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Analysis of wind farm effects on the surrounding environment: Assessing population trends of breeding passerines

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ABSTRACT

The main aim of this paper is to analyze the effect of wind farms on population trends of breeding passerines assessing between years changes in abundance of the bird species under examination. The surveys were realized in a pilot area 4 years before and 4 after the wind farm construction, by means of the point count method. The collected data were then statistically analyzed using TRIM (TRends & Indices for Monitoring data) software, developed for the analysis of count data obtained from monitoring wildlife populations. Then, in order to evaluate whether the obtained population trends were influenced by the presence of the wind farm, they were compared with the national trends of the same passerine species during the same period. The results showed that during the wind farm construction phase some species had a decreasing trends but all of them increased their trends when the wind turbines were operating.

1. Introduction

Since wind farms, together with other renewable energy sources, are a key mean of tackling climate change [1] and reducing greenhouse gases emission [2,3], their development globally provoke healthy effects on birds populations, whose geographical distribution is affected by climate changes [4]. On the other hand, wind farms could sometimes provoke potential risks to bird species which can be grouped into two main typologies: death through collision with turbine blades [5] and displacement through direct or indirect habitat loss [6].

Wind turbine collision risk, highly depending on the topography, turbine construction, and local bird species and behaviours, can be significantly reduced using models which take into account all of these factors [7]. Direct habitat loss is generally caused by the construction of the permanent infrastructures of the wind farm, such as access roads and wind turbine bases, while indirect habitat loss occurs if birds begin to avoid a wind farm surrounding areas changing their normal routes to roosting grounds or feeding. These impacts might be minimized adopting available mitigation measures and tools to aid avian conservation [8,9].

The impact of the wind farm on birds populations may thus be a reduction in local abundance by displacement of individuals to other areas which may cause loss of condition amongst the individuals and reductions in reproductive output [10].

In Italy, as in many other European countries, the number of wind farms has grown rapidly to meet EU targets of sourcing 20% of energy from renewable sources by 2020. Concerning the Italian studies on bird conservation in wind farm sites, the Italian Wind Energy Association ANEV (Associazione Nazionale Energia del Vento) and the environmentalist association Legambiente, with the collaboration of ISPRA (*Italian Institute for Environmental Protection and Research*) jointly instituted a National Wind and Wildlife Observatory in order to promote a wind energy development avoiding or minimising impacts on threatened species and their habitats, as well as supporting a correct diffusion of information based on real data.

Aiming to conciliate the development of the production of wind energy with the necessary protection, valorisation and safeguard of the environment, the Italian observatory founded a Scientific Committee of experts and academics who worked for the elaboration of a Protocol for Monitoring interactions between wind farms and birds and bats populations according to the latest scientific methods

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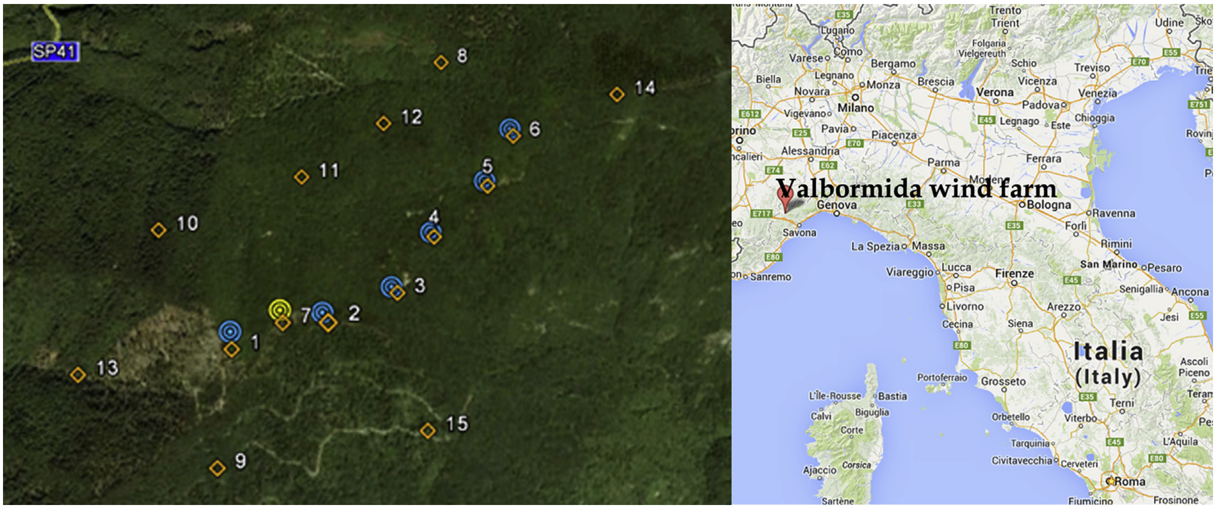

Fig. 1. Valbormida wind farm: 15 listening points (orange squares), six operational wind turbines (in blue) with one additional wind turbine (in yellow) whose construction is under evaluation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

internationally recognized. The Protocol contains technical and scientific information for planning and carrying out *ex-ante* and *ex-post* monitoring activities of birds and bats populations on and around wind farms. In particular, the protocol describes methods, materials and timing for the monitoring of the different species of birds and bats, considering also data gathering for the assessment of noise disturbance as well as the estimation of avian mortality calculating carcass removal time and the estimation of scavenging correction factor [11]. Moreover, promoting its application on the whole Italian territory, the use of the Protocol will allow the elaboration of a national database in order to compare data gathered with the same methodologies in different areas and periods. In fact, the implementation of long-term studies based on systematically collected data according to standardized protocols is crucial for a correct estimation of impact of wind parks on birds [12].

