA, or Friedman's test for two-way ANOVA (factors study plot and habitat type). Additionally, we performed a general linear mixed model to account for possible spatial dependency of habitats within one site. A triplet (study plot) identity (triplet included habitat under the pylon, habitat under the power line, and plot in the open field) was assigned as a random factor. Results of this analysis were similar to that from the nonparametric tests and are included in the Supporting Information. A canonical correspondence analysis in the CANOCO package (Leps & Smilauer 2003) was used to relate the abundance of the individual species to sites under pylons, lines, and in fields.

Results

A total of 54 bird species were recorded in the study; 34 under pylons, 33 under power lines, and 22 species in open fields (Table 1). The difference in the number of species per habitat was statistically significant (Table 1; Figure 1).

A total of 446 individual birds were recorded during the highest count (Table 1). The most abundant bird species were: skylark *Alauda arvensis*, woodpigeon *Columba palumbus*, starling *Sturnus vulgaris*, corn bunting *Miliaria calandra*, raven *Corvus corax*, and yellow wagtail *Motacilla flava*; these six species constituted more than 53% of the whole assemblage. Pylons and electricity lines significantly contributed to the variation of bird community composition as indicated by canonical correspondence analysis (Figure 2). Points associated with high

Table 1 Comparison of the breeding bird communities (expressed as number of individuals for each species) between control fields, under power lines and under electricity pylons (all $n = 91$). Species are arranged in declining order of overall abundance

Species	Species name abbreviation	Field	Line	Pylon	Total
Alauda arvensis	*Ala arv*	36	14	4	54
Columba palumbus	*Col pal*	0	36	15	51
Sturnus vulgaris	*Stu vul*	7	24	16	47
Miliaria calandra	*Mil cal*	4	13	19	36
Corvus corax	*Cor corax*	1	4	23	28
Motacilla flava	*Mot fla*	10	8	3	21
Emberiza citrinella	*Emb cit*	3	5	9	17
Hirundo rustica	*Hir rus*	3	14	0	17
Passer montanus	*Pas mon*	2	2	9	13
Corvus cornix	*Cor cornix*	2	2	6	10
Sylvia communis	*Syl com*	1	0	9	10
Corvus frugilegus	*Cov fru*	0	2	8	10
Falco tinnunculus	*Fal tin*	0	3	6	9
Carduelis cannabina	*Car can*	0	2	7	9
Lanius collurio	*Lan col*	0	1	7	8
Phasianus colchicus	*Pha col*	4	0	3	7
Coturnix coturnix	*Cot cot*	7	0	0	7
Larus ridibundus	*Lar rid*	7	0	0	7
Acrocephalus palustris	*Acr pal*	4	0	3	7
Lululla arborea	*Lul arb*	2	0	4	6
Turdus philomelos	*Tur phi*	0	0	6	6
Pica pica	*Pi pic*	0	0	5	5
Emberiza hortulana	*Emb hor*	0	2	3	5
Buteo buteo	*But but*	0	3	2	5
Turdus pilaris	*Tur pil*	0	0	3	3
Lanius excubitor	*Lan exc*	0	1	2	3
Vanellus vanellus	*Van van*	3	0	0	3
Saxicola rubetra	*Sax rubetra*	0	0	3	3
Turdus merula	*Tur mer*	0	1	2	3
Circus aeruginosus	*Cir aer*	2	0	0	2
Ardea cinerea	*Ard cin*	1	1	0	2
Saxicola rubicola	*Sax rubicola*	0	0	2	2
Motacilla alba	*Mot alb*	0	1	1	2
Streptopelia decaocto	*Stre dec*	0	2	0	2
Passer domesticus	*Pas dom*	0	2	0	2
Apus apus	*Apus apus*	1	1	0	2
Emberiza schoeniclus	*Emb sho*	1	1	0	2
Oriolus oriolus	*Ori ori*	0	0	2	2
Cuculus canorus	*Cuc can*	0	2	0	2
Columba oenas	*Col oen*	0	1	1	2
Anser anser	*Ans ans*	1	0	0	1
Oenanthe oenanthe	*Oen oen*	0	1	0	1
Accipiter nisus	*Acc nis*	0	1	0	1
Anthus campestris	*Anth cam*	0	0	1	1
Anas platyrhynchos	*Ana pla*	0	1	0	1
Crex crex	*Cred crex*	0	1	0	1
Corvus monedula	*Cor mon*	0	0	1	1
Streptopelia turtur	*Stre tur*	0	1	0	1
Sylvia curruca	*Syl cur*	0	0	1	1
Acrocephalus schoenobaenus	*Acr sho*	1	0	0	1
Cyanistes caeruleus	*Cya cae*	0	1	0	1
Sylvia atricapilla	*Syl atr*	0	0	1	1
Phoenicurus ochruros	*Pho och*	0	0	1	1
Parus major	*Par maj*	0	1	0	1
No. of individuals		**103**	**155**	**188**	**446**
No. of species		**22**	**33**	**34**	**54**

