Bird Conservation International, page 1 of 18. © BirdLife International, 2017
doi:10.1017/S095927091700017X

Effectiveness of the system of protected areas of Lombardy (Northern Italy) in preserving breeding birds

BEATRICE SICURELLA, VALERIO ORIOLI, GUIDO PINOLI, ROBERTO AMBROSINI and LUCIANO BANI

Summary

Networks of protected areas (PAs) where human activities are allowed at different degrees are fundamental to ensure the long-term conservation of biological diversity and ecological processes. However, studies aimed at assessing their effectiveness, focusing on several species simultaneously are scarce. We assessed the effectiveness of the system of protected areas (PAs) of Lombardy, Northern Italy, in conserving bird populations by comparing the changes from 1992 to 2013 in the occurrence of 54 breeding bird species censused in areas classified in different protection categories, namely Nature Reserves (NRs), areas designed predominantly for the protection of nature; Regional Parks (RPs), naturally valuable areas where human activities, including intensive agriculture, are allowed; and non-protected areas (NPAs). Overall, occurrence of common birds increased in Lombardy in the last 20 years and farmland and long-distance migrants (LDMs), which suffered sharp declines at a continental scale, showed stable and increasing trends, respectively. These trends were, however, the balance between those of species whose occurrence markedly increased, and those of species that dramatically declined. Species occurred more often in PAs than in NPAs, while temporal trends in occurrence were significantly more positive in RPs than in both NRs and NPAs. Hence, PAs seemed effective in preserving common bird communities. Occurrence of woodland and short-distance migrant species was higher in PAs than in NPAs, while occurrence of farmland species and LDMs was similar in all protection categories. PAs of Lombardy appear therefore effective only in protecting some categories of birds. Farmland and LDM birds would benefit more from ecologically sustainable land-use policies aiming at improving agro-ecosystem biodiversity than from protected areas.

Introduction

Protected areas (PAs) are created worldwide to ensure the long-term conservation of biological diversity and ecological processes (Meffe and Carroll 1994), and their designation is the most traditional and widespread tool to face the ongoing loss of biodiversity (UN 1992, Pullin 2004, Jackson *et al.* 2009). However, there is a considerable debate on the overall effectiveness of PAs in preserving habitats and species (Cabeza 2013, Geldmann *et al.* 2013), emphasised by the paucity of quantitative studies on this issue. For example, < 5% of studies on the effectiveness of PAs are based on quantitative assessments, and even fewer are studies that measure the impact of PAs on populations (Rayner *et al.* 2014). Quantitative studies are probably lacking because they require long-term monitoring records, which are costly and time-consuming. In addition, proper assessment of PA effectiveness would require comparison with long-term monitoring records of the same species in non-protected areas (NPAs), but these data are usually even scarcer than those in PAs (Boakes *et al.* 2010).

In Europe, modern PAs have been established since 1909 (Chape *et al.* 2008) following the model of national parks in the USA. Since then, the number and the total area of PAs have greatly increased, particularly after the Second World War (EEA 2012). However, the criteria according to which PAs were designed varied markedly among countries or even between administrative regions within them. Indeed, PAs in Europe range from Strict Nature Reserves (IUCN protection category I; see EEA 2012 for details) to managed agricultural landscapes (outside IUCN protection categories). Most European PAs are not reserves where all human activities are excluded; rather, they are managed to fulfil both wildlife protection and socio-economic demands (EC 2002).

In this paper, we aimed to assess the effectiveness in conserving bird communities of the system of PAs of Lombardy (c.24,000 km^2), an administrative Region of Northern Italy. Lombardy has a remarkable network of PAs with different levels of nature protection (Table 1; Figure 1). For the sake of the present study, we differentiated PAs into two categories: "Regional Parks" (RPs) and "Nature Reserves" (NRs). The basic distinction between these categories is that RPs are complex systems integrating different natural or cultural values and features, which require coordinated management approaches. In contrast, NRs require more restrictive management approaches because they aim at preserving specific natural features (Sinibaldi and Tallone 2008; see also Materials and Methods and Table 1 for further details).

Scientific management of PAs requires permanent monitoring of the environment, including populations not only of species of conservation concern, but also of common species (Lindenmayer and Likens 2010, Primack 2012), which usually provide the majority of ecosystem processes (Gaston 2011). Furthermore, monitoring is essential to obtain information needed to plan appropriate management actions to ensure conservation of the overall biodiversity (Balmford *et al.* 2003, Sekercioglu 2006). However, for practical reasons, the large majority of monitoring studies carried out in European PAs focus on one or few target species, often those of conservation concern (Pellissier *et al.* 2013; but see Devictor *et al.* 2007 and Pellissier *et al.* 2013 for remarkable exceptions).

Birds are one of the most commonly used vertebrate taxa in conservation studies, mainly because large datasets on abundance and distribution of species are available in several areas of the world (Eglington *et al.* 2012). In addition, birds include species at all trophic levels, so that the conservation status of bird communities is often used as an indicator of other taxa (Donald *et al.* 2001, Gregory *et al.* 2003). We took advantage of a large dataset of annual censuses of breeding birds collected by means of point counts in 1992–2013 all over Lombardy (Bani *et al.* 2009; Figure S1 in the online supplementary material). This dataset allowed us to calculate annual indices of population occurrence for 54 species over 18 years in NRs, RPs, and NPAs. Since we had a rather long time-series of occurrence for each species, we could also calculate temporal trends in such indices within each type of PA. Hence, our assessment of the effectiveness of the Lombardy PAs system relied on complementary pieces of information, allowing assessment and comparison of both average occurrence and temporal trend in the occurrence of each species in areas with different levels of protection, including NPAs.

In the present work, PAs were considered effective in preserving bird communities if either: i) occurrence was larger or ii) occurrence increased more (or decreased less) in them than in NPAs. We considered one of the two aforementioned conditions as sufficient to confirm that PAs are effective because: i) PAs that currently host larger number of birds than NPAs show their effectiveness in protecting birds; ii) PAs that are currently allowing larger increases (or lower decreases) in bird occurrence will probably sustain a larger number of individuals than NPAs in the future (see Donald *et al.* 2007 for a similar approach). We expected Lombardy PAs to be effective in protecting bird communities; therefore, we predicted mean values of occurrence indices to be higher in PAs (both NRs and RPs) than in NPAs and/or temporal trends to be more positive in PAs than in NPAs.

Common birds have shown divergent trends over recent decades in Europe according to their breeding habitat, with farmland birds typically showing sharp declines, while woodland species remained stable (PECBMS 2012). Lombardy is no exception to this general pattern (Bani *et al.* 2009). We therefore tested whether PAs were effective in conserving bird populations grouped by these

Table 1. Protected areas of Lombardy, their relevance, and classification for the purposes of the present study.