Studies of wind farm effects on breeding birds led to debatable results: a research conducted in upland wind farms in the UK highlights significant avoidance of otherwise apparently suitable habitat close to turbines [13]; other reliable studies suggest a low disturbance distance from the wind farm [14] or underline that wind farms may not necessarily result in declines in bird populations in the operational phase but may provoke more severe effects during the construction phase [6,15,16]. Moreover, comparing the number of birds killed per kilowatt-hour generated for wind electricity and fossil fuel power systems, a study [5] estimates that wind farms are responsible for between 0.3 and 0.4 fatalities per gigawatt-hour (GWh) of electricity while fossil fuel power stations are responsible for about 5.2 fatalities per GWh, caused by acid rain, mercury pollution, and climate change.

In the light of these considerations, the main aim of the research is to assess the potential impacts that a wind farm development may cause on the population trends of breeding passerines, using some methodologies described in the above mentioned Italian Protocol and used in previous scientific studies [10,17]. In particular,

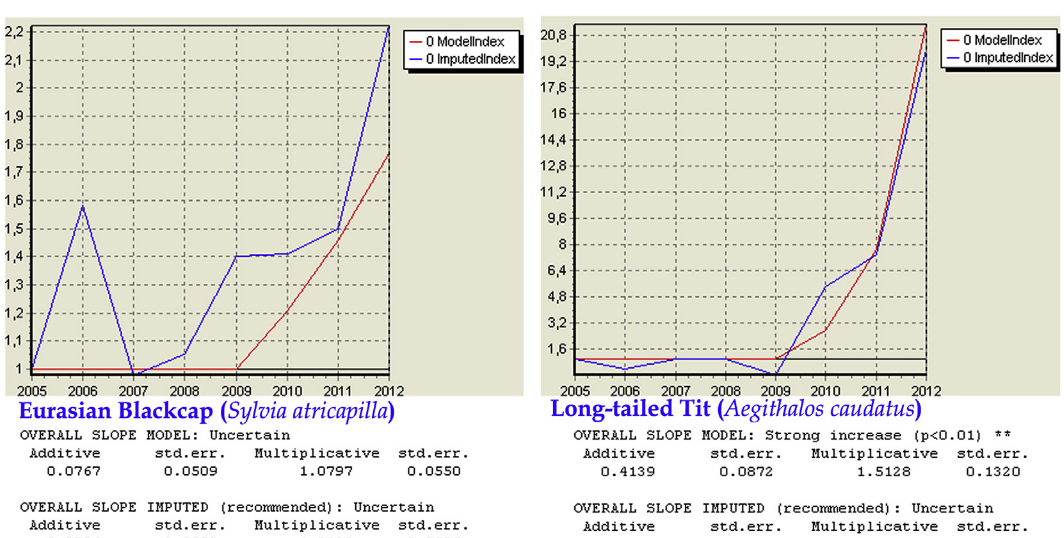

Fig. 2. Eurasian Blackcap and Long-tailed Tit population trends in the Valbormida wind farm.

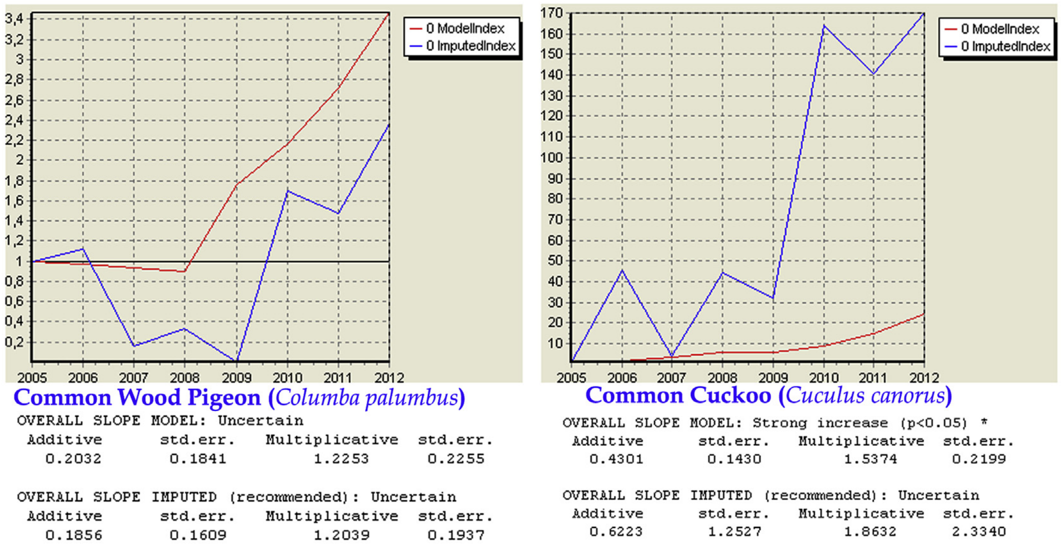

Fig. 3. Common Wood Pigeon and Common Cuckoo population trends in the Valbormida wind farm.

this research is focused on the assessment of direct and indirect habitat loss, analysing both the operational phase and the period of a wind farm construction.

