Supplementary materials

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

Beatrice Sicurella[a], Valerio Orioli[b], Guido Pinoli[c], Roberto Ambrosini[b], Luciano Bani[b]

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

b Department of Earth and Environmental Sciences, University of Milano-Bicocca, Piazza della Scienza 1, 20126 Milano, Italy.

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

Corresponding authors: Roberto Ambrosini, email: roberto.ambrosini@unimib.it, tel: +390264483415, Luciano Bani, email: luciano.bani@unimib.it, tel: +390264482944 , tel: +390264482936

Other authors email: beatrice.sicurella@gmail.com; valerio.orioli@unimib.it; guido_pinoli@regione.lombardia.it.

Text S1: Selection criterion of point counts where a species could potentially be observed

In the calculation of the number of point counts where a species could *potentially* be observed, we aimed at excluding false zeroes from the analyses i.e. at excluding point counts outside the altitude range of a species. The criterion we used was to include only the point counts between the maximum and the minimum altitude at which a species was actually detected in all the point counts in our database. We considered inappropriate any further restriction according to habitat requirement of a species as it would have led to the exclusion of individuals detected in marginal habitats or in habitats different from the main one(s) of the species. In addition, this criterion based on altitude is tenable because in Lombardy climate conditions vary mainly according to altitude, which is also the major determinant of habitat type in this area. Finally, no species included in the present work is restricted to particular geographical areas within Lombardy (i.e. no species we considered occur only e.g. in the western part of Lombardy).

Text S2: Further details on log-binomial models

The most common approach for modelling binary outcomes in a linear model is logistic regression. The logistic regression models the log of the odds-ratio of observing a species in a point count (positive outcome), given a set of predictors (e.g. year, land use around the point etc.) i.e.:

$$\log\left(\frac{\hat{\pi}}{1-\hat{\pi}}\right) = \beta_0 + \beta_1 x_1 + \cdots + \beta_p x_p$$

$$Y \sim Binomial(\hat{\pi})$$

where $\hat{\pi}$ is the predicted probability that $Y = 1$, given the values $x_1 \ldots x_p$. Now suppose that the predicted probability of observing a species at a point count is p_0 when $x = 0$ and p_1 when $x = 1$, then

$$e^{\beta_0} = \frac{p_0}{1-p_0}$$

$$e^{\beta_1} = \frac{p_1}{1-p_1} - \frac{p_0}{1-p_0}$$

In other words, a unit increase of x determines an increase of e^{β_1} of the *odds* of observing a species. If p is small, then $1 - p \approx 1$ and the odds are very similar to probabilities, but the more p increases, the more odds and probabilities differ.

The present work focuses on the occurrence of *common* species (i.e. species whose probability of occurrence p is not small), thus odds do not approximate probability of occurrence. In such a case, a drawback of modelling species occurrence via logistic regression is that the model is linear in the log of the odds of the occurrence, and model coefficients allows estimating odds ratios, but not ratios of probabilities. This is particularly unfortunate if, as in our case, one aims at modelling the year-to-year variation in the occurrence of a species. Indeed, in a logistic model, the slope of the year covariate would model the log of the ratio of the odds of observing a species (see equation above) from one year to the following, *not* the proportional variation in the occurrence of a species.

An alternative parameterization of the generalized linear model exists, which allows for modelling variation in probabilities, rather in in odds. This parameterization uses a log link function applied to a binomial model (log-binomial model), i.e.:

$$\log(\hat{\pi}) = \beta_0 + \beta_1 x_1 + \cdots + \beta_p x_p$$

According to this parameterization, a unit increase in one predictor determines an increase of e^{β} in $\hat{\pi}$ i.e. an increase in the proportional variation in the occurrence of a species. Log-binomial models are gaining popularity in epidemiology, as they model the relative risk of incurring in an event, which in our case, is the probability of occurrence of a species.

When analysing temporal variation in presence-absence data, log-binomial models allows a "natural" interpretation of (the exponential of) the slope of the time covariate, because it allows easily calculating the proportional variation in the occurrence of a species in a unit of time. Indeed, in a log-binomial model,

$$e^{\beta_1} = \frac{p_1}{p_0}.$$

Subtracting one further easies the interpretation of this index, because $e^{\beta_1} - 1$ takes negative values when occurrence decreases and positive ones when it increases. For this reason, we preferred log-binomial models to logistic regression for modelling temporal variation in species occurrence.

One additional feature of our modelling approach deserves consideration. We aimed at estimating not only temporal variation in species occurrence, but also their mean occurrence in areas with different protection categories. To obtain such estimate from the model, we centred all predictors entered in the models. When centred predictors are used, e^{β_0} estimates the occurrence of a species when all predictors take their mean value. It should be taken in mind that we ran a model for each species in each protection category, and that we included in the model only those point counts within the altitude limits of each species. Hence, models for different species were fitted on different subsets of data. By centring predictors, we obtained that e^{β_0} estimated the expected occurrence of a species in a given protection category when the land use around the points equalled the mean land use in all points in that protection category where a species could potentially be observed (i.e. in the altitude range of the species) and in the average year of census in that area. With centred variable, e^{β_0} is therefore an estimate of the average occurrence of a species in a protection category in all the years of the census. For this reason we called the value e^{β_0} "occurrence index".

In summary, by using log-binomial models fitted on centred predictors, we were able to extract from presence-absence data two complementary pieces of information:

1. An occurrence index (exponential of the intercept of the log-binomial model), which represents the average occurrence of a species in all points performed in all years in a given protection category
2. A trend index (exponential of the slope of the year covariate minus one), which represents the temporal variation in the occurrence of a species in a given protection category.

