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Estimating the indirect impact of wind farms on breeding bird assemblages: a case study in the central Apennines

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In 2011 and 2012 we carried out a monitoring study to evaluate the indirect impacts of a wind farm on the breeding bird assemblages in a high-altitude secondary prairie area of the central Apennines (Italy). We used the point count method to compare the breeding birds at species and assemblage level, using the wind farm area (36 windmills) as treatment and an equivalent habitat surface as control. We did not observe any significant difference between treatment and control areas at species level (25 species detected, seven of conservation concern at European level), in terms of species abundance frequency, and at assemblage level, in terms of species richness or assemblage structure (k-dominance plots), even if lower evenness values were detected in the control sites. Our preliminary results gave no evidence of an indirect impact of the wind farm on breeding bird assemblages, mainly composed of small passerines, in these mountain ecosystems. However, further studies should be performed to deepen the relationships between indirect impact of wind farms and site-specific characteristics.

Keywords: bird assemblage; indirect impact; point count method; k-dominance plot; wind farm

Notes on contributors

Corrado Battisti is a naturalist manager in an operational park office and contracting Professor in Applied Ecology (Department of Biology, University of Rome Three). His scientific activity is reported in about 100 papers either on peer-reviewed scientific or technical journals. The research focused on community (animal) ecology, trophic systems, applied ecology (habitat fragmentation, disturbance ecology, landscape planning and wildlife management).

Daniel Franco deepened the research fields of landscape ecology, environmental economy, environmental assessment and restoration. He had a class on Landscape Ecology at the Venice University for more than a decade and classes and workshops on sustainability development and natural resource management in several other universities.

Claudio Norscia is an expert ornithologist with a background on the birds linked to high altitude Mediterranean ecosystems.

Pasquale Santone is an expert ornithologist with a large amount of experience in ecology and conservation of bird communities of central Italy.

Christiana Soccini is an environmentalist working at the Studio associato Natura Arcadia. She collaborates in environmental projects promoted by Parks and Natural Reserves, Italian and foreign universities, museums and public agencies, associations, and scholastic institutes.

Vincenzo Ferri, biologist, is an expert zoologist with a wide background on entomology, erpetology and mammology (especially Chiroptera). He has worked at Studio associato Natura Arcadia (Scientific Researcher) and studied at University of Milan with a long experience in the Zoological Museum of Milan. His scientific activity is reported by about 100 papers on scientific journals. His research focuses also on bat behavior and ecology and on the impact of wind farms on vertebrates and invertebrates.

Introduction

High-altitude ecosystems are often characterised by xeric–mesic secondary prairies with a scattered shrubby component, and with drought, cold and grazing as main stress/disturbance factors (see Wiens 1976; Wiens 1989; Catorci et al. 2012; De Sillo et al. 2012). In the central Apennines (Italy) these plant communities support particular bird assemblages, generally structured in response to environmental constraints such as altitude, vegetation structure and internal heterogeneity (Vuerich et al. 2006; Battisti et al. 2010; Vignoli et al. 2010).

These high-altitude ecosystems often correspond to windy mountain ridges that are favourite locations for wind farm construction, which may structurally and functionally affect a large set of local abiotic and biotic components at multiple spatial and temporal scales (e.g.: 1992: Winkelman 1992; Martì & Barrios 1995; Langston & Pullan 2003). The impact (direct, indirect or potential) on the biotic components has been analysed for birds and bats in particular, showing a strong site- and species-specific response (Trille et al. 2008; Jain et al. 2010; Huso 2010; Johnson and Erikson 2010; Ferrer et al. 2012; Langston & Pullan 2003 for a review). It is also known that some ecologically characterized bird assemblages (e.g. soaring and migrant large raptors) are particularly sensitive to direct impacts of wind turbines for their

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intrinsic eco-behavioural traits (Zieliński et al. 2009; Noguera et al. 2010).

Wind farm-related infrastructures (windmills, roads, electric lines) may also indirectly impact species, as they change their habitats and consequently affect density and frequency at the species level, as well as richness, diversity and evenness at the assemblage level. Studies on the indirect impact of wind farms on breeding bird assemblages are lacking, at least in the Mediterranean area.