2. Material and methods

2.1. Field data gathering

In order to evaluate wind farm possible effects on population trends of breeding passerines a case study area has been identified in the Valbormida wind farm located in Cairo Montenotte municipality, close to the Ligurian sea, in Italy (Fig. 1), which includes six turbines with a nominal power of 800 kW each.

Considering the biological diversity peculiarities of the surrounding area, about 2.5 Km away from the wind turbines, there is “Rocca dell'Adelasia” Site of Community Importance (SCI) of the Natura 2000 ecological network. Anyway, according to the Natura 2000 data form, this area includes endemic species and habitats listed in the annexes of the Council Directive 92/43/EEC; anyway no passerine or other bird populations are considered endangered.

Field data collection began in 2005 and lasted for 8 years until 2012; since Valbormida wind farm became operational in winter 2008, we obtained 4 years of data gathered before its construction and other four years of records when the turbines were operating. The data gathered in 2008 could be associated with the construction phase since its effects persist also during the following months.

Since vocalizations are an important source of evidence on the abundance of avian population, the technique used for passerine bird census was the point count surveys [18] widely used to estimate bird species richness and population trends counting songbirds [19,20].

In particular, 15 listening points, each at 300 m spacing, were selected within 1 Km from the centre of the wind farm, so as to avoid

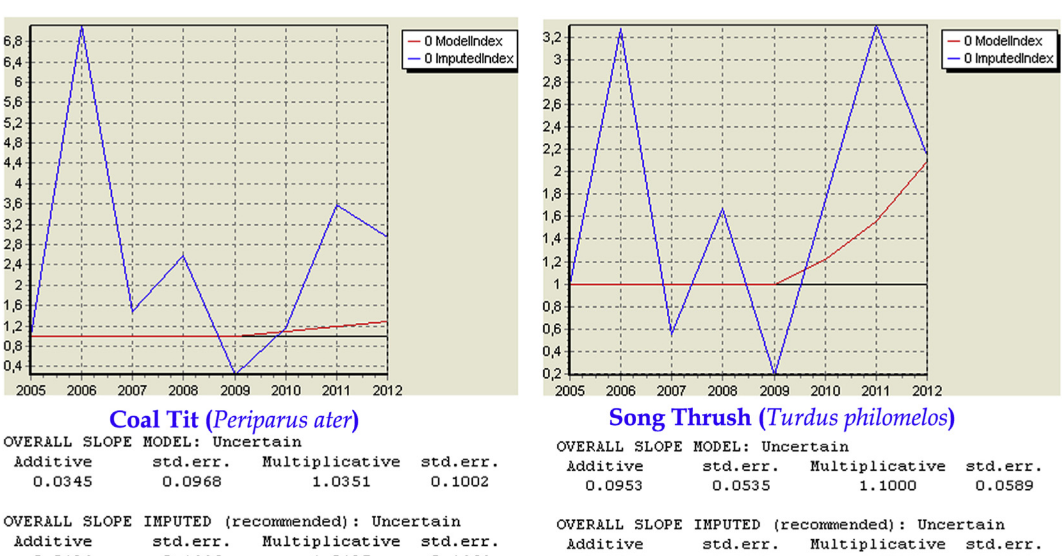

Fig. 4. Coal Tit and Song Thrush population trends in the Valbormida wind farm.

