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ORIGINAL PAPER

The impact of several environmental factors on density of woodcocks (*Scolopax rusticola*) wintering in a southern European region

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Abstract Knowledge of spatio-temporal animal distribution patterns is one of the main chapters of wildlife research, not only due to its biological and ecological importance but also its usefulness in the conservation and management of animal populations. Iberia is a target wintering region for the Eurasian woodcock (*Scolopax rusticola*). The aim of the present work is to determine which factors shape woodcock distribution patterns during the winter period. To ascertain this, we used data collected over three consecutive years (winter of 2010/2011–2012/2013) in a region from northern Iberia (Gipuzkoa). Woodcock numbers (*W*) were modeled using generalized linear mixed models. The models that best fitted our data included a significant effect of latitude, land uses, sampling year, and type of meadow on *W* (once weighted for the number of visits and the area of each meadow). Overall, *W* tended to be lower in sites from southern Gipuzkoa, in those areas where there was a higher proportion of tree plantations, in grazed mountain pastures, and during the winters of 2011 and 2012 in relation to 2010 (mean±SD values in 2010, 0.4±0.5 woodcocks/ha; 2011, 0.2±0.3 woodcocks/ha; 2012, 0.2±0.4 woodcocks/ha). Part of the observed variance was due to the "year" effect, which could include several potential explanatory variables. Future research should try to add variables such as year-associated meteorological conditions, at both breeding and non-breeding quarters. Locally, a mosaic of some forest/woodland with abundant meadows would allow numbers of woodcocks to reach an optimum within the region. Moreover, the species was more abundant in the north; hence, the zones close to the coast had more importance from a conservation standpoint.

Keywords Coastal regions · Game bird · Gipuzkoa · Hunting · Land uses · Population size

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Introduction

Knowledge of spatio-temporal animal distribution patterns constitutes one of the main chapters of wildlife research, not only due to its biological and ecological importance but also its usefulness in the conservation and management of animal populations (Arizaga et al. 2013; Cama et al. 2012; Chernetsov and Bolshakov 2006; Chernetsov and Mukhin 2006). This becomes particularly evident in species of concern, or in species subjected to intense management policies, such as game animals (Braña et al. 2013; Hobson et al. 2009; Sauter et al. 2010).

The Eurasian woodcock (*Scolopax rusticola*) is a widespread game bird found in much of the Palaearctic region (Cramp and Simmons 1983). It breeds mainly in boreal and temperate woodlands, from Portugal to eastern Asia and also in some subtropical Atlantic archipelagos in Macaronesia (Cramp and Simmons 1983). Its distribution in Europe covers much of the continent, and the population has been calculated to be 1,800,000–6,600,000 breeding pairs (Tucker and Heath 2004). Woodcocks from northern Europe are migratory, and those from southwestern Europe, including countries with a remarkably marine influence such as the Atlantic façade of France, Britain, the Low Countries, etc., are resident (Cramp and Simmons 1983; Hoodless 1995).

Although the species has been reported to be stable or even increasing in several European regions (Ferrand et al. 2008; Tucker and Heath 2004), it is declining in Russia, where its chief European breeding quarters are situated (Tucker and Heath 2004). Survival analyses also indicate the occurrence of population sinks in parts of Europe (Péron et al. 2012, 2011a). Therefore, the woodcock is classified as SPEC3 (declining) (Tucker and Heath 2004). This decline is thought to be due to both hunting and habitat loss, both at winter and, to a lesser extent, breeding quarters (Tucker and Heath 2004). In this scenario, understanding in detail which factors shape the habitat use and distribution of game species such as woodcocks is fundamental.

Iberia is a target wintering region for the woodcock in Europe (Guzmán et al. 2011; Hidalgo and Rocha 2001; Lucio and Sáenz de Buruaga 2000; Mendiburu and Arizaga 2010; Tellería et al. 1996) and is hence a region of conservation interest for the species. The spatial ecology of woodcocks wintering in Iberia has been addressed in two ways: (1) by the use of ring-recovery data (Guzmán et al. 2011; Onrubia et al. 1994) or stable hydrogen isotope analyses (Hobson et al. 2013) to determine the origin region and possible connectivity patterns and (2) by the assessment of the effects of several factors, such as habitat type, chiefly on a large-scale level (e.g., Herrando et al. 2011; Onrubia 2012), and the climatic conditions during the previous summer and winter on wintering abundance (Guzmán 2013). There is still a need for greater understanding of the factors shaping woodcock density on a smaller scale, e.g., from a regional perspective (Hidalgo and Rocha 2001). This is important from a management viewpoint since regions, not states, are often the target units for management policies.