The aim of this paper is to estimate the indirect impact of a high altitude wind farm on a breeding bird community of the central Apennine (Italy). The work is based on a large sampling scheme (2011–2012 ex-post monitoring) designed to give estimations of the indirect impact by means of the comparison of composition and structure of the bird assemblages in comparable impacted ('treatment', i.e. area with windmills) and non-impacted ('control') habitats.

Materials and methods

Study area

The study area is located in the Collarmele Municipality (Marsica District; Province of L'Aquila; central Italy) and is characterized by high-altitude secondary prairies (mesic grasslands with at least 90% herbaceous cover) of the central Italy Apennines (Santone & Di Carlo 1994; Pellegrini et al. 2007). Shrubs or trees are relatively rare and mostly represented by an artificial pine stand (*Pinus nigra*). The wind farm in the studied area is composed of 36 three-bladed windmills (type: VESTAS 2MW and GE) located between 800 and 1300 metres of altitude. The windmills, working since 2007, have the following characteristics: rotor height between 78 and 80m from the ground; length of the individual blades: 40m; overall height affected: 118–120m; area swept by the blades: between 5000 and 5200m^2. Two meteorological towers (50m high) are also present in the surroundings of the study area.

During the study (May–June 2011 and 2012; see below) the turbines were active each day (approximately 9–14 hours/day: from 9–11 a.m. to 6.–11 p.m.): consequently, disturbance caused by these structures on bird assemblages may be comparable within each year and between years.

Sampling design

In the studied area, the plant communities are characterized by a simple vertical complexity that allows long-distance bird detection and the use of direct visual methods. Therefore we used the point count method (Bibby et al. 2000; Sutherland 2006) both in the "treatment" (i.e. a sub-area with windmills) and in "control" sites (i.e. a neighbouring sub-area comparable for habitat type) to survey the bird assemblages, even if it is more efficient for small/frequent breeding birds than for larger/less frequent breeding, vagrant or migrant birds (e.g. raptors), due to the limited time span of the observation sessions.

Consequently, the results of this study are not applicable to these latter birds. For the treatment sites we established a set of point counts (hereafter PCs) located near a random sample of wind turbines. For each PC we set an equivalent (in terms of vegetation habitat and altitude) control site at least 400 metres distant from the corresponding windmill PC. We located a total of 40 PCs in both years (2011 and 2012).

Sampling was carried out from May to June, corresponding to the breeding bird season at this latitude and altitude, by means of two 10-minute-long sessions in each PC from 9 a.m. to 2 p.m. (2011: total sampling 400 minutes; 2012: total sampling 400 minutes).

In each PC, we sampled the number of individuals of each breeding species (n) and the total amount of individuals (N), both in the treatment and the control sites. From these two sessions we selected the higher registered values for each species, to account for the method's underestimation in bird detection (Sutherland 2006).

For each assemblage (control and treatment in the two years) we obtained: (1) the relative frequency (dominance; fr_i, as n/N) of each species in the bird assemblage, considering dominant species the species with $fr_i > 0{,}05$); (2) the species richness (S); (3) the Simpson diversity index, calculated as $D_S = 1–D$ where D is $\sum fr_i{,}^2$; (4) the Simpson's measure of evenness, calculated as $E_{1/D} = (1/D)/S$ (Krebs 1999). We used the Simpson index because its meaningfulness and robustness are less sensitive to species richness and independent of the sample size (Lande 1996; Magurran 2004).

We controlled for data reliability by means of: (1) randomizing the position of the PCs in the study area, (2) stratifying the data for two sampling sites (control vs. treatment), (3) spacing the PCs to account for the data independence and pseudoreplication (at least 400 metres between each one), (4) assuming a similar species detectability due to similar visual conditions (open habitats, high detectability of bird individuals; Sutherland 2006).

We analysed the data on species frequency using a k-dominance plot (Lambshead et al. 1983). In this analysis the cumulative (relative) abundance of species in an assemblage (y-axis) is plotted against log-species rank (x-axis). We used this approach because it can discriminate among assemblages exposed to different levels of disturbance (Platt et al. 1984). If the curve representing one assemblage lies entirely above another, the first assemblage can be considered less diverse and more affected by human activity than the second one, while curves that cross over may suggest a lack of effect of disturbance (Magurran 2004 for review). Despite their strong informational power, k-dominance plots have been only occasionally performed for bird assemblages (e.g., Preston 1960).