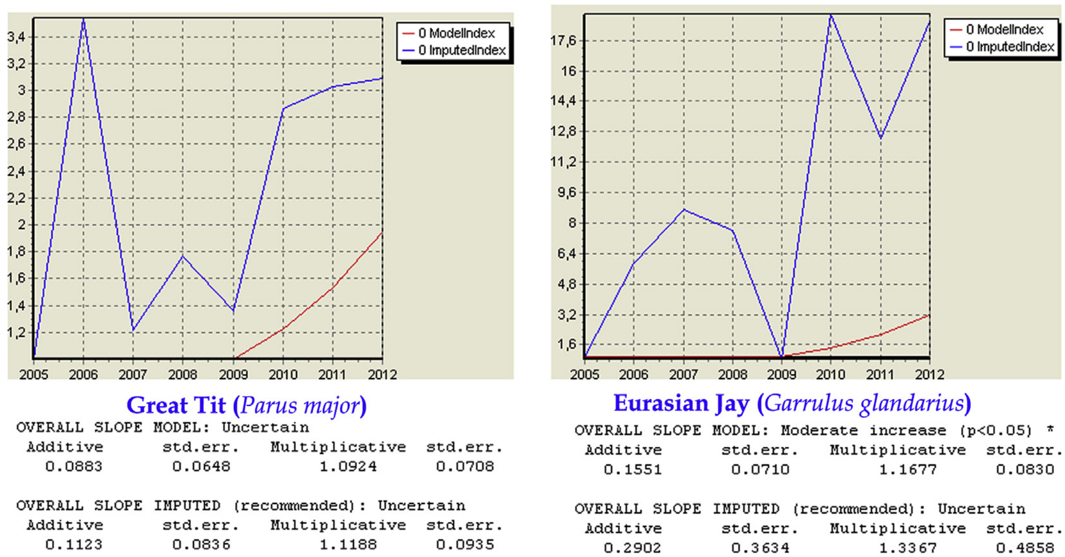

Fig. 5. Great Tit and Eurasian Jay population trends in the Valbormida wind farm.

the recount of individuals recorded in the adjacent listening points [21]. Each listening point was associated with a pair of coordinates, so as to accurately mapping the measurements (Fig. 1).

Birdsongs were recorded in mp3 format using a portable recorder connected to a satellite dish, which allowed the amplification of the sound signals of the individuals in the neighbourhood of about 100 m from the detector. Each recording was preceded by five minutes of silence to allow individuals disturbed by human presence to resume their normal activities.

The listening points of ten minutes each [22] were monitored by the two authors more experienced every three or four days between the beginning of May and the end of June, starting each survey 30 min before sunrise [23], in order to follow the circadian rhythms of the species. In fact, during the first hours of the day the activity singing of the passerine species is maximal. Then, all data collected were entered into a database.

2.2. Field data analysis for population trend assessment

Population trends of some nesting passerines species were assessed using TRIM (TRends & Indices for Monitoring data) software, developed for the analysis of count data obtained from monitoring wildlife populations [24]. TRIM is a widely used software with an efficient implementation of Poisson regression for estimating yearly indices and trends of the considered populations to analyse time-series counts (log-linear models) [25].

Therefore, TRIM programme allowed the assessment of between-year changes in abundance of the passerine species under survey; these changes are usually represented as indices, using the first year as a base year.

Using TRIM, it was possible the elaboration of models which allows the improvement of the indices estimation and can be used for predicting the missing counts. In this way, predicted counts

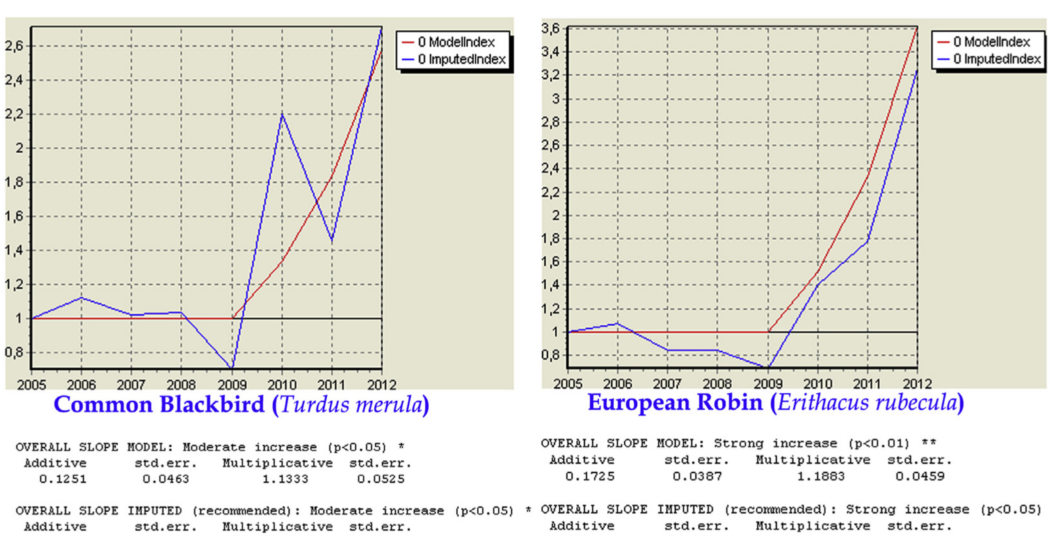

Fig. 6. Common Blackbird, and European Robin population trends in the Valbormida wind farm.