Text S3: Results of analyses on species classified as farmland and forest according to PECMBS

Among the species observed in at least five years and in at least 30 points in each protection category, only five (*Carduelis cannabina*, *Hirundo rustica*, *Passer montanus*, *Streptopelia turtur*, *Sturnus vulgaris*) are considered farmland according to PECBMS classification for the Continental bioregion of Europe (http://www.ebcc.info/index.php?ID=564, accessed June 10, 2016).

Log-occurrence indices of these species did not differ significantly among protection categories ($F_{2,8}$ = 0.316, P_{perm} = 0.837; Figure S3A), while their log-trend indices did ($F_{2,8}$ = 32.923, P_{perm} = 0.008). However, differently to what was observed on farmland species classified according to land use around point counts, NPAs showed more positive trends than NRs, while RPs showed an intermediate value, that did not differ significantly from those in the other protection categories (Figure S3B). In addition, log-trend indices of birds species classified as farmland according to PECBMS did not differ from zero in any protection category (Figure S3B), nor when all protection categories were pooled (+1.71 ± 1.58% per year, t_{10} = 1.089, P = 0.302).

Nineteen species included in our analyses were classified as “forest” species according to PECBMS (corresponding to woodland species in our classification; *Anthus trivialis*, *Carduelis flammea*, *Garrulus glandarius*, *Lophophanes cristatus*, *Muscicapa striata*, *Nucifraga caryocatactes*, *Periparus ater*, *Phylloscopus collybita*, *Phoenicurus phoenicurus*, *Picus viridis*, *Poecile montana*, *Poecile palustris*, *Prunella modularis*, *Pyrrhula pyrrhula*, *Regulus regulus*, *Sitta europaea*, *Sylvia atricapilla*, *Troglodytes troglodytes*, *Turdus philomelos*). Log-occurrence indices of these species differed significantly among protection categories ($F_{2,36}$ = 15.518, P_{perm} = 0.001), with higher values in NRs and RPs than in NPAs (Figure S3A). Log-trend indices of woodland species did not differ significantly among protection categories ($F_{2,36}$ = 0.888, P_{perm} = 0.464), but were significantly positive in all protection categories (Figure S3B) and when all protection categories were pooled (+3.53 ± 0.81 % per year, t_{38} = 4.445, P < 0.001).

Table S1. List of the 58 species considered in the analyses according to their classification into farmland (F) or woodland (W) species and migratory habit. Occurrence and trend indices of each species are reported with standard error. Symbols next to scientific names indicate the ten species that increased (+) and the ten that decreased (-) most.

Species	Main Habitat	Migratory habit	Occurrence Index (%)	Trend Index (%)
Aegithalos caudatus	W	RES	5.97 ± 0.22	1.13 ± 0.57
***Anas platyrhynchos* (+)**	F	RES	6.66 ± 0.26	6.28 ± 0.58
Anthus spinoletta		SDM	3.49 ± 0.44	2.53 ± 0.57
Anthus trivialis		LDM	10.36 ± 0.50	5.16 ± 0.73
***Apus apus* (-)**		LDM	24.54 ± 0.39	-1.48 ± 0.22
Ardea cinerea	F	SDM	11.33 ± 0.34	2.72 ± 0.36
***Carduelis cannabina* (+)**		SDM	1.81 ± 0.20	9.46 ± 1.20
***Carduelis carduelis* (-)**	F	SDM	15.89 ± 0.33	-4.82 ± 0.29
***Carduelis chloris* (-)**	F	SDM	12.96 ± 0.33	-4.11 ± 0.31
Carduelis flammea		RES	11.53 ± 0.76	1.87 ± 0.98
***Cettia cetti* (-)**	F	RES	5.82 ± 0.25	-4.17 ± 0.55
***Columba palumbus* (+)**	F	SDM	9.97 ± 0.29	9.53 ± 0.49
Corvus cornix	F	RES	51.13 ± 0.46	1.06 ± 0.11
Cuculus canorus		LDM	26.37 ± 0.40	0.72 ± 0.24
Cyanistes caeruleus	W	RES	10.09 ± 0.29	3.54 ± 0.41
***Delichon urbicum* (-)**		LDM	13.15 ± 0.31	-1.67 ± 0.32
***Dendrocopos major* (+)**		RES	7.84 ± 0.25	6.96 ± 0.51
Egretta garzetta	F	SDM	14.08 ± 0.50	3.60 ± 0.49
Erithacus rubecula	W	SDM	10.79 ± 0.31	1.16 ± 0.28
Fringilla coelebs		SDM	48.98 ± 0.45	0.51 ± 0.10
Gallinula chloropus	F	RES	6.71 ± 0.29	1.03 ± 0.50
Garrulus glandarius	W	RES	5.73 ± 0.23	4.75 ± 0.54
***Hirundo rustica* (-)**	F	LDM	31.37 ± 0.48	-1.37 ± 0.15
Lophophanes cristatus	W	RES	3.96 ± 0.28	2.85 ± 0.87
Luscinia megarhynchos	F	LDM	26.76 ± 0.43	-0.26 ± 0.17
***Motacilla alba* (-)**		SDM	9.50 ± 0.25	-1.30 ± 0.46
Motacilla cinerea		SDM	3.49 ± 0.18	-0.73 ± 0.80
Muscicapa striata		LDM	10.15 ± 0.28	5.17 ± 0.47
Nucifraga caryocatactes	W	RES	4.65 ± 0.33	4.31 ± 1.26
***Oenanthe oenanthe* (+)**		LDM	0.58 ± 0.13	5.65 ± 0.81
Oriolus oriolus	F	LDM	7.29 ± 0.27	2.88 ± 0.52
Parus major		RES	34.42 ± 0.43	2.45 ± 0.21
***Passer italiae* (-)**	F	RES	32.73 ± 0.52	-0.85 ± 0.08
Passer montanus	F	RES	16.95 ± 0.41	0.28 ± 0.23