Type	Brief description	Number (total extent in Lombardy*)	Categorization in the present study
Parks (general)	Areas organized in coordinated and unified fashion, with particular regard to the needs of protecting nature and the environment and promoting cultural and recreational uses as well as to the development of agricultural, forestry and pastoral activities and of other traditional activities that will promote the social, economic and cultural well-being of resident communities.		
National Parks	In Lombardy, only Stelvio National Park, identified by the Italian Parliament. Stronger level of protection than the other parks, similar or even higher than that of reserves.	1 (593.1 km^2)	NR
Natural Parks	Parks identified by the Parliament of Lombardy, with a stronger level of nature protection than regional parks, similar to that of reserves.	14 (650.7 km^2)	NR
Regional Parks	Parks identified by the Parliament of Lombardy with the aim of integrating nature conservation and human activities.	23 (4,411.8 km^2)	RP
Local Parks	Parks identified by one or more municipalities, but not included in the Official List of Protected Areas of Italy	92 (802.7 km^2)	NPA
Reserves (general)	Areas specifically devoted to the conservation of nature and all its phenomena that contribute to maintaining the ecosystem they host		
National Reserves	Reserves identified by the Italian Parliament.	3 (33.1 km^2)	NR
Regional Reserves	Reserves identified by the Parliament of Lombardy	71 (192.3 km^2)	NR
Natura 2000 sites	Areas comprising Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) classified under the provision of, respectively, the Habitat and the Birds directives of the EU.	260 (5,216.3 km^2)	RP

*Boundaries of PAs may overlap.

categories. We expected woodland species to occur more often and to have increased their occurrence most in NRs, at an intermediate level in RPs and least in NPAs because several NRs in Lombardy were established in residual old woodlands. Predictions for farmland birds were more difficult because farmland areas are less represented in NRs, and agricultural practices in RPs are rather similar to those in NPAs. We had therefore no clear expectations on the occurrence and on the temporal trend of farmland birds in PAs and NPAs of Lombardy. Furthermore, migrant

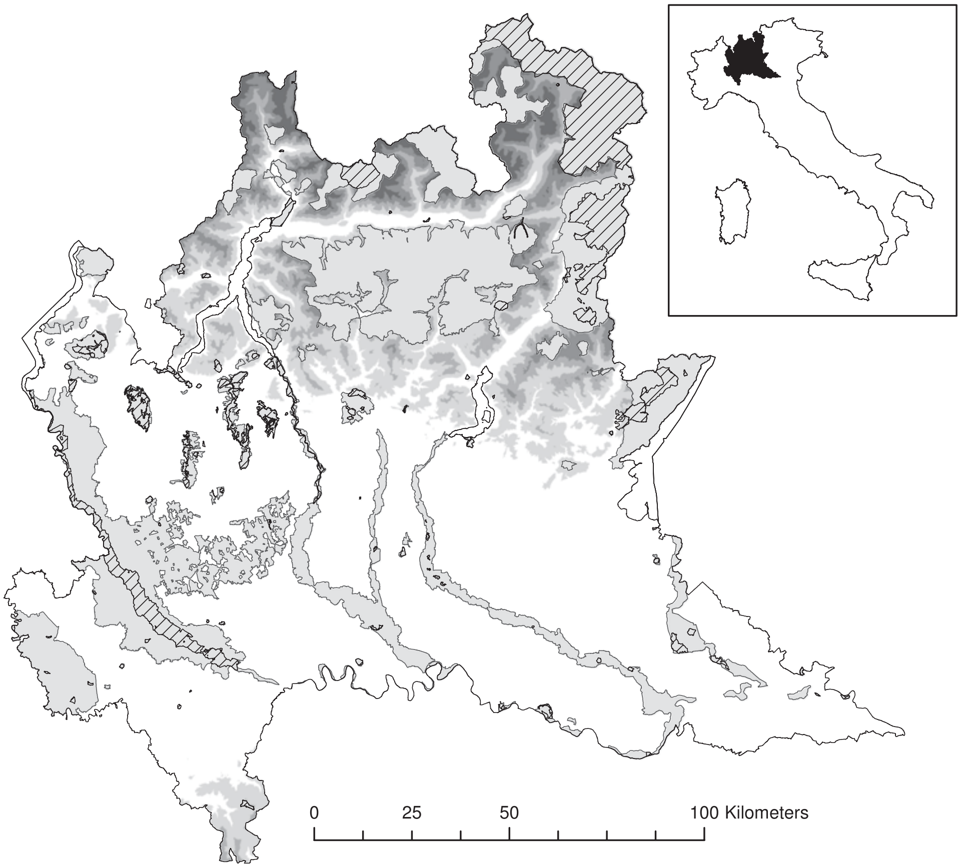

Figure 1. Protected areas of Lombardy according to protection category. Light grey: regional parks and Natura 2000 sites (RPs), simple hatched: national park and nature reserves (NRs). Orography is shown in grey scale, but hidden under protected areas for clarity of representation.

birds show marked declines both at European scale (Sanderson *et al.* 2006) and in Lombardy (Bani *et al.* 2009), with long-distance migrants suffering the most negative population trends. We therefore investigated whether occurrence and temporal trend of birds with different migration behaviour differed among NRs, RPs and NPAs. In this case, we expected average occurrence to be higher and/or its trend to be more positive (or less negative) in PAs in general than in NPAs.

Methods

Study area and field methods

Lombardy is one of the most densely populated (> 400 inhabitants/km^2) and industrialised regions of Europe (according to Eurostat, in 2013 it had the second highest GDP among the second level territorial units of the EU; http://ec.europa.eu/eurostat/, accessed on June 10, 2016), and has a remarkable network of protected areas covering 27.8% of its surface area (Figure 1; Geoportal of Lombardy, http://www.cartografia.regione.lombardia.it/geoportale/ptk, accessed on June 10, 2016).

Point counts were performed in 1992, 1995, 1996, and 1999–2013 for monitoring breeding birds (Bani *et al.* 2009). Data were collected during the main breeding season (10 May–20 June) from sunrise to 11h00, in good weather conditions (sunny to cloudy, with no rain or strong wind; Blondel *et al.* 1981, Fornasari *et al.* 1998). Location of point counts was chosen in each year according to a stratified sampling design, with a minimum distance of 500 m between locations. Figure S1 shows the spatial distribution of point counts in Lombardy. Further details on sampling methods are provided in Bani *et al.* (2009).

Data management

For the purposes of the present study, the territory of Lombardy was schematically divided into three categories ('protection categories' hereafter), according to presence or absence of PAs and to the different degrees of nature protection in each PA. The first category was "nature reserves" (NRs), which included PAs specifically designed for the conservation of nature. It included 74 reserves (both national and regional) covering on average 2.6 (0.7 SE) km^2 (see Table 1 for details); 14 natural parks covering on average 46.5 (19.2 SE) km^2; and the only national park in Lombardy (Stelvio National Park, 593.1 km^2). Inclusion of natural and national parks in the NRs category is justified by the generally stronger level of regulation of human activities in these parks than in the regional parks of Lombardy (Table 1). Total extent of NRs was 1,403.9 km^2.

The second category was "regional parks" (RPs), which included PAs designed for both protecting nature and promoting sustainable human activities. It included 23 regional parks covering on average 191.8 (52.1 SE) km^2 and 260 Natura 2000 (N2000) sites, covering 20.1 (3.7 SE) km^2 on average. The N2000 network of PAs was established by the European Union (EU) in response to the Rio the Janeiro Convention on Biological Diversity of 1992, with the double aim of conserving biodiversity and ensuring the sustainability of human activities (EC 2002, Cabeza 2013; see also Table 1). After accounting for partial overlap among different protected areas, the total area of RPs was 6,461.9 km^2. The third protection category consisted of non-protected areas (NPAs) and was composed of areas outside PAs. Total area of NPAs was 17,370.3 km^2.

Other kinds of protected areas exist in Lombardy. Local Parks are identified by one or more municipalities, but have a very low level of nature protection, and are not included in the Official List of Protected Areas of Italy (http://www.minambiente.it/sites/default/files/archivio/normativa/dm_27_04_2010.pdf). We therefore considered these areas as NPAs. Wetlands protected under the Ramsar convention and areas protected under the UNESCO Man and Biosphere programme overlap with natural parks and reserves, and were therefore considered NRs. We stress that we were forced to reduce the number of protection categories in order to base comparison on a minimum number of point counts and species and that a certain degree of heterogeneity in the level of nature protection exists within each group of PAs. Nevertheless, we are confident that our categorisation was able to capture the degree of nature protection ensured by the different types of PAs of Lombardy.

Each point count was assigned to a 'protection category' (three-level factor), accounting for the point being within NRs, RPs or NPAs (see Table 2). Points performed in areas where NRs and RPs overlap were considered in NRs. This is justified by the general stronger level of protection in NRs than in RPs.