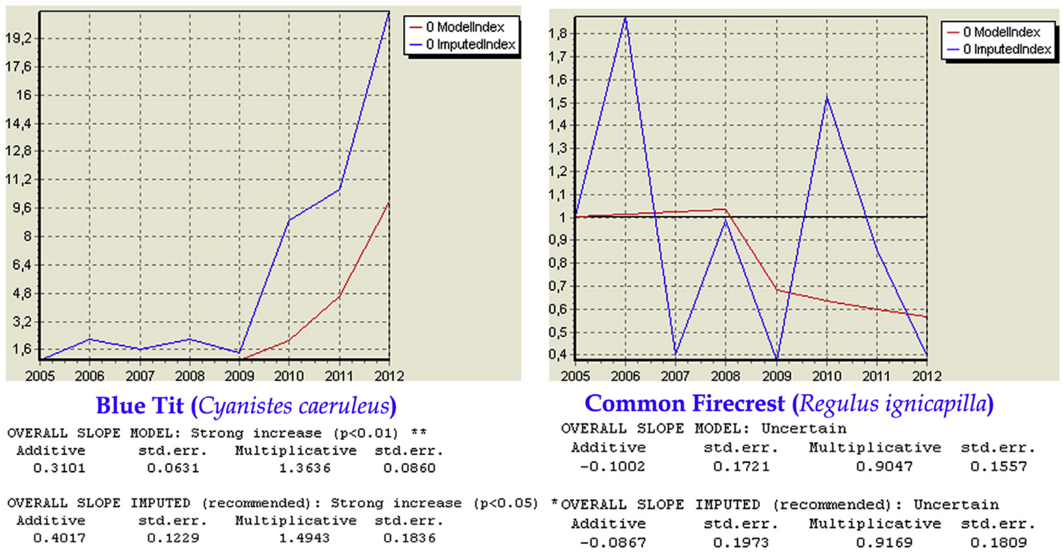

Fig. 7. Blue Tit, and Common Firecrest population trends in the Valbormida wind farm.

were used for replacing the missing ones, in order to obtain indices calculated on the basis of a completed data set [26]. In fact, generally the data analysed by TRIM are counts obtained from a number of sites at a number of time-points (years). In particular, the count or frequency in site *i* at time *j* will be denoted by the function f_{ij} where *i* is included between 1 and *j* between 1 and J (I is the total number of sites and J the total number of time points). There will usually not be observations f_{ij} for every combination of site and time and the unobserved counts are called missing counts [24].

Moreover, TRIM was used for analysing trends in these indices, estimating if the abundance of any passerine species under exam were increasing or decreasing during the years of survey. This analysis allowed a comparison of population trends before and after the wind farm constructions, in order to highlight if there were changes or not in the populations abundance between years [27].

The goodness-of-fit of loglinear models was tested by Pearson's chi-squared statistic and by the likelihood ratio test, that can be used to test for the difference between models. Model indices express the expected counts as a function of site-effects and time-effects, whereas imputed indices are obtained by replacing missing observations by estimated counts [24]. Another approach used to comparing models is the Akaike's Information Criterion (AIC) [28].

3. Results and discussions

During the point count surveys, 15 passerine species have been recorded. All data gathered were entered into the software TRIM obtaining population trends by model and imputed indices.

The Eurasian Blackcap, the Long-tailed Tit show uncertain population trends before the wind farm construction in winter 2008, while in the following years their trends appear increasing in accordance with the national trend (increase of +2% and +4.9% respectively) (Fig. 2).

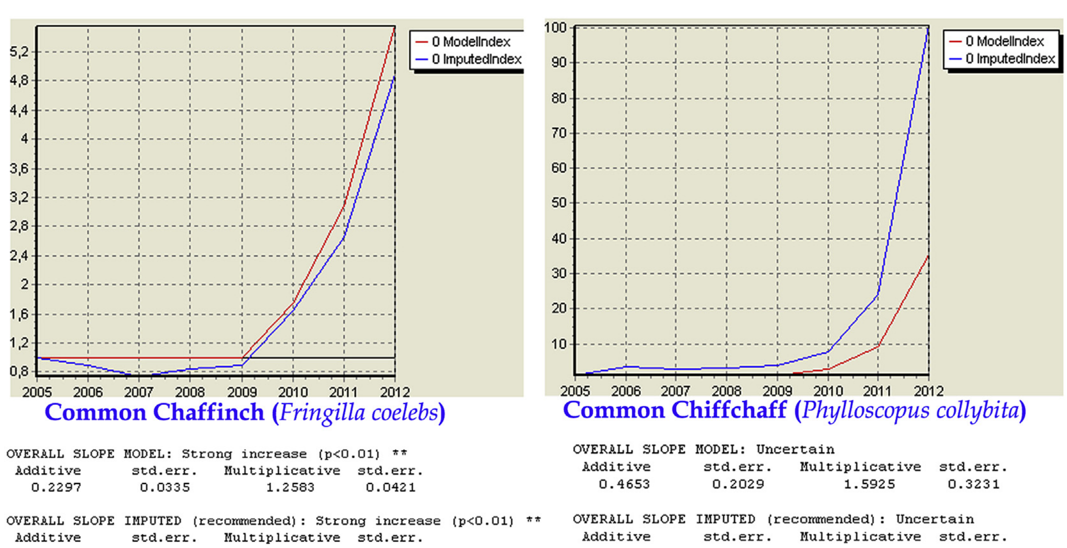

Fig. 8. Common Chaffinch, and Common Chiffchaff population trends in the Valbormida wind farm.