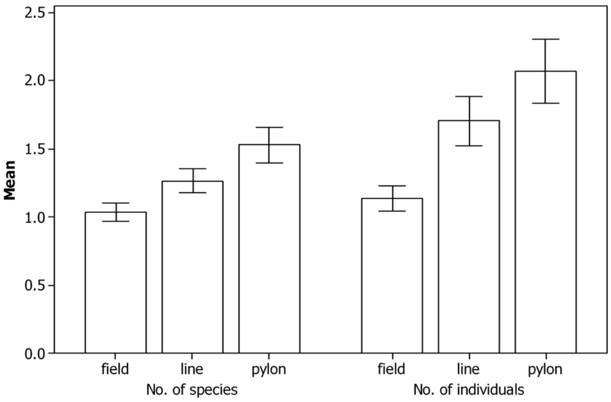

Figure 1 Mean (±SE) number of species and mean number of individuals for three habitats: field, line, and pylon (n = 91 in each category). Differences were statistically significant for both comparisons (Friedman ANOVA, respectively: $H = 8.77$, $P = 0.012$, and $H = 9.36$, $P = 0.009$).

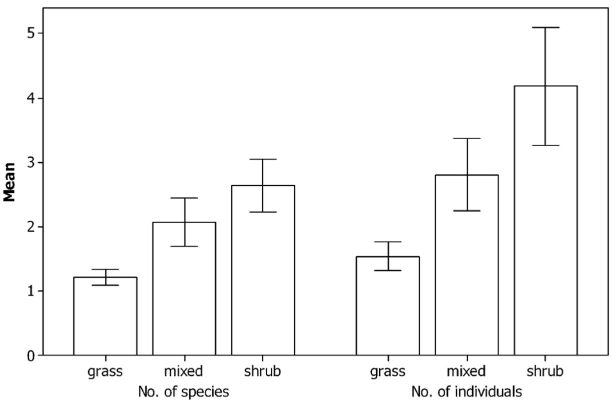

Figure 2 Mean (±SE) number of species and mean number of individuals for three vegetation types under pylons: grass (n = 65), mixed (n = 15), and shrub (n = 11). Differences were statistically significant for both comparisons (Kruskal-Wallis ANOVA, respectively: $H = 12.99$, $P = 0.002$, and $H = 14.27$, $P = 0.001$).

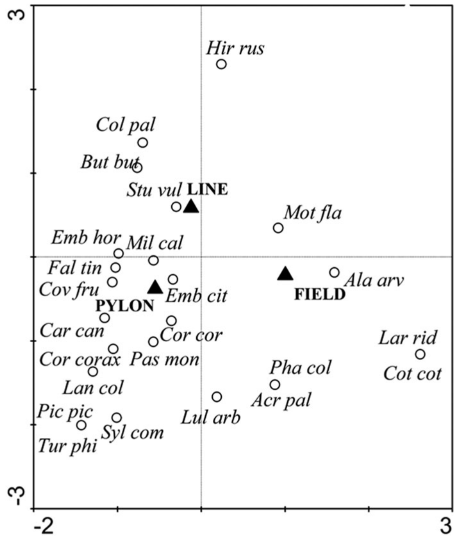

Figure 3 CCA ordination of farmland bird species in relation to three habitat types (triangles). Species are represented by abbreviated scientific names (see Table 1). Species occurring in less than five points have been omitted. The ordination axes explained 16% of the variation in species composition of which 100 % was explained by habitat type.

species richness were also associated with higher abundance (rank correlation $r_s = 0.946$, $P < 0.001$, $n = 273$).