Land use strongly influences bird communities (Wiens 1989). We therefore calculated the proportional extent of farmlands (arable, rice fields and meadows), woodlands (broadleaved, coniferous and mixed forests, including reforestation), urban areas (residential, industrial and commercial areas, including urban green areas, and infrastructures), and open non-farmland environments (mountain grasslands, areas with sparse vegetation, rocks and riverbeds) in a radius of 150 m from the point, as obtained from digital maps of land use. Since our study spanned 22 years, and several digital land use maps were released during these years, we selected the digital land use map temporally

Table 2. Number and percentage of point counts performed in each protection category, and of species classified as farmland or woodland and according to their migratory habit.

Factor	Levels	Number of point counts	% of point counts
Protection Category	NRs	718	4.9
	RPs	1490	10.1
	NPAs	12488	85.0
Factor	**Levels**	**Number of species**	**% of species**
Farmland		17	31.5
Woodland		15	27.8
Migratory Habit	RES	20	37.0
	SDM	22	40.8
	LDM	12	22.2

closest to each survey year (CLC90, released in 1990, for survey years 1992–1996; DUSAF 1.1, released in 2001, for survey years 1999-2004; and DUSAF 2.1, released in 2007, for survey years 2005–2013; CLC90 is available at http://www.eea.europa.eu/, DUSAF 1.1 and DUSAF 2.1 are available at www.geoportale.regione.lombardia.it/; accessed June 10, 2016).

Bird species were classified according to their migratory behaviour in three levels according to 'migratory habit' indicating whether in Lombardy they are residents (RES), short-distance migrants (SDM) or long-distance migrants (LDM; Table S1). Migratory habit was deduced by comparing information and maps from atlases of breeding (Brichetti and Fasola 1990) and wintering (Fornasari *et al.* 1992) birds in Lombardy, and by data on migratory movements in Italy (Spina and Volponi 2008a,b). Bird species were also classified as being 'farmland' or 'woodland' species (Table S1) based on land use of the points where each species was observed. In detail, a species was classified as farmland when the mean extent of farmlands within 150 m from all the point counts where it was observed was > 50%. Similarly, a species was classified as woodland when the mean extent of woodlands around the points where it was observed was > 50%.

Statistical analyses

We based our analyses on population indices comparable between protection categories, which largely vary in extent and land use, and years, when different numbers of point counts were performed. We first selected, for each year and protection category, the point counts where a species could *potentially* be observed as those point counts between the minimum and the maximum altitude at which a species has ever been detected in all the point counts in our database. This selection criterion was used with the aim of excluding false zeroes from the analyses, i.e. point counts outside the altitudinal range of a species (see also Appendix S1 in the supplementary materials for further details).

We acknowledge that a species may potentially also occur in point counts at altitudes slightly above or below these limits. However, we are unaware of any comprehensive list of altitude ranges for common species specific to Lombardy, and we refrained from using altitude ranges described in the literature because we found that, for some species, they largely differ from the altitude ranges observed in Lombardy. For example, the Eurasian Linnet *Carduelis cannabina* usually breeds in lowlands in Central, Northern and Western Europe and it is therefore classified as a farmland bird in the continental ecoregion of Europe by the PECBMS (http://www.ebcc.info/index.php?ID=564, accessed June 10, 2016). In contrast, in Lombardy this species is a strictly alpine breeder. Indeed, the average elevation of point counts where we detected this species was 1,821.9 ± 32.0 SE, m. Thus, using altitude ranges described in the literature for identifying points where a species could potentially be observed, would have determined the inclusion of a large number of "false absences" in the dataset. We therefore preferred to base our selection of points to be included in the analyses on our own data, also because we are confident that our extensive survey (Figure S1) was able to capture the actual altitudinal range of common bird species in Lombardy.

Analyses were run in two steps. First, we ran separate GLMs for each species and protection category with the aim of obtaining indices of the mean occurrence and temporal trend of each species in each protection category. In detail, we modelled the presence/absence of a species at a point count according to the year and the proportional extent of farmlands, woodlands, urban areas and open non-farmland environments around each point. In the models of points in NRs and RPs, we also included as predictor the year when the protected area was declared. For N2000 sites (included in the RP category), we considered the year of approval of management plans, because conservation measures are effective in N2000 areas only after that date (Parks and Biodiversity Unit of Lombardy Regional Administration pers. comm.). When points were performed in areas where different types of protected areas overlap (e.g. N2000 sites and regional parks), we considered the earliest year of institution of any protected area at that point.

Only information on presence or absence of a species at each point count was considered, and only those species detected in at least five years of our survey and in at least 30 point counts in each protection category were selected. This ensured that we had sufficient data to estimate occurrence and trend indices for all species by protection category combinations. The Common Pheasant *Phasianus colchicus* was excluded because its distribution is largely influenced by game restocking. The Feral Pigeon *Columba livia domestica* was excluded because its distribution and population dynamics are strictly determined by human activities. Models were fitted assuming a binomial error distribution and a log link function (log-binomial models or "relative risk" models; McNutt *et al.* 2003). In the supplementary materials (Appendix S2), we provide a technical description of log-binomial models and of the interpretation of their coefficients, and of the reason why we preferred these models to logistic regressions.

All predictors were centred to their mean value before the analyses. With this parameterization, the intercept of the model represents the log-transformed mean proportion of point counts performed in a given protection category in all years, after accounting for the different land use around the point and, for NRs and RPs, also for the different year of establishment of the PAs. This index therefore estimates the (log-transformed) average "relative risk" of observing a species in a point count performed in a given protection category in all years ("log-occurrence index" hereafter). In contrast, the slope of the year covariate from the same model represents the log-transformed variation in the proportion of points where a species was detected from one year to another (i.e. the year-to-year variation in the relative risk of observing a species) in a given protection category ("log-trend index" hereafter).

Each log-binomial GLM allowed estimation of two indices providing different pieces of information on, respectively, the occurrence of a species and its temporal trend in a protection category. These indices were used in the second step of the analyses. In the text and the graphs we reported their exponentials ("occurrence index") or their exponential minus one ("trend index") in percentage to facilitate the interpretation of their values (see Appendix S2 for further details).

In the second step of the analyses, we compared log-occurrence indices and log-trend indices between protection categories in Linear Mixed Models (LMMs), assuming a Gaussian error distribution, with species as a random grouping factor. LMMs were corrected for non-homogeneity of variances whenever necessary (Zuur *et al.* 2009; details not shown). Statistical significance was assessed by a permutation test (999 permutations, P_{perm} hereafter) to assure that our conclusions were robust whenever we detected (small) deviations from normality of model residuals during routine model diagnostics or the presence of (few) outliers (details not shown). Post-hoc tests were conducted by pairwise comparisons, with permutation-based *P*-values corrected for multiple statistical tests by the False Discovery Rate (FDR) procedure (Storey 2002). We also used a LMM with species as a random factor to assess whether average population trends at each protection category, or at all protection categories pooled, significantly differed from zero. The same analytical procedure was repeated separately for farmland and woodland species and for species with different migratory habits.

In order to represent temporal variation in species occurrence, for each species, year and protection category, we calculated the proportion of point counts where a species was detected over the number of point counts performed in that year and protection category within the altitudinal range of that species. We then reported the mean occurrence among all species, farmland and woodland species, and RESs, SDMs and LDMs in each year. This mean occurrence does not strictly correspond to the occurrence index, because it does not account for land use around point counts or for the year where protection measures started in an area. However, it allows visualisation of year-to-year variation in occurrence (Figures 2 and S2). All analyses were run in R 3.1.1 (R Core Team 2015) with the *logbin* (Donoghoe 2015), *nlme* (Pinheiro *et al.* 2015), *lsmeans* (Lenth 2015), *predictmeans* (Luo *et al.* 2014) and *multtest* (Pollard *et al.* 2005) packages.