Periparus ater	W	RES	13.07 ± 0.38	1.55 ± 0.36
Phoenicurus ochruros		SDM	3.97 ± 0.18	5.19 ± 0.54
Phoenicurus phoenicurus		LDM	8.84 ± 0.26	3.93 ± 0.47
***Phylloscopus collybita* (-)**	W	SDM	8.56 ± 0.32	-1.03 ± 0.36
***Picus viridis* (+)**		RES	4.60 ± 0.20	5.31 ± 0.69
Poecile montana	W	RES	6.29 ± 0.40	4.27 ± 1.14
***Poecile palustris* (+)**	W	RES	3.16 ± 0.19	8.78 ± 0.71
***Prunella modularis* (+)**		SDM	2.03 ± 0.15	8.30 ± 0.79
Pyrrhula pyrrhula	W	SDM	6.75 ± 0.39	3.14 ± 0.92
***Regulus regulus* (-)**	W	SDM	7.33 ± 0.36	-0.92 ± 0.64
Serinus serinus		SDM	11.98 ± 0.31	2.20 ± 0.36
Sitta europaea	W	RES	1.97 ± 0.15	2.75 ± 0.83
Streptopelia decaocto	F	RES	19.24 ± 0.45	4.38 ± 0.26
Streptopelia turtur	F	LDM	10.48 ± 0.30	2.42 ± 0.45
Sturnus vulgaris	F	SDM	40.67 ± 0.53	0.84 ± 0.13
Sylvia atricapilla		SDM	66.22 ± 0.42	0.52 ± 0.10
***Sylvia curruca* (+)**		LDM	2.17 ± 0.19	8.72 ± 1.19
Troglodytes troglodytes	W	SDM	13.03 ± 0.33	-0.30 ± 0.31
Turdus merula		SDM	59.5 ± 0.44	0.36 ± 0.11
***Turdus philomelos* (+)**	W	SDM	4.14 ± 0.27	10.83 ± 0.82

Figure S1. Map of Lombardy showing the distribution of point counts. Orography is also shown in grey scale.