The vegetation under pylons was grass and short vegetation for 65 (71%) patches, mixed for 15 (16%), and shrubs in 11 (12%). The number of bird species, as well as the number of individuals differed significantly between vegetation types (Figure 3).

The type of power line (110 or 220 kV) and the basal area of the pylon patch were not significantly related to either the number of species or individuals recorded there (Spearman rank correlation, all $P > 0.269$).

Discussion

We found that the presence of high-voltage pylons and power lines significantly improved bird species number, abundance, and diversity in an intensive agricultural landscape. Farmland birds are commonly used as an index of the strongly declining farmland biodiversity in Europe (e.g., Stoate *et al.* 2001; Donald *et al.* 2002). The populations of many species have been shown to suffer from intensification of land management, reduction of landscape heterogeneity, habitat loss, and fragmentation (review: Tryjanowski *et al.* 2011). Generally, it is believed that man-made structures (roads, wind farms, and settlements) negatively affect bird survival and diversity in farmland (Soini & Aakkula 2007; Clarke & White 2008). Our study is a rare example of an opposite but very instructive finding. Thus, the negative effect of such structures may be unexpectedly balanced by their benefits for many taxa living in a changing agricultural landscape (e.g, *L. collurio, S. communis, E. citrinella,* and *M. calandra*), because these species may use shrubs and grass patches developing under pylons for nesting and foraging. Hence, this produces a paradox for conservation, since pylons may both directly and indirectly benefit many declining farmland bird species. Further studies are necessary to disentangle the question whether it is the pylons themselves or only the shrubs in the marginal habitat under pylons that are the key factor responsible for the positive effect on bird species richness and abundance.

However, the negative effects of electricity power lines on birds must also be taken into account. Pylons and power lines cause fatalities to birds through collisions (Savereno *et al.* 1996; Bevanger 1998; Martin & Shaw

2010), electrocution (Janss 1998, 2000; Infante & Peris 2003; Jenkins *et al.* 2010), and generation of electromagnetic fields that affect avian physiology (immune system and embryodevelopment) as well as behavior (Fernie & Reynolds 2005). We should also consider the effect on flight behavior (particularly negative in large birds; Faanes 1987; Raab *et al.* 2010) and habitat loss due to clearance for power lines. Moreover, some bird species may respond behaviorally to pylons by avoiding them (Naugle *et al.* 2011). However, there are a growing number of methods and safety devices that minimize collision and electrocution risk (e.g., Harness & Carlton 2001; Barrientos *et al.* 2011; Kaługa *et al.* 2011).

Our study is the first step to better understand the potential beneficial role of electricity pylons for declining farmland birds. So, how can electricity pylons be beneficial to birds? First, the structures of pylons and/or power lines can be directly used by birds as nest sites, song posts, as well as for perching and resting (Bevanger 1994; Janss 1998; Janss 2000; Garrido & Fernandez-Cruz 2003; Haas & Nipkow 2006). Second, pylons can create habitat patches around their base that can be valuable, especially in an open, intensive landscape. Such patches are unlikely to exist within crops except under pylons. It is likely that unfarmed patches under pylons offer habitat for nesting, foraging, and resting for many species. This is supported by the fact that birds in our study farmland differed significantly, not only between the three habitat categories, but also with respect to different vegetation types under pylons. Moreover, bird species richness and abundance were significantly higher in patches under the electricity lines in comparison with patches on open fields, probably because even the lines are used by birds as perching or resting sites.

Therefore, the effect of pylons and lines is partly analogous to the role of trees spread across an open agricultural landscape. Orłowski & Nowak (2007) showed that even single trees add significantly to local biodiversity in intensive farmland.