The aim of the present work is to determine which factors shape woodcock distribution patterns (in particular, woodcock density) during the winter period, at a regional level (mesoscale level sensu Braña et al. 2013). To determine this, we used data collected over three consecutive years (winter of 2010/2011–2012/2013) at a region located in northern Iberia (Gipuzkoa).

Material and methods

Sampling area and survey method

This study was carried out in the province of Gipuzkoa, a region situated in northern Iberia (Fig. 1). Gipuzkoa is a very mountainous area, situated between the Pyrenees and the Cantabrian Mountains. It is crossed by several main rivers of less than 40 km in length (in a straight line), flowing in parallel along a south-north axis from the Basque inland hills, at an altitude of more than 1000 m, down to sea level in the southeastern Bay of Biscay. Gipuzkoa covers an area of ca. 1900 km^2.

Field work was carried out during the non-breeding period, from October through to February. The data used here were obtained over three consecutive winters, from October 2010 to February 2013. Hereafter, we will refer to these as the winter periods of 2010, 2011, and 2012. Woodcocks remain in the forest during the day and forage in open areas, chiefly meadows, at night (Braña et al. 2010; Duriez et al. 2005a, c). They were therefore surveyed in meadows at night, using a 12-V, 100-W lamp. The survey was carried out from dusk onwards, in complete darkness. The survey was designed in such a way that the entire area of each meadow studied was controlled. Since weather affects the probability of detection (Mendiburu and Arizaga 2010), we avoided nights without wind and/or with a full moon. Under these conditions, woodcocks are more likely to detect observers and escape before being recorded.

The number of sampling points (meadows) per winter (each meadow considered only once) ranged from 114 (2011) to 155 (2012), and they were considered to be well distributed throughout Gipuzkoa (Fig. 2). During the survey, each meadow was also checked for signs of grazing. We considered three categories of meadows: grazed lowlands (if a meadow showed recent or actual presence of cattle, as evidenced by dung, cut vegetation, and footprints), grazed mountain (mountain pastures), and ungrazed.

Data analysis

For each meadow sampled, we calculated both its area and its centroid. The latter was then used as a reference to calculate some of the potential explanatory variables used in the study (see below for details). For each year and meadow, the total number of woodcocks observed (W) was calculated. We used W as an object (dependent) variable and the log of the meadow area and the number of visits as offset variables. Only the months of December and January can be considered to host a relatively stable winter population (J. Arizaga, pers. obs.), so we only used such months for the analyses. Data from cold spills (5–14 January 2010) were excluded, since during these periods, birds show a geographic re-distribution within the region, which could be non-representative for the habitual woodcock distribution during the winter (J. Arizaga, pers. obs.).

During each winter, most meadows were surveyed only once (67.4 %), and only a relatively small fraction (14.8 %) was surveyed three times or more (maximum: eight times). As we used number of visits as an offset variable, and given the reasonably high within-year repeatability at each sampling meadow (see below for further details), we consider that our approach rendered a “mean” density value which was representative for each meadow for the entire season. To test for