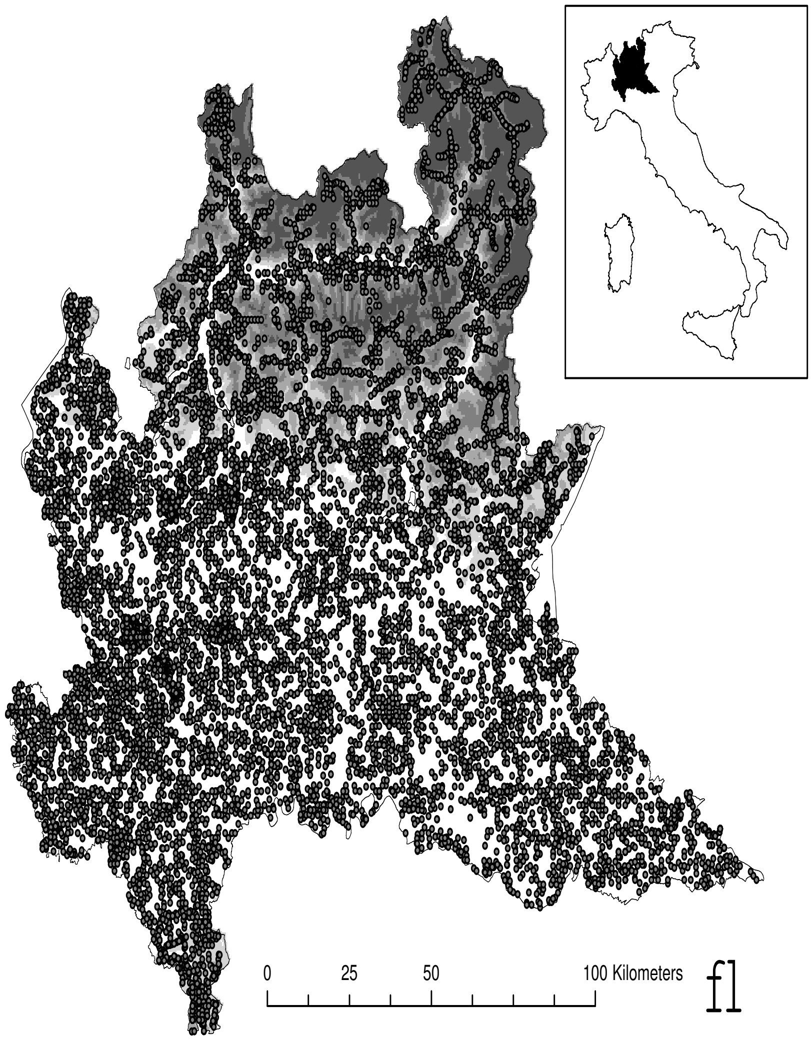
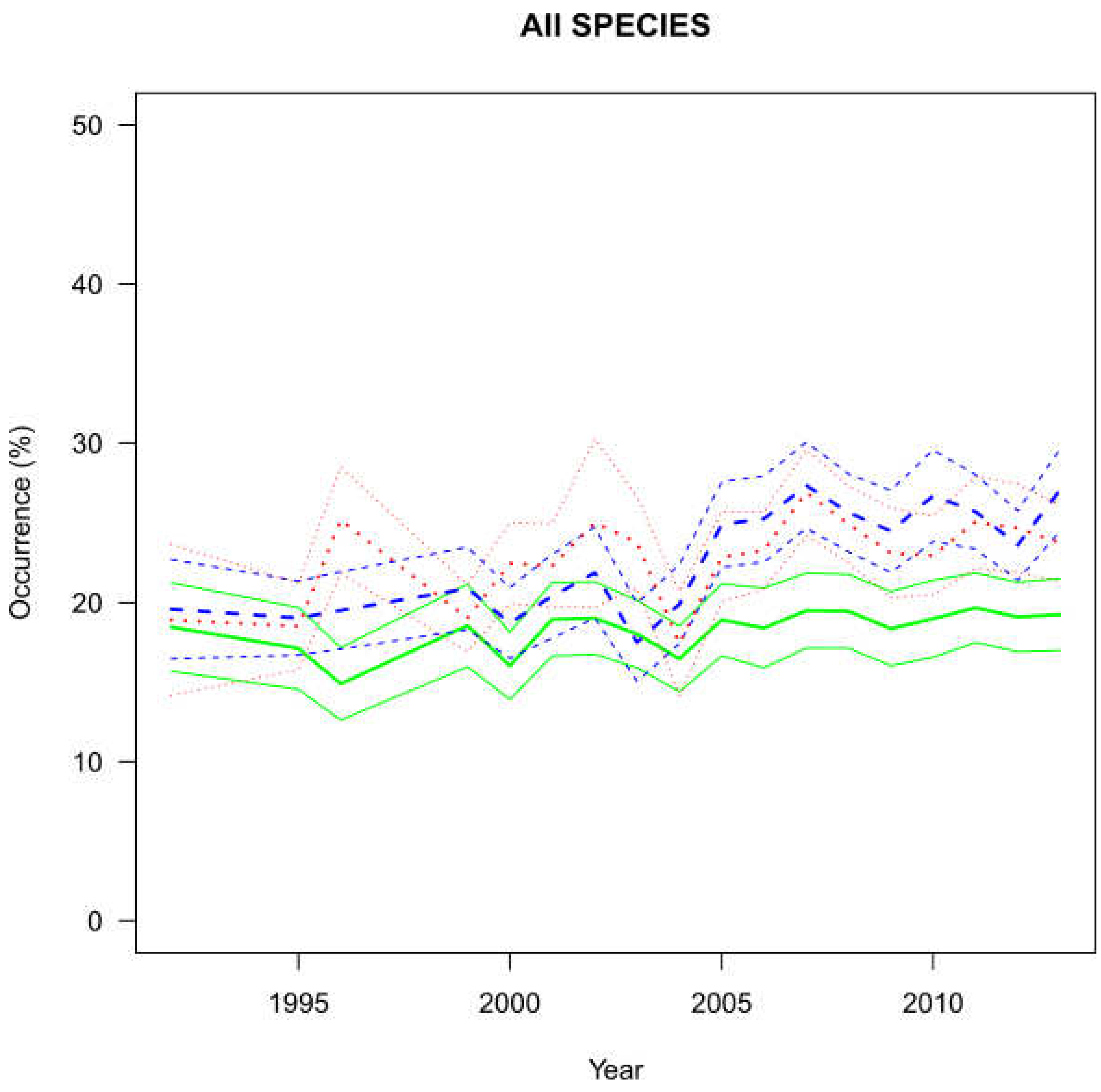