However, we should also consider that electricity pylons may be an ecological trap. Pylons built in open farmland serve as artificial perches: for resting and searching for prey by various bird species, including nest predators and predators of fledglings and adults (Wolff *et al.* 1999; Tryjanowski 2001). In addition, red foxes *Vulpes vulpes* may have dens under pylons, and old raven nests may be occupied by kestrels *Falco tinnunculus*, and both species negatively affect small birds in farmland (Nordahl & Korpimäki 1998; Tryjanowski *et al.* 2002). Accordingly, breeding passerines should avoid the vicinity of pylons (Lima & Dill 1990). However, this was not the case in our study. We suggest that small passerines would benefit from breeding near raven nests because ravens actively discourage diurnal birds of prey, other corvids, and even predatory mammals (Tryjanowski 2001). Inevitably, more thorough studies that would include estimates of nest and chick survival as well as predation rate are necessary to assess the possible role of predation on birds using habitats under electricity pylons.

There are hundreds of thousands of pylons in Europe and some may provide valuable habitats at their base, especially in intensive landscapes. Therefore, we predict, but cannot yet test, that the positive effect of pylons will be higher in the more intensive farmland of Western Europe than the more traditional farmland of Eastern Europe (see Tryjanowski *et al.* 2011). The total length of electricity lines (equal to or over 110 kV) in Poland is 13,294 km (PSE 2010). Our study showed that pylons positively affect a number of species that show a strong decline in Poland and across Europe (Tryjanowski 2000; Donald *et al.* 2002): for example, hooded crow *Corvus corone*, great grey shrike *Lanius excubitor*, ortolan bunting *Emberiza hortulana*, whinchat *Saxicola rubetra*, tree sparrow *Passer montanus*, and linnet *Carduelis cannabina*. Therefore, habitat patches under pylons may contribute greatly to the protection of endangered species in European farmland. However, in order for pylons to produce a net benefit, it is essential to ensure that safety devices are in place to minimize the risks of collision and electrocution.

Our data were collected during one breeding season and did not cover potential year-to-year variation in bird assemblages. However, it is difficult to imagine that our general findings would differ substantially between years (our unpublished preliminary observations from earlier years showed a similar pattern to that found in this study). Moreover, the weather conditions in 2011 were average for the area. Furthermore, our study region is similar to intensive farmland in western Europe; thus, comparable effects are expected in those countries.

Conservation applications

Our results offer a counter argument to the generally accepted view of the negative impact of power lines on bird populations. Vegetation patches under pylons may play an important role for bird diversity and, together with the pylon structure, constitute landscape features that may be managed to increase bird species richness and abundance in intensive farmland. Even though the size of the area under pylons was a nonsignificant factor in the analyses, we believe that if they were made larger, this would be more beneficial for birds and other taxa. This is an action quite easy to achieve by leaving wider unfarmed and unmanaged strips around the base of pylons. Such enlarged areas under pylons would probably provide more resources (nesting sites, shelter, and food). Weeds and shrubs could be encouraged to attract insects (food resource for some birds) and to provide shelter and nesting sites. Our results provide some recommendations for land planners and managers about how to thread new electricity power lines through the landscape. Land planners may place power lines within large fields with a low number of natural elements (e.g., trees and field margins). Such planning would represent a win-win strategy for both birds and from the biodiversity conservation point of view.

Acknowledgments

We would like to thank all landowners for access to the fields and to A. Wuczynski and three referees who critically commented on a previous version of the manuscript. THS acknowledges the support of the Technische Universität München – Institute for Advanced Study, funded by the German Excellence Initiative. Z. M. Rosin was supported by a scholarship from the Adam Mickiewicz University (AMU) Foundation in Poznań in 2012.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Figure S1. Differences in numbers of bird species and individuals by habitat type. Habitat types were significantly different ($P < 0.05$), which are indicated by an asterisk.

Figure S2. Differences in numbers of bird species and individuals by vegetation cover under pylons. Significant differences ($P < 0.05$) are indicated by an asterisk.

References

Báldi, A., Batáry, P. & Erdős, S. (2005) Effects of grazing intensity on bird assemblages and populations of Hungarian grasslands. *Agric. Ecosyst. Environ.*, **108,** 251-263.