Results

Analyses of all species

The whole dataset included 14,696 10-minute point counts, corresponding to (mean ± SE) 816.44 ± 63.33 point counts per year. Overall, 54 species were included in the analyses. Table 2 provides the number of point counts performed in each protection category, the number of farmland and woodland species included in the analyses, the number of species with each migratory habit. Table S1 provides occurrence and trend indices of each species.

Occurrence indices of species in each protection category ranged from 0.58 ± 0.31% (Northern Wheatear *Oenanthe oenanthe* in RPs) to 72.85 ± 1.21% (Eurasian Blackcap *Sylvia atricapilla* in RPs).

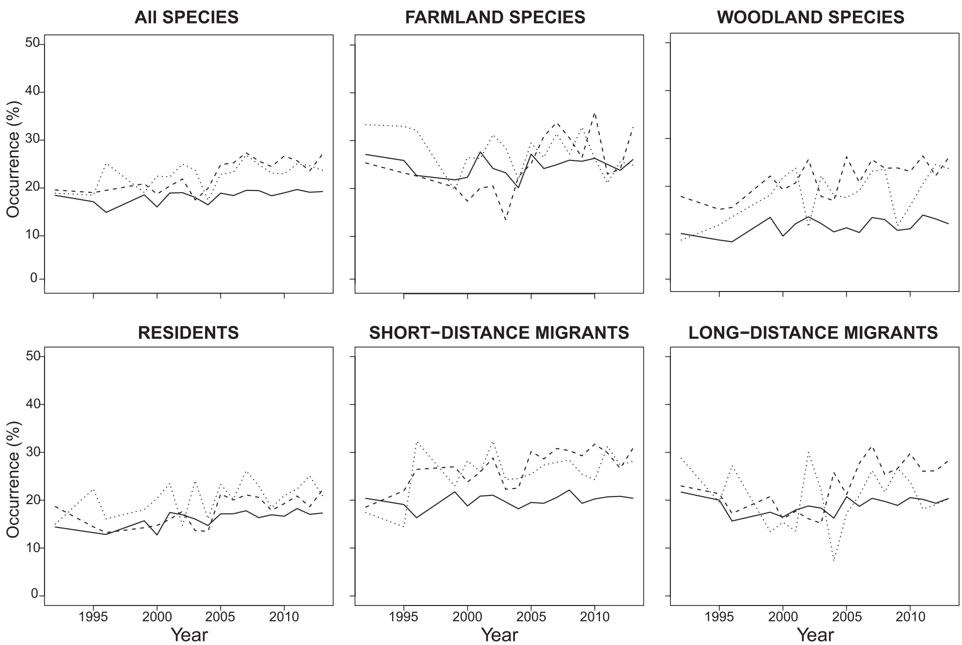

Figure 2. Mean occurrence of all species and of different subsets of species in each year and protection category. Occurrence of a species was calculated as the ratio of point counts where that species was detected in each year and protection category over the total number of point counts performed in that year and protection category within the altitudinal range of that species. Solid lines: non protected areas, dashed lines: regional parks, dotted lines: nature reserves (see Figure S2 for larger images reporting also standard errors).

Log-occurrence indices significantly differed among protection categories ($F_{2,106} = 9.252$, $P_{perm} = 0.001$), with significantly lower values in NPAs than in both RPs and NRs, which did not differ to one another (Figure 3A).

Overall, bird populations significantly increased in Lombardy during the study period by 2.46 ± 0.48% per year ($t_{54} = 5.165$, $P < 0.001$), as indicated by a LMM run on log-trend indices reported in Table S1 with only the intercept as fixed effect and species as random factor. However, we note that this general increase was the balance between trends of species that showed marked increases (e.g. Song Thrush *Turdus philomelos*: +10.83 ± 0.82% per year; Woodpigeon *Columba palumbus*: +9.53 ± 0.49% SE per year; Linnet: +9.46 ± 1.20% per year) and those of species that sharply declined in the last two decades (e.g. European Goldfinch *Carduelis carduelis*: -4.82 ± 0.29% per year; Cetti's Warbler *Cettia cetti*: -4.17 ± 0.55% per year; European Greenfinch *Carduelis chloris*: -4.11 ± 0.31% per year; see Table S1 for trends of all species).

Trend indices of species in each protection category ranged from -11.37 ± 2.81% per year (Cetti's Warbler *Cettia cetti* in NRs) to +15.45 ± 4.22% per year (Spotted Flycatcher *Muscicapa striata* in NRs) with significant differences among protection categories ($F_{2,106} = 3.422$, $P_{perm} = 0.026$). Indeed, log-trend indices were more positive in RPs than in both, NRs and NPAs, which, in turn, did not differ significantly from one another (Figure 3B). In addition, log-trend indices were significantly positive only in RPs (Figure 3B).

Farmland and woodland species

Log-occurrence indices of farmland species did not differ among protection categories ($F_{2,32} = 0.084$, $P_{perm} = 0.925$). In contrast, those of woodland species did ($F_{2,28} = 24.439$, $P_{perm} = 0.001$) and

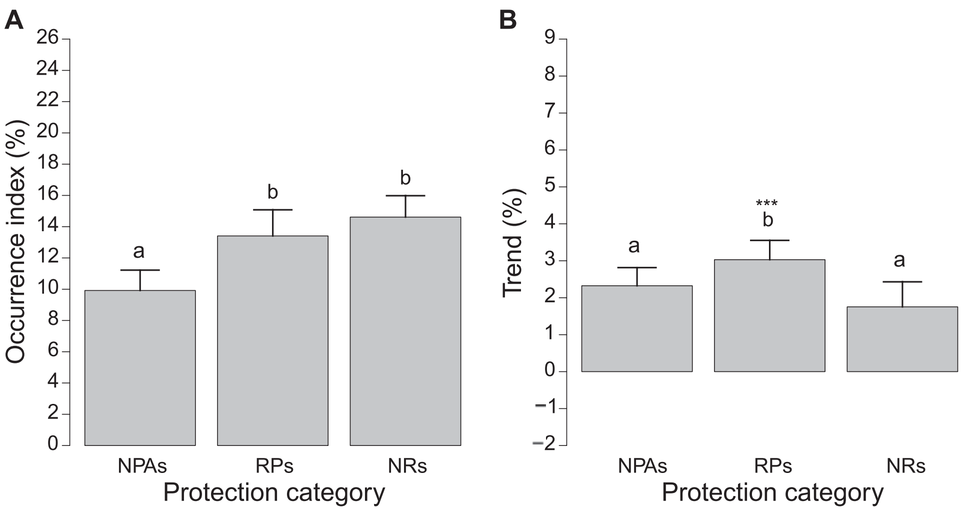

Figure 3. A) Occurrence indices (exponential of the intercept of log-binomial GLMs) and B) trends (exponential of the slope of log-binomial GLMs minus one) of all species in different protection categories (NPAs: non-protected areas, RPs: regional parks and Natura 2000 sites, NRs: national park and nature reserves). Bars represent standard errors. Different letters above bars denote protection categories that differed at post-hoc tests. In B, asterisks above bars denote protection categories where log-trend indices were significantly positive (* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$). Scales of vertical axes are held constant in all figures to facilitate comparison of population indices and trends.

were lower in NPAs than in both RPs and NRs (Figure 4A). Log-trend indices of farmland species differed significantly among protection categories ($F_{2,32} = 7.285$, $P_{perm} = 0.003$). In particular, they showed higher values in RPs than in the other protection categories, which, in turn, did not differ significantly from one another (Figure 4B).