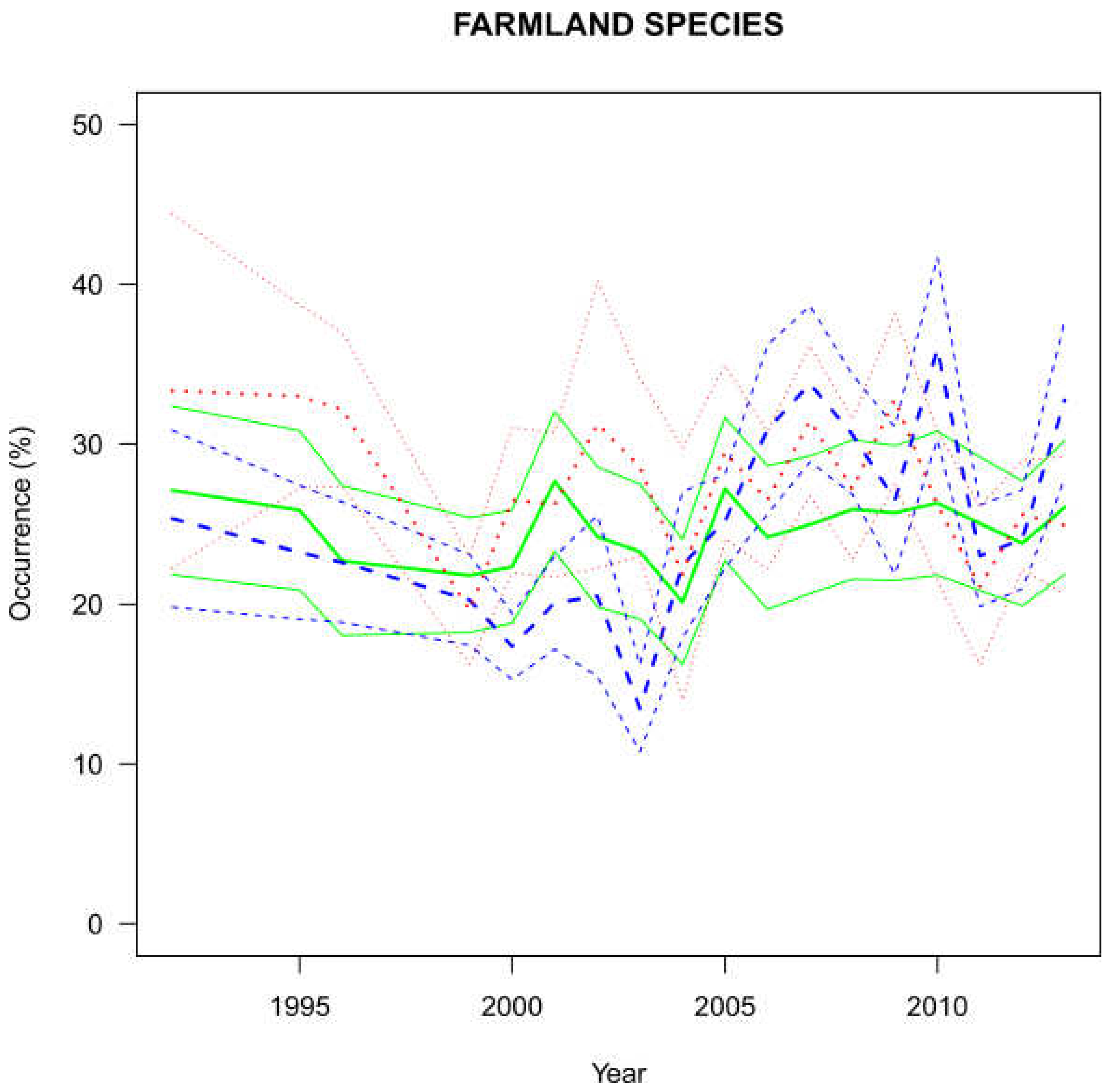
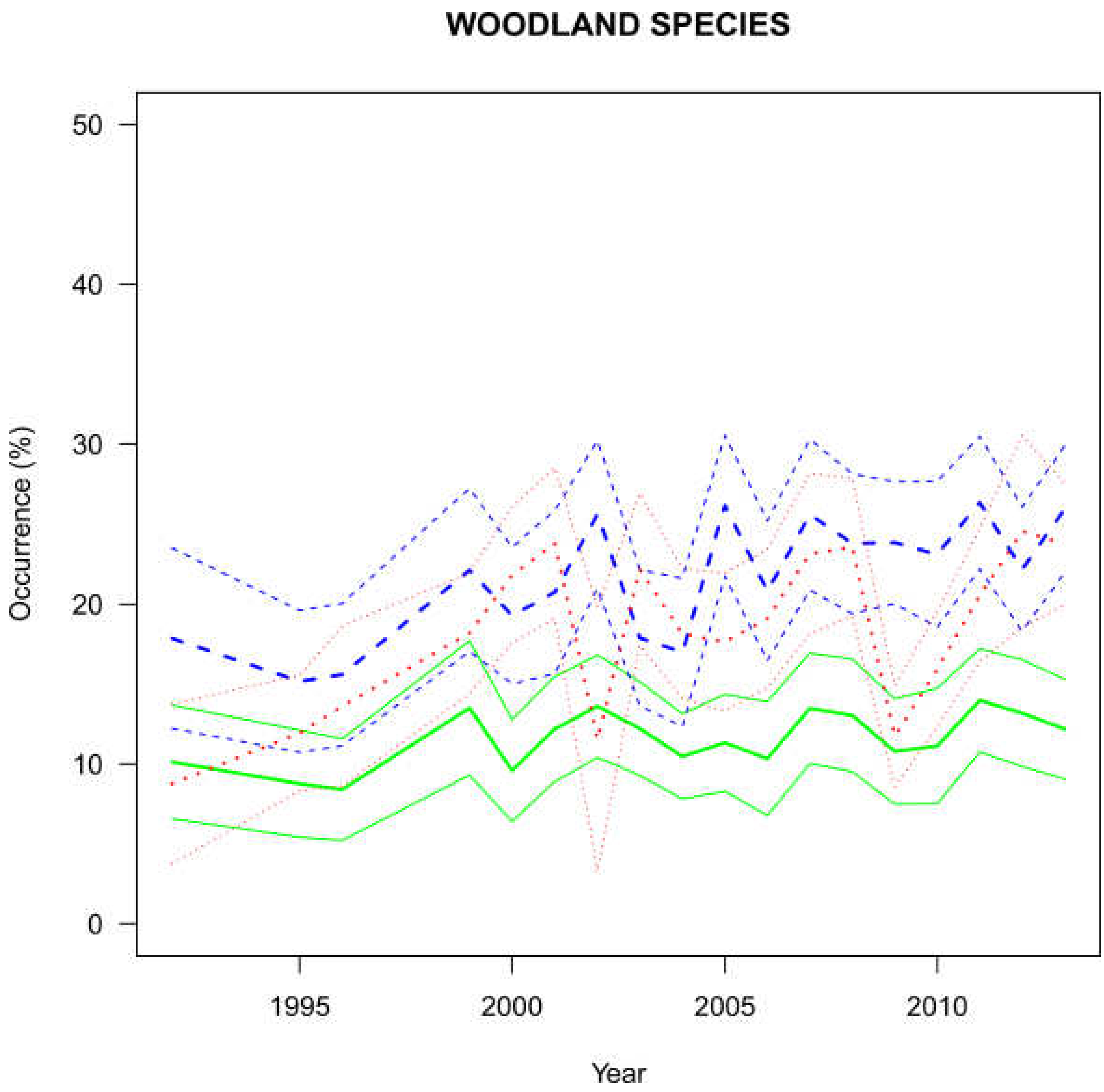