Balmori, A. (2005) Possible effects of electromagnetic fields from phone masts on a population of white stork (*Ciconia ciconia*). *Electromagn. Biol. Med.*, **24,** 109-119.

Barrientos, R., Alonso, J.C., Ponce, C. & Palacin, C. (2011) Meta-analysis of the effectiveness of marked wire in reducing avian collisions with power lines. *Conserv. Biol.*, **25,** 893-903.

Benton, T.G., Vickery, J.A. & Wilson, J.D. (2003) Farmland biodiversity: is habitat heterogeneity the key? *Trends Ecol. Evol.*, **18,** 182-188.

Bevanger, K. (1994) Bird interactions with utility structures – collision and electrocution, causes and mitigating measures. *Ibis*, **136,** 412-425.

Bevanger, K. (1998) Biological and conservation aspects of bird mortality caused by electricity power lines: a review. *Biol. Conserv.*, **86,** 67-76.

Bibby, C.J., Burgess, N. & Hill, N.D. (1992) *Bird census techniques*. Academic Press, London.

Clarke, D.J. & White, G.J. (2008) Towards ecological management of Australian powerline corridor vegetation. *Land. Urban Plan.*, **86,** 257-266.

Donald, P.F., Pisano, G., Rayment, M.D. & Pain, D.J. (2002) The Common Agricultural Policy, EU enlargement and the conservation of Europe's farmland birds. *Agric. Ecosys. Environ.*, **89,** 167-182.

Elphick, C.S. (2008) How you count counts: the importance of methods research in applied ecology. *J. Appl. Ecol.*, **45,** 1313-1320.

Faanes, C.A. (1987) *Bird behavior and mortality in relation to power lines in prairie habitats*. Fish and Wildlife Technical Report No. 7.

Fernie, K.J. & Reynolds, S.J. (2005) The effects of electromagnetic fields from power lines on avian reproductive biology and physiology: a review. *J. Toxicol. Environ. Health, B.*, **8,** 127-140.

Garrido, J.R., Fernandez-Cruz, M. (2003) Effects of power lines on a White Stork Ciconia ciconia population in central Spain. *Ardeola.*, **50,** 191-200.

Gregory, R.D., Gibbons, D.W. & Donald, P.F. (2004) Bird census and survey techniques. Pages 17-56 in W.J. Sutherland, I. Newton, R.E. Green, editors. *Bird ecology and conservation; a handbook of techniques*. Oxford University Press, Oxford.

Haas, D. & Nipkow, M. (2006) *Caution: electrocution! Suggested practices for bird protection on power lines*. NABU-German Society for Nature Conservation, Bonn.

Harness, R.E. & Carlton, R. (2001) New solutions for bird collision and electrocution outage problems. *Power Eng. Soc. Winter Meet.*, **1,** 341-354.

Infante, O. & Peris, S. (2003) Bird nesting on electric power supports in northwestern Spain. *Ecol. Eng.*, **20,** 321-326.

Janss, G.F.E. (1998) Nests of white storks on electric utility towers. *Wildlife Soc. B.*, **26,** 274-278.

Janss, G.F.E. (2000) Avian mortality from power lines: a morphologic approach of a species-specific mortality. *Biol. Conserv.*, **95,** 353-359.

Janss, G.F.E. & Ferrer, M. (1999) Mitigation of raptor electrocution on steel power poles. *Wildl. Soc. Bull.*, **27,** 263-273.

Jenkins, A.R., Smallie, J.J. & Diamond, M. (2010) Avian collision power line: a global review of causes and mitigation with a South Africa perspective. *Bird Conserv. Int.*, **20,** 263-278.

Kaługa, I., Sparks, T.H. & Tryjanowski, P. (2011) Reducing death by electrocution of the white stork *Ciconia ciconia*. *Conserv. Lett.*, **4,** 483-487.

Leps, J. & Smilauer, P. (2003) *Multivariate analysis of ecological data using CANOCO*. Cambridge University Press, Cambridge, UK.