Finally, log-trend indices of farmland birds were significantly positive only in RPs, while they did not differ from zero in the other protection categories (Figure 4B), or when all protection

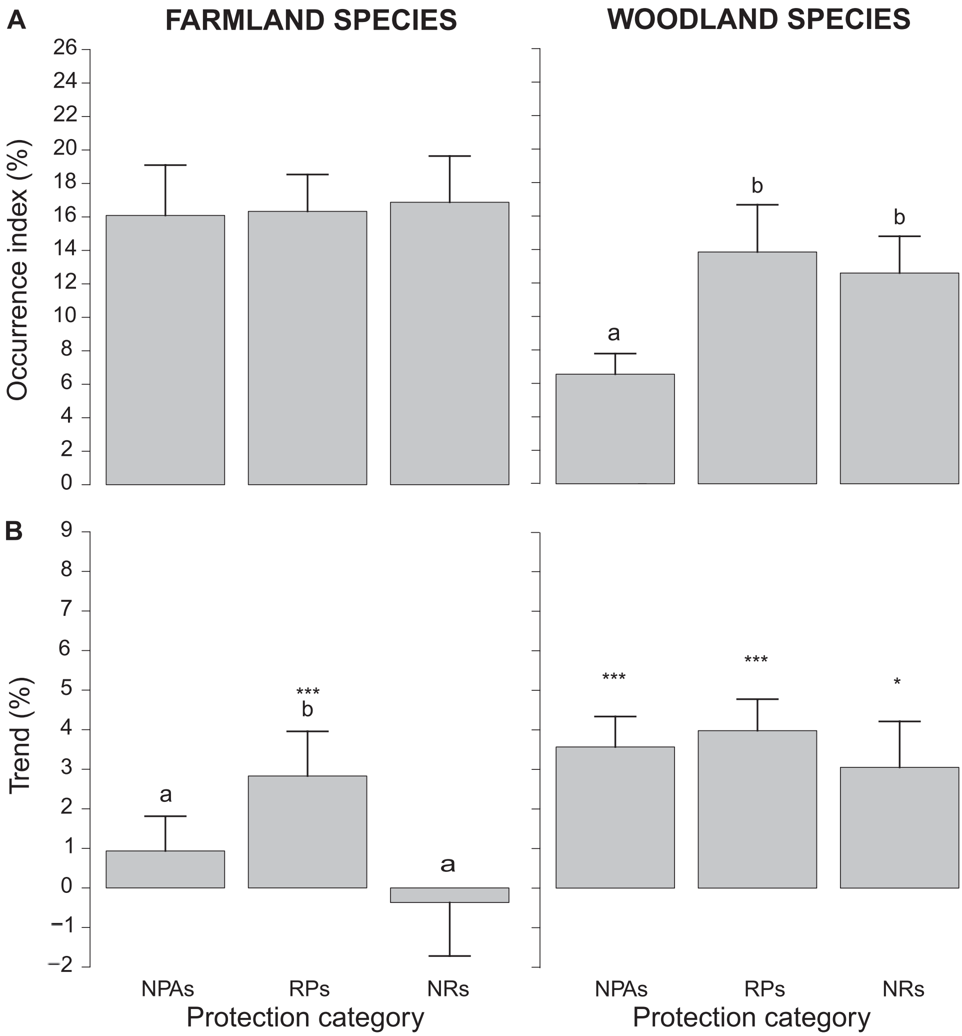

Figure 4. A) Occurrence indices (exponential of the intercept of log-binomial GLMs) and B) trends (exponential of the slope of log-binomial GLMs minus one) of farmland and woodland species in different protection categories (NPAs: non-protected areas, RPs: regional parks and Natura 2000 sites, NRs: national park and nature reserves). Bars represent standard errors. Different letters above bars denote protection categories that differed at post-hoc tests. In B, asterisks above bars denote protection categories where log-trend indices were significantly positive (* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$). Scales of vertical axes are held constant in all figures to facilitate comparison of indices.

categories were pooled (+1.12 ± 0.98% per year, $t_{34} = 1.157$, P = 0.255). In contrast, log-trend indices of woodland species did not differ among protection categories ($F_{2,28} = 1.600$, $P_{perm} = 0.258$), were significantly positive in all protection categories (Figure 4B), and when all protection categories were pooled (+2.96 ± 0.89% per year, $t_{30} = 3.376$, $P = 0.002$).

Resident species and short- and long-distance migrants

The analyses run separately for species with different migratory habits showed that log-occurrence indices of RESs and SDMs differed significantly among protection categories (RESs: $F_{2,38} = 5.499$, $P_{perm} = 0.013$: SDMs: $F_{2,42} = 7.987$, $P_{perm} = 0.003$). In details, log-occurrence indices of RESs were significantly higher in NRs than in NPAs, while in RPs they were intermediate and not significantly different from those in the other protection categories (Figure 5A). In contrast, those of SDMs were significantly lower in NPAs than in the other protection categories (Figure 5A). Finally, log-occurrence indices of LDMs did not differ significantly among protection categories ($F_{2,22} = 0.175$, $P_{perm} = 0.863$; Figure 5A). Log-trend indices of RESs differed significantly among protection categories ($F_{2,38} = 6.127$, $P_{perm} = 0.005$) and were significantly lower in NRs than in

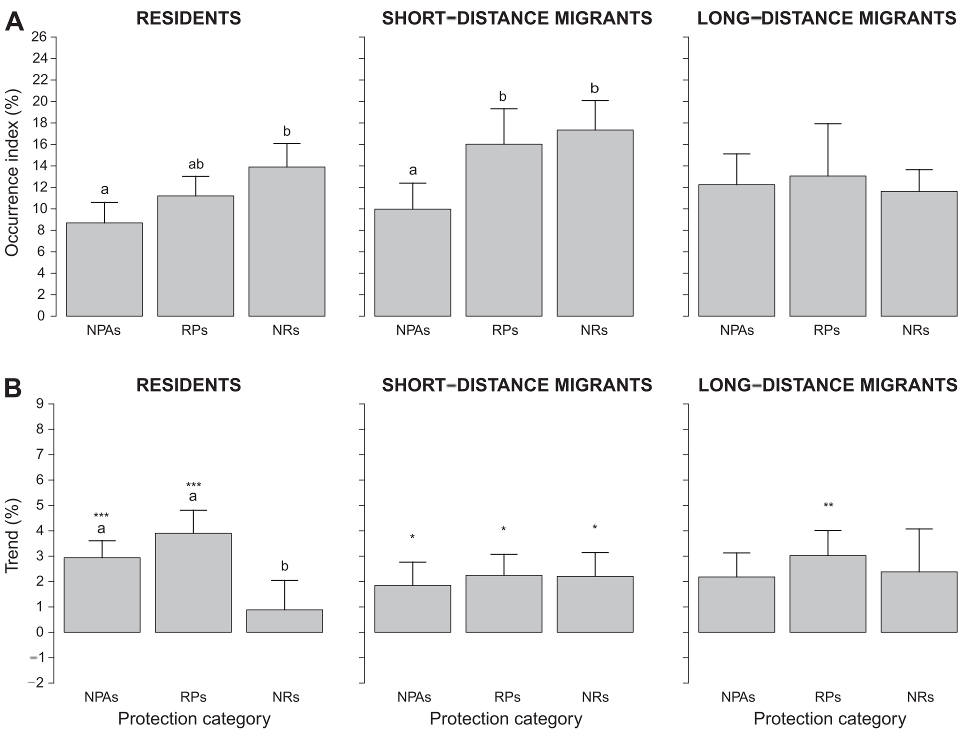

Figure 5. A) Occurrence indices (exponential of the intercept of log-binomial GLMs) and B) trend indices (exponential of the slope of log-binomial GLMs minus one) of residents, short-distance migrants and long-distance migrants in different protection categories (NPAs: non-protected areas, RPs: regional parks and Natura 2000 sites, NRs: national park and nature reserves). Bars represent standard errors. Different letters above bars denote protection categories that differed at post-hoc tests. In B, asterisks above bars denote protection categories where log-trend indices were significantly positive (* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$). Scales of vertical axes are held constant in all figures to facilitate comparison of indices.

both NPAs and RPs (Figure 5B). In contrast, log-trend indices of both SDMs and LDMs did not differ significantly among protection categories (SDMs: $F_{2,38} = 6.127$, $P_{perm} = 0.005$; LDMs: $F_{2,22} = 1.320$, $P_{perm} = 0.349$; Figure 5B).