Figure S2. Occurrence of all species and of different subsets of species in each year and protection category, showing both mean values (as in Figure 2) and standard errors. Occurrence of a species was calculated as the ratio of point counts where that species was detected in each year and protection category over the total number of point counts performed in that year and protection category within the altitudinal range of that species. Wide lines represent the mean trends, tiny lines represent standard errors. Solid green lines: non protected areas, dashed blue lines: regional parks, dotted red lines: nature reserves.

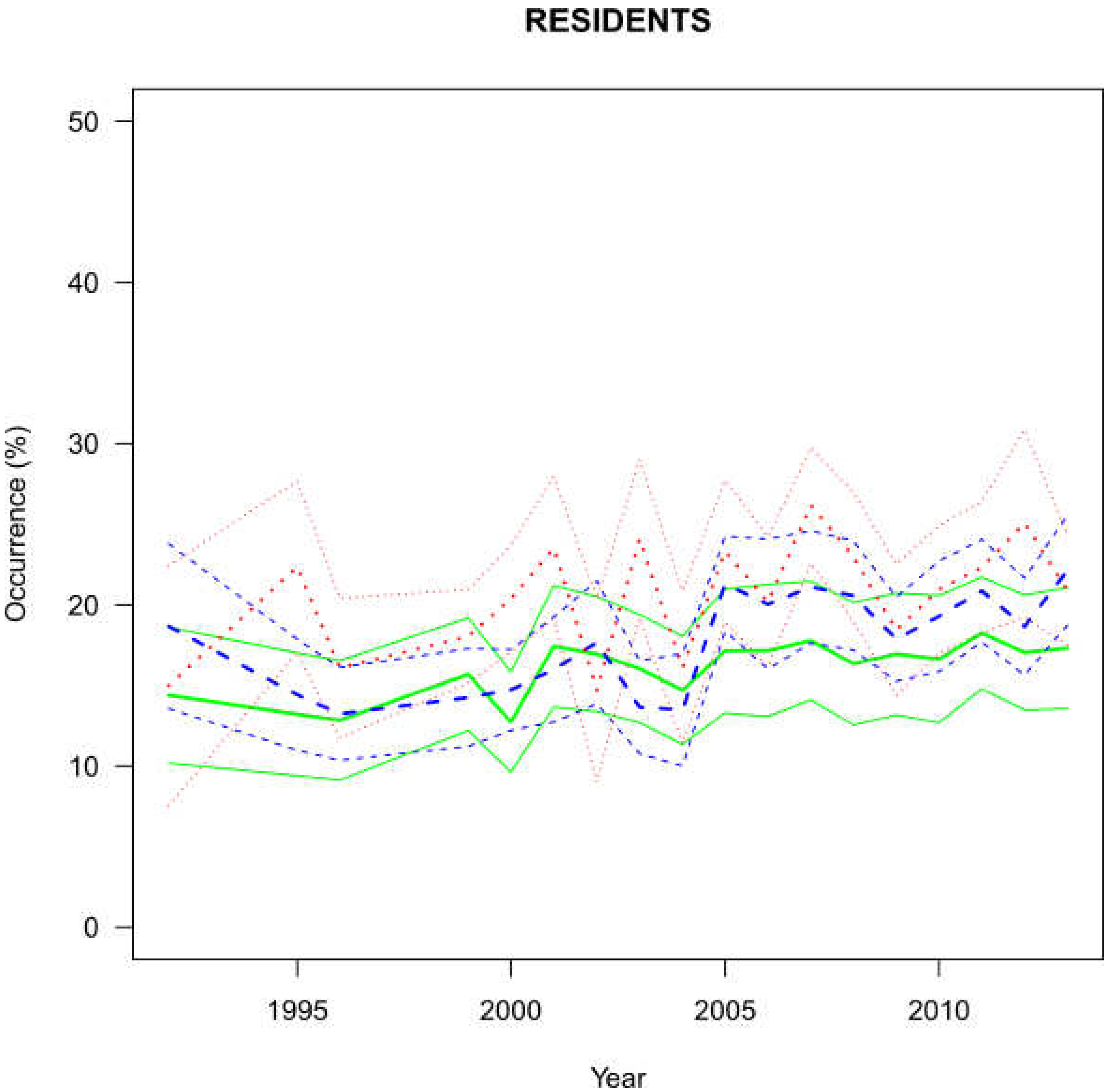


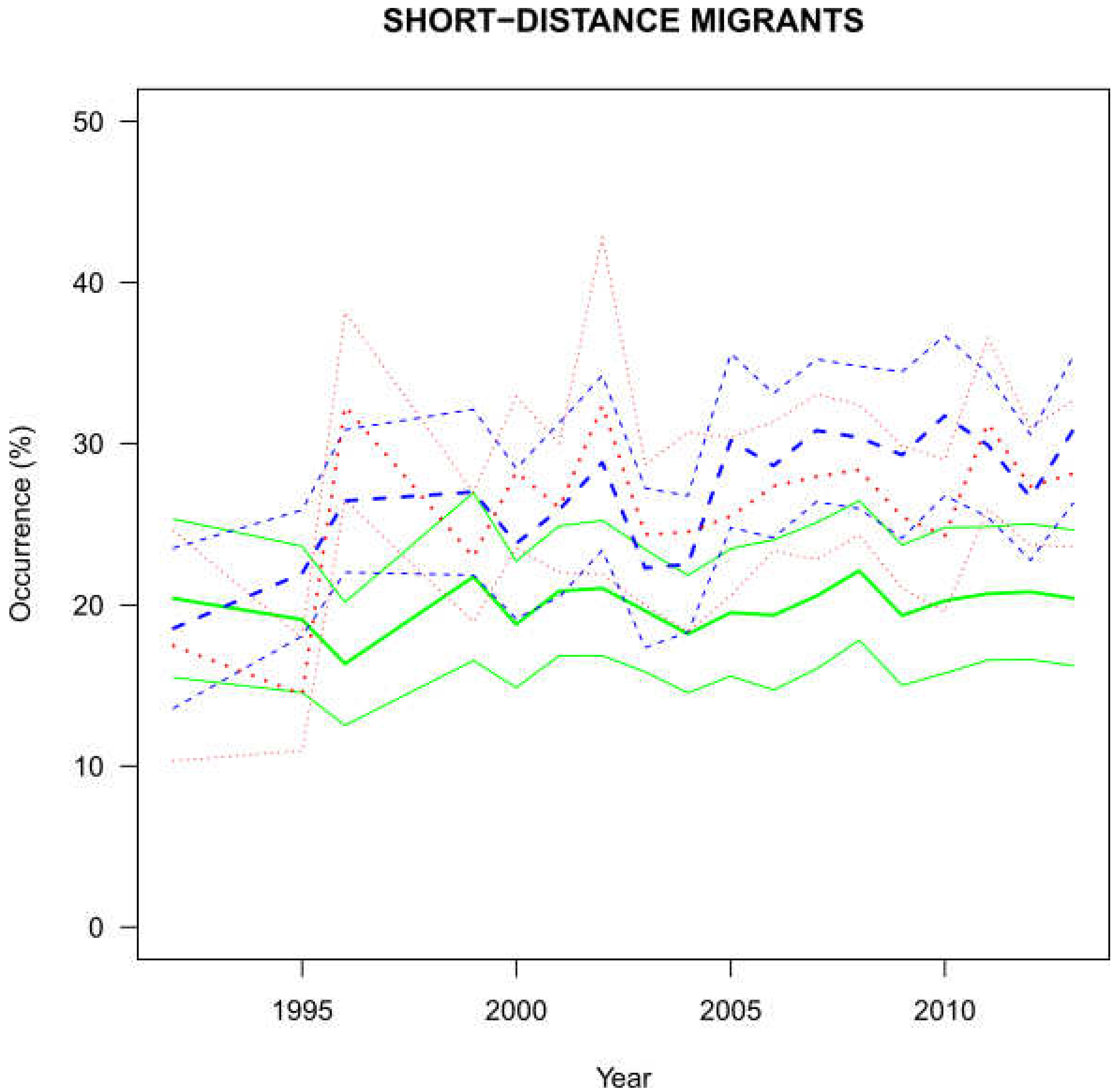


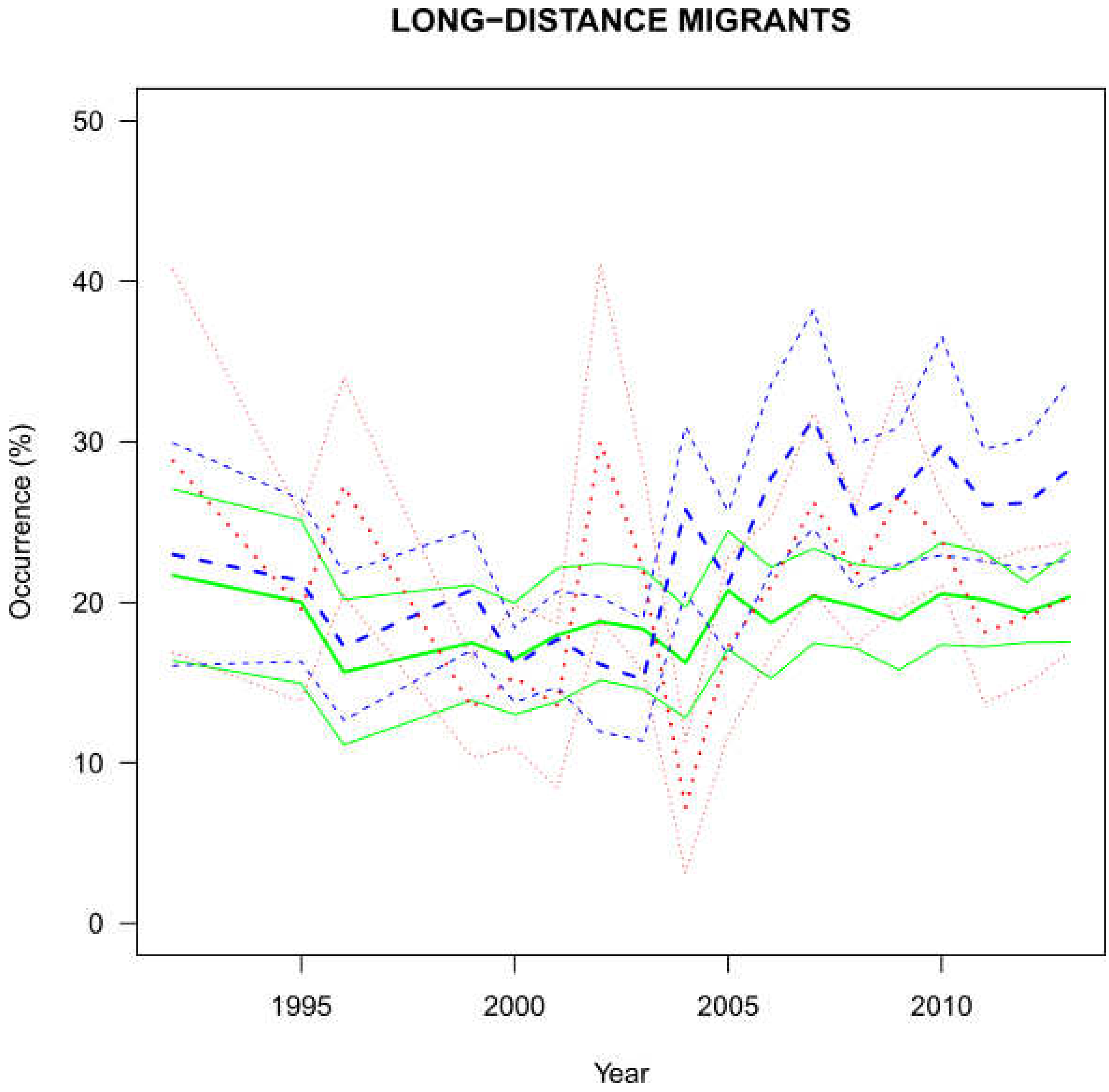
FARMLAND SPECIES
Occurrence (%)
0
10
20
30
40
50
1995
2000
2005
2010
Year