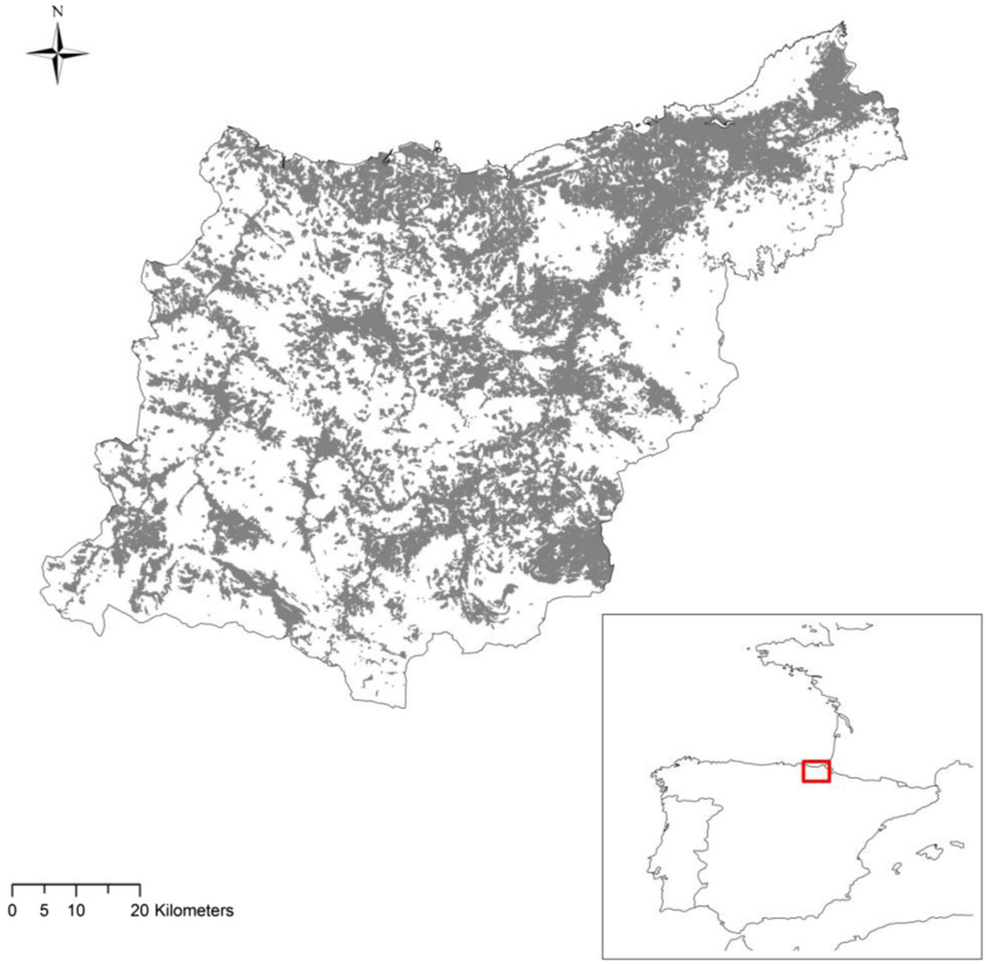

Fig. 1 Geographic location of the province of Gipuzkoa and the area covered by meadows (*gray*)

this repeatability, we considered the subset of those meadows which were sampled three times (n=37). We conducted an ANOVA of repeated measures with three intra-subjects levels (visits 1 to 3). This ANOVA showed that the within-subjects effect was non-significant (F_2=2.288, P=0.109). Moreover, Mauchly's test was also non-significant (W=0.857, P=0.960), indicating that the variance of the differences between paired levels was the same.

To explain variation in W in Gipuzkoa, we considered a number of potential explanatory variables: (1) sampling year,

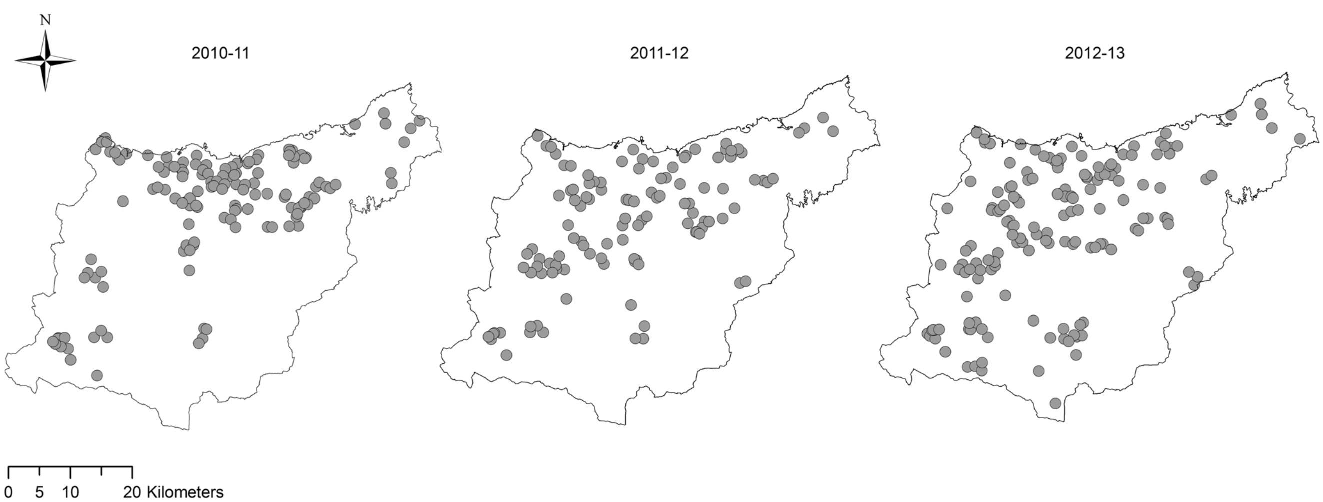

Fig. 2 Distribution of the sampling points for each sampling year (winter) in the province of Gipuzkoa. The period considered for each winter lasted from December to January