We used AERC-TAC (2003) for bird taxonomic nomenclature (Fracasso et al. 2009). To assess the differences between species richness and relative frequency of the species in treatment and control areas, we performed a χ^2 test. Alfa was set to 0.05.

Results

We detected 630 individuals (242 in 2011 and 388 in 2012) belonging to 25 breeding bird species (21 in 2011

Table 1. Structure of the breeding bird assemblages in treatment and control areas (2011 and 2012). Number of individuals (n) correspond to the maximum value between the two sampling sessions; fr_i = relative frequencies. Conservation status: 1: SPEC (Species of European Conservation Concern) 3, 2: SPEC 2; 3: Annex 79/409/CEE Birds Directive. In bold the dominant species (fr_i >0,05). Statistic (differences between relative frequencies: χ^2 test): *Alauda arvensis*: 2011: $\chi^2 = 1.168$, p = 0.28; 2012: $\chi^2 = 0.353$, p = 0.55; *Anthus campestris*: $\chi^2 = 1.344$, p = 0.246; 2012: $\chi^2 = 1.454$, p = 0.23, *Oenanthe oenanthe*: $\chi^2 = 0.303$, p = 0.582; 2012: $\chi^2 = 1.516$, p = 0.22; *Carduelis cannabina*: $\chi^2 = 2.432$, p = 0.119; 2012: $\chi^2 = 0.022$, p = 0.82.

	2011						2012					
number of point count	10		10		20		11		9		20	
	treatment		control		total		treatment		control		total	
species	n	fr_i	n	fr_i	n	fr_i	n	fr_i	n	fr_i	n	fr_i
Buteo buteo	1	0.010			1	0.004						
Falco tinnunculus [1]			4	0.028	4	0.017	4	0.021	2	0.010	6	0.015
Lullula arborea [2, 3]	1	0.010	3	0.021	4	0.017	6	0.031	**10**	**0.051**	16	0.041
Alauda arvensis [1]	**31**	**0.307**	**59**	**0.418**	**90**	**0.372**	**46**	**0.240**	**55**	**0.281**	**101**	**0.26**
Anthus campestris [1, 3]	**14**	**0.139**	**11**	**0.078**	**25**	**0.103**	**26**	**0.135**	**17**	**0.087**	**43**	**0.111**
Anthus spinoletta	3	0.030	6	0.043	9	0.037			2	0.010	2	0.005
Erithacus rubecula							1	0.005	1	0.005	2	0.005
Saxicola torquatus			1	0.007	1	0.004						
Oenanthe oenanthe [1]	**10**	**0.099**	**19**	**0.135**	**29**	**0.120**	**20**	**0.104**	**12**	**0.061**	**32**	**0.082**
Turdus viscivorus							1	0.005			1	0.003
Turdus merula	2	0.020	1	0.007	3	0.012	3	0.016	6	0.031	9	0.023
Sylvia atricapilla	1	0.010	2	0.014	3	0.012	9	0.047	6	0.031	15	0.039
Regulus ignicapilla			1	0.007	1	0.004						
Periparus ater			1	0.007	1	0.004	2	0.010	3	0.015	5	0.013
Cyanistes caeruleus			1	0.007	1	0.004	4	0.021	6	0.031	10	0.026
Parus major			1	0.007	1	0.004						
Lanius collurio									1	0.005	1	0.003
Corvus cornix	**6**	**0.059**	3	0.021	9	**0.037**	**19**	**0.099**	**18**	**0.092**	**37**	**0.095**
Passer domesticus									2	0.010	2	0.005
Fringilla coelebs	3	0.030	2	0.014	5	0.021	26	0.135	26	0.133	52	0.134
Serinus serinus	2	0.020			2	0.008	5	0.026	6	0.031	11	0.028
Carduelis chloris	1	0.010	1	0.007	2	0.008	1	0.005	3	0.015	4	0.01
Carduelis carduelis	**7**	**0.069**	**8**	**0.057**	**15**	**0.062**	3	0.016	5	0.026	8	0.021
Carduelis cannabina [2]	**13**	**0.129**	**8**	**0.057**	**21**	**0.087**	**10**	**0.052**	**12**	**0.061**	**22**	**0.057**
Emberiza calandra [2]	**6**	**0.059**	**9**	**0.064**	**15**	**0.062**	6	0.031	3	0.015	9	0.023
N	101		141	1	242		192		196		388	