Overall, log-trend indices of RESs, SDMs and LDMs were positive when all protection categories were pooled together (RESs: +2.57 ± 0.80% per year, $t_{40} = 3.336$, $P = 0.002$; SDMs: +2.10 ± 0.81% per year, $t_{44} = 2.602$, $P = 0.013$; LDMs: +2.53 ± 1.08% per year, $t_{240} = 2.376$, $P = 0.026$). In contrast, when we analysed log-trend indices of RESs, SDMs and LDMs in each protection category separately, we found that RESs increased significantly in NPAs and RPs, but not in NRs, SDMs increased significantly in all protection categories, and LDMs increased significantly in RPs only (Figure 5B).

Discussion

Occurrence and trend indices of common birds in PAs and NPAs

Our analyses showed that occurrence indices were, on average, larger in PAs (both NRs and RPs) than in NPAs (Figure 3A). This finding is consistent with our predictions, and confirms the general effectiveness of PAs of Lombardy in conserving breeding birds. Trend indices of common bird species differed among protection categories, and were significantly positive only in RPs, while they did not differ from zero in both NRs and NPAs (Figure 3B). This result is only partly consistent with our expectations, because we predicted trend indices to be more positive in all PAs than in NPAs. Most PAs considered in the present study were established between the 1980s and the 1990s (Lombardy Regional Law n. 86, 30 November 1983; Canova 2006), so the effects of protection measures should have had time to produce detectable responses at the population level. Indeed, it has been recognised that there is often a lag of about 10 years between establishment of a protected area and detectable responses at population levels (Male and Bean 2005, Donald *et al.* 2007).

The fact that bird populations increased in RPs only, while trends were similar and stable in both NRs and NPAs may be explained by different, not mutually exclusive, processes. First, we can speculate that NRs are close to their carrying capacity, and bird populations in them are therefore stable. Second, NRs may act as sources of individuals that move to surrounding areas. Importantly, some NRs were established in the best natural areas within RPs. The increase observed in RPs may therefore be due both to protection measures in RPs and to the dispersal of individuals from source areas in NRs. If this interpretation were true, PAs of Lombardy would have fully achieved their goals, even if populations in NRs sites of Lombardy are increasing less than in RPs, as they conserve bird communities and allow their increase within RPs or in surrounding areas. In the present study, we cannot assess if this interpretation is correct, and further studies on this topic are therefore needed. Such studies may investigate, for example, not only species occurrence, but also abundance and breeding success in different protection categories as well as investigate dispersal of individuals from NRs. Indeed, differences in breeding output and studies on dispersal may elucidate whether NRs actually act as sources of individuals for RPs. We stress that the implementation of large-scale studies on breeding output of common bird species, as well as on dispersal of individuals from areas at different protection categories, should be a priority for the decision-makers involved in the management of the network of PAs in Lombardy, because they will provide pivotal information to assess further the effectiveness of PAs.

Farmland and woodland species

The analyses run on farmland and woodland species indicated that PAs were only partially effective in preserving farmland birds, because occurrence indices of these species were similar in all protection categories and their trend indices increased in RPs only (Figure 4). In contrast, they were effective in protecting woodland birds, because occurrence indices were larger in them than in NPAs and trend indices of these species were positive in all protection categories, including NPAs.

We had no clear view the effectiveness of PAs in preserving farmland birds. Farmlands are often regarded as low-value areas for nature conservation (Oldfield *et al.* 2004, Powell at al. 2000, Scott *et al.* 2001). Consequently, very few NRs have been established in agricultural areas (indeed farmlands represent only the 10.1% of the total area of NRs in Lombardy). Most farmland birds covered by this study are common and widespread. PAs may thus not be suited to protect such species, because they perform much better at protecting species with more restricted ranges and specific habitat needs (this applies also to LDMs, see below). Different forms of protection should therefore be envisaged for these species, which are generally declining at a continental scale (Tucker and Heath 1994, Pain and Pienkowski 1997, Donald *et al.* 2001, Gregory and Strien 2010). They should recommend environmentally friendly agricultural practices and a strong involvement of private landowners with the precise aim of favouring the growth of farmland bird populations and the overall agro-ecosystem biodiversity.

In contrast to NRs, RPs of Lombardy also protect agricultural areas (farmlands represent 28.9% of the total area of RPs). However, in these PAs management plans exist that promote agro-ecosystem biodiversity (Sinibaldi and Tallone 2008). The fact that farmland birds are increasing in RPs only, may therefore suggest that more environmentally friendly agricultural practices may be effective for protecting farmland birds.

Finally, we stress that the overall stability (or increase, in RPs only) of population trends of farmland birds should be cautiously interpreted, because trends in these species are largely divergent, with some species that largely increased (e.g. Woodpigeon, +9.53 ± 0.49% per year) and species that suffered dramatic declines (e.g. European Goldfinch, -4.82 ± 0.29% per year). Moreover, some farmland bird species that are declining most in Lombardy, such as the Skylark *Alauda arvensis* and the Red-backed shrike *Lanius collurio* (Bani *et al.* 2009) were not detected in a sufficient number of point counts to be included in the present analyses. This may have determined a possible overestimate of the general trend of farmland species.

PAs of Lombardy seem effective in preserving woodland birds, at least because occurrence indices are higher in them than in NPAs. A large number of NRs in Lombardy were established in residual forests (which indeed represent 30.0% of the total area of NRs in Lombardy), so that their effectiveness in preserving woodland birds was expected. The fact that trend indices of woodland birds were positive and did not differ among protection categories may be due to the general increase in woodland extent that is occurring in Lombardy due to the abandonment of farming in the mountains and the consequent re-colonisation of pastures by secondary woods (Scazzosi 2013, Garbarino 2014).

Our classification of farmland and woodland birds was based on the land use around point counts where a species was detected. On the one side, this classification is based on the data, and therefore represents the habitat preference of these species in Lombardy. On the other side, we acknowledge that the classification of some species may be surprising. For example, the Grey Heron *Ardea cinerea* and the Mallard *Anas platyrhynchos* are commonly considered wetland rather than farmland species. However, the first species is often observed foraging in arable fields in Lombardy, and the second, albeit always linked to watercourses, very often occurs in canals between fields. In order to assess whether this selection of species may have biased our conclusions on farmland and woodland birds, we re-ran the analyses by including only species classified farmland or woodland by PECBMS for the continental bioregion of Europe (http://www.ebcc.info/index.php?ID=564, accessed June 10, 2016). We found that results were identical for woodland species and only partially different for farmland species (Appendix S3). Indeed, log-occurrence indices of species classified as farmland by PECBMS did not differ among protection categories (Figure S3A), while their log-trends indices showed higher values in NPAs than in NRs, and intermediate values in RPs (Figure S3B). In addition, log-trend indices of farmland species showed no significant increase in any protection category (Figure S3B), nor when all protection categories were pooled (Appendix S3). Despite a slight difference in the results of log-trend indices, these analyses confirmed that PAs of Lombardy do not seem effective in protecting farmland species. Hence, our results seem robust to the different criteria used to classify farmland and woodland species.