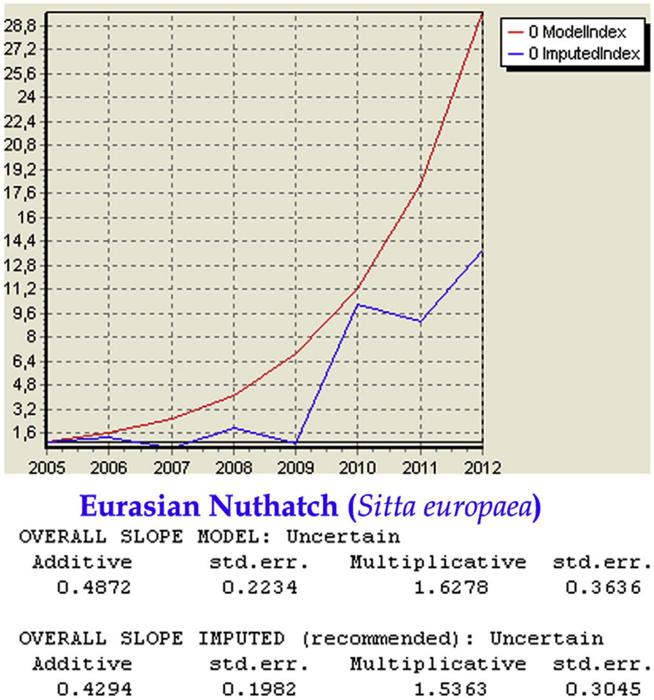

Fig. 9. Eurasian Nuthatch population trend in the Valbormida wind farm.

Also the Common Wood Pigeon and the Common Cuckoo have an uncertain population trend before the wind farm construction and an increasing trend in the following years, but the Common Wood Pigeon model has not a strong significance for the low number of total surveys (only 13 individuals in 8 years of surveys) (see Fig. 3). At national level, the same species has a strong increasing population trends (+12.2% per annum), while the Common Cuckoo has a stable trend (+0.1% per annum).

The Coal Tit and the Song Thrush population trends are uncertain (Fig. 4) while the Great Tit one shows a moderate increase (Fig. 5). The data of the three species show a decline between 2006 and 2007, that cannot be caused by the presence of the wind farm, and another decline between 2008 and 2009 that could be attributed to the construction phase. The national population trends show a moderate decrease (−4.6% per annum) for the Coal Tit and a moderate increase for the Great Tit and the Song Thrush (respectively +1.5% and +3% per annum).

Also the Eurasian Jay (Fig. 5), the Common Blackbird, and the European Robin (Fig. 6) population trends have a decreasing population trend between 2008 and 2009 and a moderate increasing trend after the wind farm construction, in accordance with national levels (respectively +1.9%, +2.8% and +1.6 per annum).

The Blue Tit has a strong increase population trend starting from 2009 in the study area and a moderate increase (+5.5% per annum) at national level, whereas the Common Firecrest has an uncertain population trend for the low number of total surveys (11 individuals in 8 years) and a moderate increasing national population trend (+3.3% per annum) (Fig. 7).

The Common Chaffinch has a strong increasing population trend in the study area since 2009 while at National level its trend is stable (+0.6% per annum), whereas the Common Chiffchaff population appears with a strong increasing trends, but its model is classified as uncertain (Fig. 8), as for the Eurasian Nuthatch, due to the lack of data (Fig 9). At national level their trends are both stable (respectively +0.3% and +1.1% per annum).

Moreover, in order to evaluate if the trends of the monitored populations have been modified by the presence of the wind farm, they were compared with the national population trends of the same passerine species during the same period [29,30] (Table 1).

Table 1
Comparison between local (with statistical data) and national population trends of 15 breeding passerines.

Breeding passerines	Chi-square df: degree of freedom	Likelihood ratio	AIC (up to a constant)	Local population trend	National population trend
Common Wood Pigeon (*Columba palumbus*)	41.49 df: 27; p: 0.037	28.17 df: 27; p: 0.402	−25.83	?	↑↑
Common Cuckoo (*Cuculus canorus*)	16.29 df: 22; p:0.801	16.14 df: 22; p: 0.809	−27.87	?	=
European Robin (*Erithacus rubecula*)	35.76 df: 52; p: 0.958	42.53 df: 52; p: 0.822	−61.47	↑↑	↑
Common Blackbird (*Turdus merula*)	34.49 df: 51; p: 0.963	38.27 df: 51; p: 0.906	−63.73	↑	↑
Song Thrush (*Turdus philomelos*)	59.9 df: 52; p: 0.210	60.72 df: 52; p: 0.190	−43.28	?	↑
Eurasian Blackcap (*Sylvia atricapilla*)	66.47 df: 52; p: 0.085	70.59 df: 52; p: 0.044	−33.41	?	↑
Common Chiffchaff (*Phylloscopus collybita*)	29.47 df: 42; p: 0.927	28.06 df: 42; p: 0.951	−55.94	?	=
Common Firecrest (*Regulus ignicapilla*)	31.53 df: 22; 0.085	25.02 df: 22; p: 0.296	−18.98	?	↑
Long-tailed Tit (*Aegithalos caudatus*)	61.23 df: 39; p: 0.019	40.55 df: 39; p: 0.401	−37.45	↑↑ − ?	↑↑
Blue Tit (*Cyanistes caeruleus*)	38.03 df: 42; p: 0.646	31.17 df: 42; p: 0.890	−52.83	↑↑	↑
Great Tit (*Parus major*)	50.52 df: 52; p: 0.532	51.53 df: 52; p: 0.492	−52.47	?	↑
Coal Tit (*Periparus ater*)	48.93 df: 45; p: 0.318	43.85 df: 45; p: 0.520	−46.15	?	↓
Eurasian Nuthatch (*Sitta europaea*)	78.89 df: 37; p: 0.0001	29.86 df: 37; p: 0.791	−44.14	↑↑	=
Eurasian Jay (*Garrulus glandarius*)	29.01 df: 31; p: 0.569	25.05 df: 31; p: 0.765	−36.95	↑ − ?	↑
Common Chaffinch (*Fringilla coelebs*)	37.15 df: 55; p: 0.969	46.20 df:55; p: 0.794	−63.80	↑↑	=