and 21 in 2012; Table 1). Of these, seven species were of conservation concern (Species of European Conservation Concern; Tucker & Heath 1994; BirdLife International 2004; included in Annex I of 79/409/CEE Birds Directive; Table 1).

A total of four species were dominant (fr_i>0.05) in 2011 and 2012 both in treatment and control sites (*Alauda arvensis*, *Anthus campestris*, *Oenanthe oenanthe* and *Carduelis cannabina*). No significant differences in frequency between treatment and control areas were observed (χ^2 test; Table 1).

At the assemblage level, species richness did not significantly differ between treatment and control area in either 2011 ($\chi^2 = 0.08$, p = 0.780) or 2012 ($\chi^2 = 0$, p = 0.991).

In all assemblages the Simpson diversity index ranged between 0.8 and 0.9, and Simpson evenness index showed lower values in the control sites in both 2011 and 2012 (Table 2).

The k-dominance plots showed that the treatment and control assemblage curves crossed over in the two monitoring years (Figure 1).

Table 2. Ecological parameters of the breeding bird assemblages both for treatment and control communities: S = species richness; D_S = Simpson diversity index; $E_{1/D}$ = Simpson evenness index.

	2011			2012		
	treatment	control	total	treatment	control	total
S	15	19	21	18	20	21
D_S	0.845	0.786	0.817	0.876	0.872	0.876
$E_{1/D}$	0.431	0.246	0.260	0.449	0.391	0.384

Discussion

The studied breeding bird assemblages are typical of the medium–high altitude open mountain ecosystems commonly found in the Mediterranean areas (Santone & Di Carlo 1994; Vuerich et al. 2006; Pellegrini et al. 2007). The low vertical complexity and horizontal heterogeneity of these ecosystems is known to affect bird assemblage complexity (Wiens 1989) and can explain the low

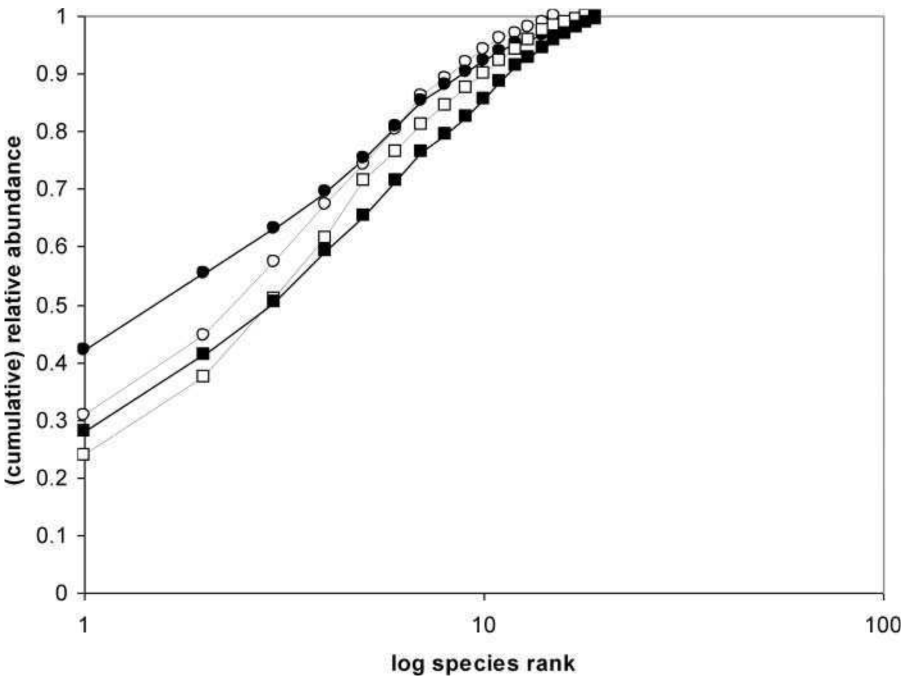

Figure 1. K-dominance plot for the treatment and control breeding bird assemblages in high altitude secondary prairies of central Apennines. Black circles with bolded line: 2011 treatment (wind farm area); white circles with continuous line: 2012 control; black squares with bolded line: treatment (wind farm area); white squares with continuous line: control.