Resident and migratory birds

Species with different migratory habits showed different patterns of variation in occurrence and trend indices among protection categories. NRs seem to favour RESs and SDMs, at least because occurrence indices were more positive in NRs than in NPAs, but population trends of these species did not differ among protection categories, and RESs seem not to increase in NRs (Figure 5). In contrast, both occurrence and trend indices of LDMs in PAs were similar to those in NPAs. We must therefore conclude that there is little evidence that PAs of Lombardy favour LDMs. This is particularly worrying because LDM populations are suffering sharp declines at a continental scale (Sanderson *et al.* 2006). Importantly, these species were generally not declining in Lombardy, and they were slightly increasing in RPs. However, also in this case, some of these species largely increased (e.g. Lesser Whitethroat *Sylvia curruca*, +8.72 ± 1.19% per year) while other declined (e.g. Common House Martin *Delichon urbicum*, -1.67 ± 0.32% per year). Similar to farmland birds, LDMs covered by this study are common and widespread species, so PAs may not be suited to protect them (see above). LDMs and farmland species may therefore need novel and different protection measures, like more environmentally friendly land management (see also above).

Comparison with bird population trends at continental scale

The results of the present study partially contrast with estimates of bird population trends in Europe (Tucker and Heath 1994, BirdLife International 2004, PECBMS 2012), which showed a general decline of bird populations in the last few decades, and in particular a strong decline in farmland birds (Donald *et al.* 2001, 2006) and LDMs (Both *et al.* 2010, Møller *et al.* 2008, Sanderson *et al.* 2006). In Lombardy, we observed a general increase in bird occurrence in the last 20 years, an increase of LDMs, and a non-significant trend of farmland species. It should be stressed that the general trend we observed in any group of species is the balance among those of species that showed opposite tendencies. For example, among the 10 species that declined more, five were farmland and eight migrant birds, three of which LDMs, while among the 10 species that increased more, only two were farmland species and six were migrants, only two of which were LDMs (Table S2). Hence, the evidence that generally LDMs were increasing and farmland birds were not declining in Lombardy must not be interpreted as evidence that *any* LDM or farmland species was not declining, and therefore must not reduce existing efforts to protect those species that are suffering sharp declines in all environments.

Conclusions and conservation implications

In the present study, we showed that PAs of Lombardy were effective in preserving common breeding bird populations in the last two decades. This conclusion is based on the observation that occurrence indices were higher in PAs than in NPAs. Trend indices of bird populations showed on average positive values in Lombardy, which were, however, the balance between large increases of some species, and sharp declines of other ones. This evidence suggests that the general environment of Lombardy became more suitable for some common bird populations during the last 20 years, but not for others.

PAs seemed effective in protecting woodland and SDM species because their occurrence indices were larger in PAs than in NPAs. This may be because 30.3% of PAs is woodlands, six out of 22 SDM species are woodland species, and forest areas of Lombardy have increased in extent and have been less intensively exploited in the last two decades (Massimino *et al.* 2010). PAs of Lombardy seem less effective in protecting farmland birds and LDMs. Low effectiveness of PAs in protecting farmland birds has been documented also in the recent Regulatory Fitness and Performance Programme (REFIT, http://ec.europa.eu/environment/nature/legislation/fitness_check/index_en.htm, accessed on July 26, 2016) of the EU aiming at assessing the effectiveness of the

N2000 network of PAs. Indeed the REFIT procedure generally found that N2000 network performed well in protecting birds, but according to the Italian National Summary for Article 12 of the Birds Directive (https://circabc.europa.eu/sd/a/b97edd9d-cd83-4cc7-8ca2-c66997b2e2f4/IT_A12NatSum_20141031.pdf, accessed on July 26, 2016), agriculture was the main pressure in these PAs in Italy.

Most farmland birds and LDMs covered by this study are common and widespread species, so that they may not be suited to being well protected by PAs. If this interpretation were correct, the best way to protect these species would be to implement ecologically sustainable land use policies, particularly in agro-environment schemes. These new conservation measures should recommend environmentally friendly agricultural practices and strong involvement of private landowners with the precise aim of favouring the growth of farmland and LDM bird populations and the overall agro-ecosystem biodiversity.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/S095927091700017X

Acknowledgements

We are grateful to Dr. Vittorio Vigorita (former Head of Planning Wildlife and Hunting Office of Agriculture General Directorate) and Dr. Laura Cucé. Special thanks go to Professor Renato Massa, who first had the idea to start the Breeding Bird Monitoring Program in Lombardy. Comments by two anonymous reviewers greatly improved the quality of the paper. Regional Agency for Agriculture and Forestry (ERSAF, Ente Regionale per i Servizi all'Agricoltura e alle Foreste) and the Agriculture General Directorate of Lombardy Regional Administration (DG - Agricoltura, Regione Lombardia) supported the Regional Breeding Bird Monitoring Program.

References

Balmford, A., Green, R. E. and Jenkins, M. (2003) Measuring the changing state of nature. *Trends Ecol. Evol.* 18: 326–330.

Bani, L., Massimino, D., Orioli, V., Bottoni, L. and Massa, R. (2009) Assessment of population trends of common breeding birds in Lombardy, Northern Italy 1992-2007. *Ethol. Ecol. Evol.* 21: 27–44.

BirdLife International (2004) *Birds in Europe. Population estimates, trends and conservation status*. Cambridge, UK: BirdLife International.

Blondel, J., Ferry, C. and Frochot, B. (1981) Points counts with unlimited distance. *Stud. Avian Biol.* 6: 414–420.

Boakes, E. H., McGowan, P. J. K., Fuller, R. A., Chang-qing, D., Clark, N. E., O'Connor, K. and Mace, G. M. (2010) Distorted views of biodiversity: Spatial and temporal bias in species occurrence data. *PLoS Biol* 8(6): e1000385.

Both, C., van Turnhout, C. A. M., Bijlsma, R. G., Siepel, H., Van Strien, A. J. and Foppen, R. P. B. (2010) Avian population consequences of climate change are most severe for long-distance migrants seasonal habitats. *Proc. R. Soc. B Biol. Sci.* 277: 1259–1266.

Brichetti, P. and Fasola, M. eds (1990) *Atlante degli uccelli nidificanti in Lombardia*. Brescia, Italy: Editoriale Ramperto (In Italian).

Cabeza, M. (2013) Knowledge gaps in protected area effectiveness. *Anim. Conserv.* 16: 381–382.

Canova, L. (2006) Protected areas and landscape conservation in the Lombardy plain (northern Italy): An appraisal. *Landsc. Urban Plan.* 74: 102–109.

Chape, S., Spalding, M. and Jenkins, M. D. (2008) *The world's protected areas*. Prepared by the UNEP World Conservation Monitoring Centre. Berkeley, USA: University of California Press.

Devictor, V., Godet, L., Juliard, R., Couvet, D. and Jiguet, F. (2007) Can common species benefit from protected areas? *Biol. Conserv*. 139: 29–36.

Donoghoe, M. W. (2015) logbin: Relative Risk Regression Using the Log-Binomial Model. Permanent url: http://cran.r-project.org/package=logbin (accessed 12 December 2016).

Donald, P. F., Green, R. E. and Heath, M. F. (2001) Agricultural intensification and the collapse of Europe's bird populations *Proc. R. Soc. B Biol. Sci.* 268: 25–29.

Donald, P. F., Sanderson, F. J., Burfield, I. J and van Bommel, F. P. J. (2006) Further evidence of continent-wide impacts of agricultural intensification on European farmland birds, 1990-2000. *Agric. Ecosyst. Environ*. 116: 189–196.

Donald, P. F., Sanderson, F. J., Burfield, I. J., Bierman, S. M., Richard, D. and Waliczky, Z. (2007) International conservation policy delivers benefits for birds in Europe. *Science* 317: 810–813.

EC (2002) *Commission working document on Natura 2000*. Brussels, Belgium: European Commission.

EEA (2012) *Protected areas in Europe - an overview*. Copenhagen, Denmark: European Environment Agency.

Eglington, S. M., Noble, D. G. and Fuller, R. J. (2012) A meta-analysis of spatial relationships in species richness across taxa. Birds as indicators of wider biodiversity in temperate regions. *J. Nat. Conserv.* 20: 301–309.