Lima, S.L. & Dill, L.M. (1990) Behavioural decisions made under the risk of predation: a review and prospectus. *Can. J. Zool*. **68,** 619-640.

Martin, G.R. & Shaw, J.M. (2010) Bird collisions with power lines: failing to see the way ahead? *Biol. Conserv*., **143,** 2695-2702.

Naugle, D.E., Doherty, K.E., Walker, B.L., Holloran, M.J. & Copeland, H.E. (2011) Energy development and Greater Sage-Grouse. *Stud. Avian Biol*., **38,** 489-504.

Norrdahl, K. & Korpimäki, E. (1998) Fear in farmland: how much does predator avoidance affect bird community structure? *J. Avian Biol*., **29,** 79-85.

Orłowski, G. & Nowak, L. (2007) The importance of marginal habitats for the conservation of old trees in agricultural landscapes. *Land. Urban Plan*., **79,** 77-83.

PSE Operator S.A. (2010) Polish power system. Annual Report 2010. http://www.pse-operator.pl/uploads/kontener/raport_pse_2010_en.pdf (access date: 04.03.2012)

Raab, R., Spakovszky, P, Julius, E., Schütz, E. & Schulze, C.H. (2010) Effects of power lines on flight behavior of the West-Pannonian Great Bustard *Otis tarda* population. *Bird Conserv. Int*., **1,** 1-14.

Savereno, A.J., Savereno, L.A., Boettcher, R. & Haig, S.M. (1996) Avian behavior and mortality at power lines in coastal South Carolina. *Wild. Soc. Bull*., **24,** 636-648.

Soini, K. & Aakkula, J. (2007) Framing the biodiversity of agricultural landscape: the essence of local conceptions and constructions. *Land Use Policy*, **24,** 311-321.

Stoate, C., Boatman, N.D., Borralho, R.J., Carvalho, C.R., Snoo, G.R. & Eden, P. (2001) Ecological impacts of arable intensification in Europe. *J. Environ. Manag*., **63,** 337-365.

Surmacki, A. & Tryjanowski, P. (1999) Efficiency of the line transect and point count method in agricultural landscape of western Poland. *Vogelwelt*, **120,** 201-203.

Tryjanowski, P. (1999) Effect of habitat diversity on breeding birds: comparison of farmland bird community in the region of Wielkopolska (W. Poland) with relevant data from other European studies. *Polish J. Ecol*., **47,** 153-174.

Tryjanowski, P. (2000) Changes in breeding bird populations of some farmland birds in W Poland in relation to changes in crop structure, weather conditions and number of predators. *Folia Zool*., **49,** 39-51.

Tryjanowski, P. (2001) Proximity of raven (*Corvus corax*) nest modifies breeding bird community in an intensively used farmland. *Ann. Zool. Fennici*, **38,** 131-138.

Tryjanowski, P., Gołdyn, B. & Surmacki, A. (2002) Influence of the red fox (*Vulpes vulpes*) on distribution and number of breeding birds in an intensively used farmland. *Ecol. Res*., **17,** 395-399.

Tryjanowski, P., Hartel, T., Baldi, A. *et al*. (2011) Conservat-ion of farmland birds faces different challenges in Western and Central-Eastern Europe. *Acta Ornithol*., **46,** 1-12.

Tryjanowski, P., Kosicki, J.Z., Kuźniak, S. & Sparks, T.H. (2009) Long-term changes in, and breeding success in relation to, nesting structures used by the white stork *Ciconia ciconia*. *Ann. Zool. Fenn*., **46,** 34-38.

Walker, M.J., Dover, J.W., Hinsley, S.A. & Sparks, T.H. (2005) Birds and green lanes: breeding season bird abundance, territories and species richness. *Biol. Conserv*., **126,** 540-547.

Wolff, J., Fox, T., Skillen, R. & Wang, G. (1999) The effects of supplemental perch sites on avian predation and demography of vole populations. *Can. J. Zool*., **77,** 535-541.

Wuczyński, A., Kujawa, K., Dajdok, Z. & Grzesiak, W. (2011) Species richness and composition of bird communities in various field margins of Poland. *Agric. Ecosyst. Environ*., **141,** 202-209.