WOODLAND SPECIES
Occurrence (%)
Year
0
10
20
30
40
50
1995
2000
2005
2010

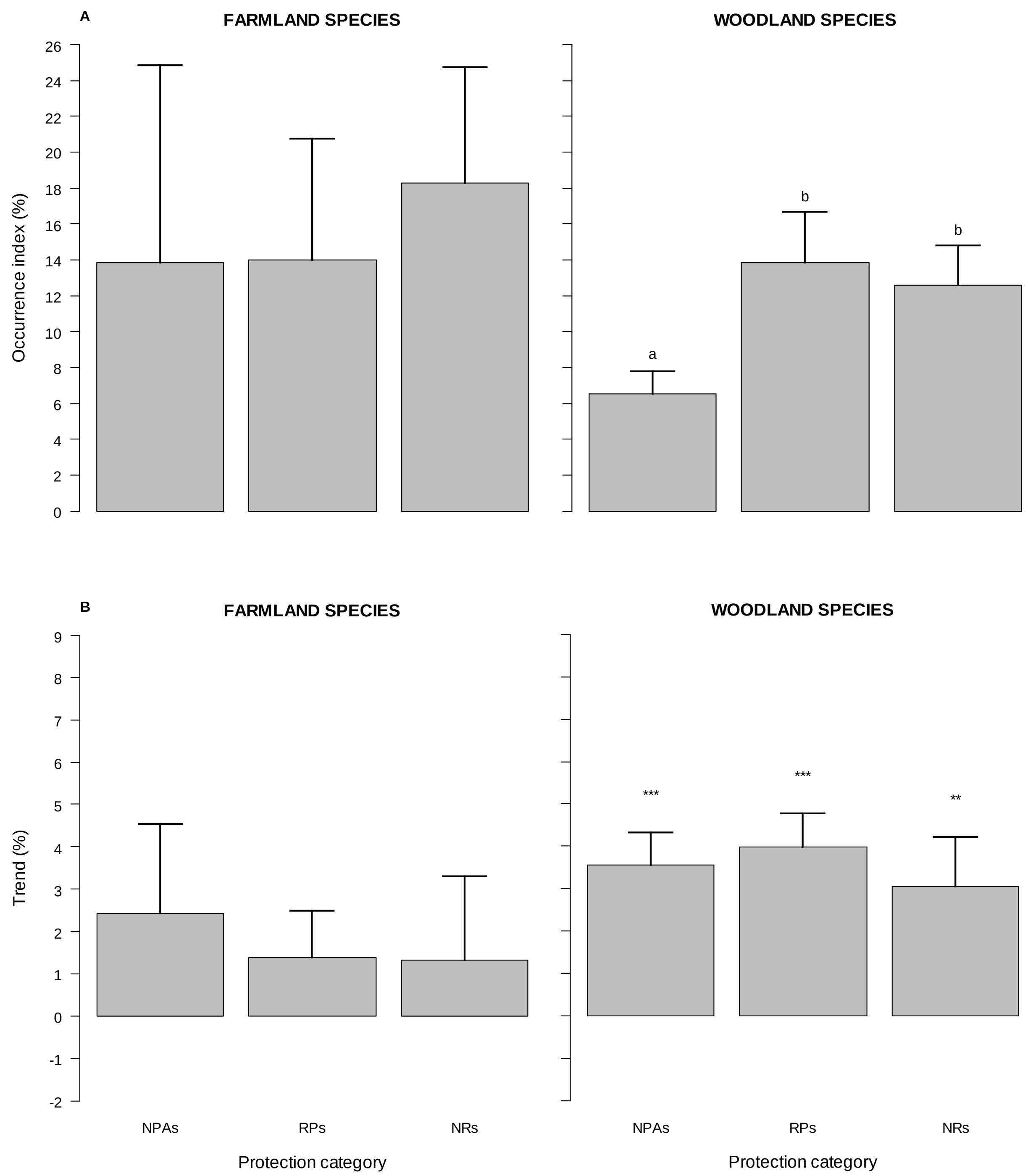

RESIDENTS
Occurrence (%)
0
10
20
30
40
50
1995
2000
2005
2010
Year


SHORT−DISTANCE MIGRANTS
Occurrence (%)
Year
0
10
20
30
40
50
1995
2000
2005
2010



LONG−DISTANCE MIGRANTS
Occurrence (%)
0
10
20
30
40
50
1995
2000
2005
2010
Year

Figure S3. **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 species classified as farmland and forest (= woodland) according to PECBMS (2016) 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.


A
FARMLAND SPECIES
WOODLAND SPECIES
Occurrence index (%)
26
24
22
20
18
16
14
12
10
8
6
4
2
0
a
b
b
B
FARMLAND SPECIES
WOODLAND SPECIES
Trend (%)
9
8
7
6
5
4
3
2
1
0
-1
-2
***
***
**
NPAs
RPs
NRs
Protection category
NPAs
RPs
NRs
Protection category