All the analyzed population trends were classified into these categories:

- Strong increase (↑↑): increase higher than 5% yearly.
- Moderate increase (↑↑): significant increase but lower than 5% a year.
- Stable (=): population trends without significant increases or decreases.
- Moderate decrease (↓): significant decrease but lower than 5% a year.
- Strong decrease (↓↓): decrease higher than 5% yearly.
- Uncertain (?): it was no possible to assert any population trend.

Since the following species were rare in the study area, observations for those species might not represent the right trend: Common Wood Pigeon (13 observations in 8 years), Common Firecrest (11 observations in 8 years), Eurasian Nuthatch (18 observations in 8 years) and Song Thrush (28 observations in 8 years).

4. Conclusions

The population trends of the 15 breeding passerines analysed in the Valbormida wind farm are similar to national trends; in particular the increasing population trends found at national level have been recorded also in the wind farm areas, although there was no possible to define a population trend due to lack of data for some species.

It is also interesting to note that among the 15 species considered, 12 of them have a decreasing trend between 2008 and 2009; in fact only Eurasian Blackcap, Common Chaffinch and Common Chiffchaff do not show this trend, probably related to the construction of the wind farm which probably have caused a disturbance to nesting birdlife.

Considering these 12 species, 10 of them (the 83%) show a clear population increase in the years following the construction of the wind farm (2010 and 2011).

Most likely, this trend would presume that the species "disturbed" by the wind farm construction return to the old nesting sites when the construction phase is completed.

Overall it can be said that the construction of the analyzed wind farm did not affect the conservation of the breeding passerine populations.

These results confirmed other important studies, such as the results obtained by Researchers from the Royal Society for the Protection of Birds (RSPB), Scottish Natural Heritage and the British Trust for Ornithology (BTO) [31]: looking at 10 bird species at 18 wind farm sites in the UK, they established that wind farms provoke minimal impact on birds from flying into rotating turbines, even if the same study recognized that some bird species suffer harm while wind farms are being built.

Moreover, due to their mobility, responsiveness to environmental changes and sensitiveness to anthropogenic changes [32], bird species are important ecological indicators for the conservation of other kind of biodiversity [33]. Therefore the population trends of the monitored nesting passerines constitute also a useful tool for the assessment of the environmental and ecosystem health [34] as well as species richness and endemism patterns [35].

References

[1] Carvalho PCM. Wind energy and greenhouse gases emission market: the Brazilian potential. Wind Eng 2003;27:135–42.

[2] Cumo F, Astiaso Garcia D, Calcagnini L, Rosa F, Sferra AS. Urban policies and sustainable energy management. Sustain Cities Soc 2012;4:29–34.

[3] Yuksel I. Energy utilization, renewables and climate change mitigation in Turkey. Wind Eng 2008;26(1):35–51.

[4] Huntley B, Collingham YC, Green RE, Hilton GM, Rahbeck C, Willis SG. Potential impacts of climatic change upon geographical distribution of birds. Ibis 2006;148:8–28.

[5] Sovacool BJ. The avian benefits of wind energy: a 2009 update. Renew Energy 2013;49:19–24.

[6] Drewitt AL, Langston RHW. Assessing the impacts of wind farms on birds. Ibis 2006;148:29–42.

[7] Holmstrom LA, Hamer TE, Colclazier EM, Denis N, Verschuyl JP, Ruché D. Assessing avian-wind turbine collision risk: an approach angle dependent model. Wind Eng 2011;35(3):289–312.

[8] Ling S, Linehan A. Guidelines for wind power and wildlife in Washington State, USA. Wind Eng 2003;27(4):273–83.

[9] Bright JA, Langston RHW, Bullman R, Evans RJ, Gardner S, Pearce-Higgins J, et al. Map of bird sensitivities to wind farms in Scotland: a tool to aid planning and conservation. Biol Conserv 2008;141:2342–56.

[10] Masden EA, Fox AD, Furness RW, Bullmand R, Haydon DT. Cumulative impact assessments and bird/wind farm interactions: developing a conceptual framework. Environ Impact Asses 2010;30:1–7.