diversity values registered here as well as in other sites in the same Apennine areas (Mancinelli et al. 2009; Battisti et al. 2010; Vignoli et al. 2010). Despite these assemblages being poor in species richness, they are of high conservation concern (more than 50% of the species are included in the European Directive or SPEC annexes; BirdLife International 2004).

In this study we did not detect any indirect impact of wind farms on breeding birds, at either the species or the assemblage level. At the species level we did not observe differences in the relative frequencies of the four most abundant breeding bird species comparing treatment and control sites. At the assemblage level, although we observed lower evenness values in control sites in both years, the repeated crossing over of the treatment and control curves in the k-dominance plot suggests a substantial lack of stress at this hierarchical level (see Lambshead et al. 1983; Magurran 2004; Dornelas et al. 2011). Our results show that a wind farm located in this specific site condition (Mediterranean high-medium altitude secondary prairies) does not indirectly impact breeding birds, at least in the short–medium term.

These results are preliminary because they are limited to a short monitoring period (two years) and focused on small-sized breeding birds in the spring. Therefore, our results cannot exclude an indirect (e.g. for habitat change induced by wind farm) or direct impact (for collision with turbines) on other bird assemblage sub-groups (e.g. migrants or wintering raptors and/or other larger/less frequent breeding birds). Further studies should be focused on other phenological or taxonomical-characterized assemblages of these Mediterranean ecosystems, possibly for a longer monitoring period.

Despite these limitations, we can conclude that wind farms' indirect impact on birdlife is a very site-specific matter and that more research should be dedicated to better understanding the relationship between indirect impact and site-specific habitat/assemblage characteristics to produce a more general framework in supporting the planning and design of wind farms.

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References

AERC TAC, 2003. AERC TAC Checklist of bird taxa occurring in Western Palearctic Region, with distributional notes on subspecies – 15th Draft on line: http://www.aerc.be

Battisti C, Vignoli L, Bologna MA. 2010. Breeding birds in an Appennine massif (Majella, central Italy): Do "common species" could act as surrogate for characterize species richness and composition of the communities? Ekológia (Bratislava). 29:207–218.

Bibby CJ, Burgess ND, Hill DA, Mustoe S. 2000. Bird Census Techniques. 2nd ed. London: Academic Press.

Birdlife International 2004. Birds in Europe: population estimates, trends and conservation status. Cambridge, UK: Birdlife International. Birdlife Conservation Series 12.

Catorci A, Ottaviania G, Vitasović Kosićb I, Cesaretti S. 2012. Effect of spatial and temporal patterns of stress and disturbance intensities in a sub-Mediterranean grassland. Plant Biosystems. 2:352–367.

De Sillo R, De Sanctis M, Bruno F, Attorre F. 2012. Vegetation and landscape of the Simbruini mountains (Central Apennines). Plant Sociology. 1:3–64.

Dornelas M, Soykan CU, Ugland KI. 2011. Biodiversity and disturbance. In: Magurran A, McGill BJ, editors. Biological diversity. Frontiers in measurements and assessments. Oxford, New York: Oxford University press; p. 237–251.

Ferrer M, de Lucas M, Janss GFE, Casado E, Muñoz AR, Bechard MJ, Calabuig CP. 2012. Weak relationship between risk assessment studies and recorded mortality in wind farms. J Appl Ecol. 49:38–46.

Fracasso G, Baccetti N, Serra L. 2009. La lista CISO-COI degli Uccelli italiani parte prima: liste A, B e C. Avocetta Ital J Ornithol. 33:5–24.

Huso MMP. 2010. An estimator of wildlife fatality from observed carcasses. Environmetrics. 22:318–329.