Fornasari, L., Bani, L., de Carli, E. and Massa, R. (1998) Optimum design in monitoring common birds and their habitat. *Gibier Faune Sauvage* 15: 309–322.

Fornasari, L., Bottoni, L., Massa, R., Fasola, M., Brichetti, P. and Vigorita, V., eds. (1992) *Atlante degli uccelli svernanti in Lombardia*. Milano, Italy: Regione Lombardia-Università degli Studi di Milano. (In Italian).

Garbarino, M. (2014) Wood pasture profiles: Musella, Italy. In: T. Hartel and T. Plieninger, eds. *European woodland pastures in transition. A socio-ecological approach*. Abingdon, UK: Routledge.

Gaston, K. J. (2011) Common ecology *BioScience* 61: 354–362.

Geldmann, J., Barnes, M., Coad, L., Craigie, I. D., Hockings, M. and Burgess, N. D. (2013) Effectiveness of terrestrial protected areas in reducing habitat loss and population declines. *Biol. Conserv.* 161: 230–238.

Gregory, R. and Strien, A. (2010) Wild bird indicators: using composite population trends of birds as measures of environmental health. *Ornithol. Sci.* 22: 3–22.

Gregory, R. D., Noble, D., Field, R., Marchant, J., Raven, M. and Gibbons, D. W. (2003) Using birds as indicators of biodiversity. *Ornis Hungarica* 12: 11–24.

Jackson, S. F., Evans, K. L. and Gaston, K. J. (2009) Statutory protected areas and avian species richness in Britain. *Biodivers. Conserv*. 18: 2143–2151.

Lenth, R. (2015) lsmeans: Least-Squares Means. Permanent url: http://cran.r-project.org/package=lsmeans (accessed 12 December 2016).

Lindenmayer, D. B. and Likens, G. E. (2010) The science and application of ecological monitoring. *Biol. Conserv*, 143: 1317–1328.

Luo, D., Ganesh, S. and Koolaard, J. (2014) predictmeans: Calculate Predicted Means for Linear Models. Permanent url: http://cran.r-project.org/package=predictmeans (accessed 12 December 2016).

Male, T. D. and Bean, M. J. (2005) Measuring progress in US endangered species conservation. *Ecol. Lett.* 8: 986–992.

Massimino, D., Orioli, V., Pizzardi, F., Massa, R. and Bani, L. (2010) Usefulness of coarse grain data on forest management to improve bird abundance models. *Ital. J. Zool*. 77: 71–80.

McNutt, L-A., Wu, C., Xue, X. and Hafner, J. P. (2003) Estimating the relative risk in cohort studies and clinical trials of common outcome. *Am. J. Epidemiol.* 157: 940–943.

Meffe, G. K. and Carroll, C. R. (1994) *Principles of conservation biology*. Sunderland, USA: Sinauer Associates, Inc.

Møller, A P., Rubolini, D. and Lehikoinen, E. (2008) Populations of migratory bird species that did not show a phonological response to climate change are declining. *Proc. Natl. Acad. Sci. USA*. 105: 16195–16200.

Oldfield, T., Smith, R. J., Harrop, S. R. and Leader-Williams, N. (2004) A gap analysis of terrestrial protected areas in England and its implications for conservation policy. *Biol. Conserv*. 120: 303–309.

Pain, D. J. and Pienkowski, M. W. (1997) *Farming and birds in Europe*. London, UK: Academic Press.

PECBMS (Pan-European Common Bird Monitoring Scheme) (2012) *Population trends of common European breeding birds 2011*. Prague, Czech Republic: CSO/RSPB.

Pellissier, V., Touroult, J., Julliard, R., Siblet, J. P. and Jiguet, F. (2013) Assessing the Natura 2000 network with a common breeding birds survey. *Anim. Conserv*. 16: 566–574.

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., and Core Team, R (2015) nlme: Linear and Nonlinear Mixed Effects Models. Permanent url: http://cran.r-project.org/package=nlme (accessed 12 December 2016).

Pollard, K. S., Dudoit, S., and van der Laan, M. J. (2005) *Multiple testing procedures: R mult-test package and applications to genomics, in bioinformatics and computational biology solutions using R and bioconductor*. New York, NY: Springer.

Powell, G. V. N., Barborak, J. and Rodriguez, M. (2000) Assessing representativeness of protected natural areas in Costa Rica for conserving biodiversity, a preliminary gap analysis. *Biol. Conserv*. 93: 35–41.

Primack, R. B. (2012) *A primer of conservation biology*. 5th edition. Sunderland, USA: Sinauer Associates, Inc.

Pullin, A. S. (2004) *Conservation biology*. Cambridge, UK: Cambridge University Press.

R Core Team (2015) *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Rayner, L., Lindenmayer, D. B., Wood, J. T., Gibbons, P. and Manning, A. D. (2014) Are protected areas maintaining bird diversity? *Ecography*, 37: 43–53.

Sanderson, F. J., Donald, P. F., Pain, D. J., Burfield, I. J. and van Bommel, F. P. J. (2006) Long-term population declines in Afro-Palearctic migrant birds. *Biol. Conserv*. 131: 93–105.

Scazzosi, L. (2013) *Lombardy*. In M. Agnoletti, ed. *Italian historical rural landscapes. Cultural values for the environment and rural development*. Berlin, Germany: Springer.

Scott, J. M., Davis, F. W., McGhie, R. G., Wright, R. G., Groves, C. and Estes, J. (2001) Nature reserves, do they capture the full range of America's biological diversity? *Ecol. Appl*. 11: 999–1007.

Sekercioglu, C. H. (2006) Increasing awareness of avian ecological function. *Trends Ecol. Evol*. 21: 464–471.

Sinibaldi, I. and Tallone, G. (2008) Classification of protected areas in the Italian regional legislation with special reference to the Lazio region. Pp. 87–105 in G. Tamburelli, ed. *Legal systems for the management of protected areas in Italy and Ucraina*. Milano, Italy: Giuffrè Editore.

Spina, F. and Volponi, S. (2008a) *Atlante della migrazione degli uccelli in Italia. 1. Non-Passeriformi*. Rome, Italy: Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA). (In Italian and English).

Spina, F. and Volponi, S. (2008b) *Atlante della migrazione degli uccelli in Italia. 2. Passeriformi*. Rome, Italy: Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA). (In Italian and English).

Storey, J. D. (2002) A direct approach to false discovery rates. *J. Roy. Stat. Soc. B* 64: 479–498.

Tucker, G. M. and Heath, M. F. (1994) *Birds in Europe, their conservation status*. Cambridge, UK: Birdlife International.

UN (United Nations) (1992) *Convention on biological diversity*. Brazil, Rio de Janeiro: United Nations conference on environment and development.

Wiens, J. A. (1989) *The ecology of bird communities. Vol. 1: Foundations and patterns*. New York, NY : Cambridge University Press.

Zuur, A. F., Ieno, E. N., Walker, N. J., Saveliev, A. A. and Smith, G. M. (2009) *Mixed effects models and extensions in ecology with R*. Berlin, Germany: Springer Verlag.

BEATRICE SICURELLA*
Department of Biotechnology and Biosciences, University of Milano-Bicocca, Piazza della Scienza 2, 20126 Milano, Italy.

VALERIO ORIOLI, ROBERTO AMBROSINI*, LUCIANO BANI*
Department of Earth and Environmental Sciences, University of Milano-Bicocca, Piazza della Scienza 1, 20126 Milano, Italy.

GUIDO PINOLI
Lombardy Region General Directorate for Agriculture, Piazza Città di Lombardia 1, 20124 Milano, Italy.

**Authors for correspondence; e-mail: roberto.ambrosini@unimib.it; luciano.bani@unimib.it; beatrice.sicurella@gmail.com*

Received 30 October 2015; revision accepted 13 April 2017