[11] Astiaso Garcia D, Canavero G, Curcuruto S, Ferraguti M, Nardelli R, Sammartano L, et al. Il protocollo di monitoraggio avifauna e chirotterofauna dell'Osservatorio Nazionale su Eolico e Fauna. In: Mezzavilla F, Scarton F, editors. Atti Secondo Convegno Italiano Rapaci Diurni e Notturni. 1st ed. Venezia: Associazione Faunisti Veneti; 2013.

[12] Katsaprakakis DA. A review of the environmental and human impacts from wind parks. A case study for the prefecture of Lasithi. Crete Renew Sust Energy Rev 2012;16(5):2850–63.

[13] Pearce-Higgins JW, Stephen L, Langston RHW, Bainbridge IP, Bullman R. The distribution of breeding birds around upland wind farms. J Appl Ecol 2009;46:1323–31.

[14] Ketzenberg C, Exo KM, Reichenbach M, Castor M. Einfluss von Windkraftanlagen auf brütende Wiesenvögel. Nat Landsch 2002;77:144–53.

[15] Douglas DJT, Bellamy PE, Pearce-Higgins JW. Changes in the abundance and distribution of upland breeding birds at an operational wind farm. Bird Study 2011;58:37–43.

[16] De Santoli L, Albo A, Astiaso Garcia D, Bruschi D, Cumo F. A preliminary energy and environmental assessment of a micro wind turbine prototype in natural protected areas. Sustain Energy Techs Asses 2014;8:42–56.

[17] Santos M, Bastos R, Travassos P, Bessa R, Repas M, Cabral JA. Predicting the trends of vertebrate species richness as a response to wind farms installation in mountain ecosystems of northwest Portugal. Ecol Indic 2010;10(2):192–205.

[18] Bibby CJ, Burgess ND, Hill DA. Point counts. Bird Census Tech 1992:85–104.

[19] Tegeler AK, Morrison ML, Szewczak JM. Using extended-duration audio recordings to survey avian species. Wildl Soc Bull 2012;36(1):21–9.

[20] Blondel J. Evolution and ecology of birds on islands: trends and prospects. Life Env 2000;50:205–20.

[21] Dawson DK, Efford MG. Bird population density estimated from acoustic signals. J Appl Ecol 2009;46:1201–9.

[22] Blake JG. Temporal variation in point counts of birds in a low-land wet forest in Costa Rica. Condor 1992;94:265–75.

[23] Schmidt JH, McIntyre CL, MacCluskie MC. Accounting for incomplete detection: what are we estimating and how might it affect long-term passerine monitoring programs? Biol Conserv 2013;160:130–9.

[24] Pannekoek J, Van Strien A. TRIM 3 manual (trends and indices for monitoring data). Statistic Netherlands. The Netherlands: Voorburg; 2005.

[25] Van Dyck H, Van Strien AJ, Maes D, Van Swaay CAM. Declines in common, widespread butterflies in a landscape under intense human use. Conserv Biol 2009;23:957–65.

[26] Both C, Van Turnhout CAM, Bijlsma RG, Siepel H, Van Strien A, Foppen R. Avian population consequences of climate change are most severe for long-distance migrants in seasonal habitats. Proc R Soc Bull 2010;277:1259–66.

[27] Gregory RD, Van Strien A, Vorisek P, Gmelig Meyling A, Noble DG, Foppen RP, et al. Developing indicators for European birds. Proc R Soc Bull 2005;360:269–88.

[28] McCullagh P, Nelder JA. Generalized linear models. 2nd ed. London: Chapman and Hall; 1989.

[29] Rete Rurale Nazionale, LIPU. Uccelli comuni in Italia. Gli andamenti di popolazione dal 2000 al 2010. Roma: Ministero delle Politiche Agricole Alimentari e Forestali; 2011.

[30] Gustin M, Brambilla M, Celada C. Valutazione dello Stato di Conservazione dell'avifauna italiana, vol. II. Roma: Passeriformes. Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Lega Italiana Protezione Uccelli (LIPU); 2010.

[31] Pearce-Higgins JW, Leigh S, Douse A, Langston RHW. Greater impacts of wind farms on bird populations during construction than subsequent operation: results of a multi-site and multi-species analysis. J Appl Ecol 2012;49(2):386–94.

[32] Furness RW, Greenwood JJD. Birds as monitors of environmental change. London: Chapman & Hall; 1993.

[33] Canterbury GE, Martin TE, Petit DR, Petit LJ, Bradford DF. Bird communities and habitat as ecological indicators or forest condition in regional monitoring. Conserv Biol 2000;14:544–58.

[34] Gregory RD, Van Strien A. Wild bird indicators: using composite population trends of birds as measures of environmental health. Ornithol Sci 2010;9(1):3–22.

[35] Burgess ND, Rahbek C, Larsen FW, Williams P, Balmford A. How much of the vertebrate diversity of sub-Saharan Africa is catered for by recent conservation proposals? Biol Conserv 2002;107:327–39.