Jain AA, Koford RR, Hancock AW, Zenner GG. 2010. Bat mortality and activity at a Northern Iowa wind resource area. Am Midl Nat. 165:185–200.

Johnson GD, Erickson WP. 2010. Avian, bat and habitat cumulative impacts associated with wind energy development in the Columbia Plateau Ecoregion of Eastern Washington and Oregon. Klickitat County Planning Department, Western EcoSystems Technology, Inc.

Krebs CJ. 1999. Ecological methodology. 2nd ed. New York: Harper & Row.

Lambshead PJD, Platt HM, Shaw KM. 1983. The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. J Nat Hist. 17:859–874.

Lande R. 1996. Statistics and partitioning of species diversity, and similarity among multiple communities. Oikos. 76:5–13.

Langston RHW, Pullan JD. 2003. Windfarms and birds: an analysis of the effects of windfarms on birds, and guidance on environmental assessment criteria and site selection issues. XXIII Meeting of Standing Committee, BirdLife International, RSPB; Strasbourg.

Magurran A. 2004. Measuring biological diversity. Malden, MA: Blackwell Publishing.

Mancinelli A, De Castro G, De Sanctis A, Posillico M. 2009. La comunità ornitica delle praterie d'altitudine di monte Greco, Appennino centrale. Atti XV Convegno italiano di Ornitologia, Alula. 16:366–368.

Martì MRE, Barrios J. 1995. Effects of wind turbine power plants on the avifauna in the campo de Gibraltar region. Madrid: Spanish Ornithological Society.

Noguera JC, Pérez I, Minguez E. 2010. Impact of terrestrial wind farms on diurnal raptors developing a spatial vulnerability index and potential vulnerability maps. Ardeola. 57: 41–53.

Pellegrini M, Antonucci A, Artese C, Carafa M, Cirillo M, De Sanctis A, Dundee V, Lalli G, Strinella E. 2007. Check-list degli uccelli d'Abruzzo. Riv ital Ornitol. 77:27–38.

Platt HM, Shaw KM, Lambshead PJD. 1984. Nematode species abundance patterns and their use in the detection of environmental perturbation. Hydrobiologia. 118:59–66.

Preston FW. 1960. Time and space and the variation of species. Ecology. 41:612–627.

Santone P, Di Carlo EA. 1994. Check-list degli Uccelli d'Abruzzo e Molise. Gli uccelli d'Italia. 19:25–38.

Sutherland WJ. 2006. Ecological Census Techniques. Massachussets: Blackwell Science.

Trille M, Liozon R, Talhoët S. 2008. Suivi ornithologique et chiroptérologique du parc éolién de Castelnau-Pégayrols. Bilan de la première année de suivi. LPO-AVEYRON, Paris.

Tucker GM, Heath MF. 1994. Birds in Europe Their conservation status. Birdlife Conservation Series. 3.

Vignoli L, Battisti C, Bologna MA. 2010. Landscape heterogeneity affects the use of sampling methods: a case study of bird communities in mountains of Central Italy. Rend Fis Acc Lincei. 21:315–322

Vuerich V, Bologna MA, Battisti C. 2006. Comunità ornitiche nidificanti in tre tipologie vegetazionali lungo un gradiente altitudinale nei monti Simbruini (Lazio, Appennini centrali) (Aves). Aldrovandia, Rivista Museo Civico Storia naturale di Roma. 2:49–53.

Wiens JA. 1989. The ecology of bird communities. Vol. 2. Processes and variations. Cambridge, UK: Cambridge studies in ecology, Cambridge University Press.

Wiens JA. 1976. Population responses to patchy environments. An Rev Ecol Evol Syst. 7:81–120.

Wiens JA. 1989. The ecology of bird communities. Cambridge studies in ecology, Cambridge University Press, Cambridge.

Winkelman JE. 1992. The impact of the Sep wind park near Oosterbierum (Fr.), the Netherlands, on birds, 1: collision victims. DLO Instituut voor Bos-en Natuuronderzoek. RIN-rapport 92/3. 4 volumes.

Zieliński P, Bela G, Marchlewski A. 2009. Report on monitoring of the wind farm impact on birds in the vicinity of Gnieźdźevo (gmina Puck, pomorskie voivodeship). Available on line.