(2) temperature, (3) precipitation, (4) land use, (5) soil type, and (6) type of meadow in relation to its use (management). Climatic variables (temperature, precipitation) were obtained from the Digital Climatic Atlas for the Iberian Peninsula (Ninyerola et al. 2005). Mean values for each point were obtained by averaging the mean values for the two sampling months (December and January). Land uses and soil type were obtained from the website of the Basque Government (www.euskadi.net). All land uses (36 original categories) were lumped into six new categories: native deciduous forest [mostly oak (*Quercus* spp.) and beech (*Fagus sylvatica*)], holm oak (*Quercus ilex*) forest, meadow, tree plantation [mostly of Monterey pine (*Pinus radiata*)], shrub, and others (urban areas, reservoirs, wetlands, etc.). Categories considered for the variable "soil type" were determined in relation to soil depth: 0–0.5-, 0.5–1-, 1–2-, 2–4-, and >4-m reservoirs. Land uses were quantified as the proportion of each land use within a radius of 1 km from each meadow's centroid. We used the same method for the soil type. Categories of land uses and soil type were, by definition, highly correlated (their values summed 1). With the aim of not including into our models very highly correlated variables, we used in each case the first component which was obtained from a principal component analysis (PCA). The PCA on land uses revealed a PC1 both highly and negatively correlated with the proportion of meadow and highly and positively correlated with the proportion of tree plantations (Table 1). The PCA on soil type revealed a PC1 highly and positively correlated with 0.5–1-m soil depths and highly but negatively correlated with 1–2-m soil depths (Table 1).

We used generalized linear mixed models on *W* with the six potential explanatory variables shown above as a factor (variables: year, type of meadow) or as linear predictors (remaining variables). Moreover, we always included in all the models the location (longitude and latitude) of the meadows to control for the spatial structure of our data and minimize problems derived of spatial auto-correlation. Additionally, sampling points (i.e., meadow identity) were also always included as a random factor within all models. All linear variables (temperature, precipitation, longitude and latitude, and the PC1 assessing the land use and soil type) were standardized (mean=0; SD=1) for the analyses. Due to the nature of the object variable (bird counts), we used a log-linear link function with Poisson errors for the models.

We used the small sample sizes-corrected Akaike information criterion (AICc) to test for the fit of models to data (Burnham and Anderson 1998). Models differing by less than 2 AICc (ΔAICc <2) values were considered to fit the data equally well (Burnham and Anderson 1998). We averaged the subset of all the models with an AICc <2 in relation to the first model for the estimation of the *B* parameters of the function (Burnham and Anderson 1998). *B* parameters were considered to have a significant weight within the function when they showed associated *P* values <0.05.

We used ArcGIS 9.3 and MiraMon 7.0 for the GIS calculations and R (R Development Core Team 2008) for the statistical procedure.

Table 1 Proportion of land uses and soil type observed around the sampled meadows and the PC1 obtained from a principal component analysis on the six land uses considered in this work

	Mean±SD	Range	PC1
Land uses			
FORE-Deci	0.08±0.07	0.00–0.45	+0.473
FORE-Holm	0.01±0.04	0.00–0.23	−0.023
MEAD	0.43±0.21	0.01–0.86	−0.956
PLAN	0.34±0.20	0.01–0.89	+0.824
SHRU	0.12±0.12	0.00–0.66	+0.114
Others[a]	0.01±0.04	0.00–0.38	−0.134
Soil type			
0–0.5 m	0.10±0.15	0.00–0.94	−0.219
0.5–1 m	0.41±0.34	0.00–0.99	−0.945
1–2 m	0.39±0.33	0.00–0.99	+0.918
2–4 m	0.05±0.12	0.00–0.70	+0.419
>4 m	0.05±0.08	0.00–0.61	−0.003
Reservoirs	0.001±0.012	0.00–0.13	+0.115

PC1 (land uses): eigenvalue 1.972, 32.87 % variance; PC1 (soil type): eigenvalue 1.848, 30.80 % variance

FORE-Deci native deciduous forest, *FORE-Holm* holm oak forest, *MEAD* meadow, *PLAN* exotic tree plantation, *SHRU* shrubby habitat

[a] Includes bare soil, parks, wetland-associated vegetation, urban areas, and others

Results

Overall, 260 meadows were sampled. Most of them (54.6 %) were lowland grazed, with only 6.2 % being mountain grazed (Table 2). Each meadow occupied a mean area of 3.6 (±SD= 2.9 ha). We surveyed a total meadow area of 1461.4 ha (Table 2).

Table 2 Characteristics of sampled meadows in relation to their management and use. We also show the mean (±SD) density of woodcocks

Type of meadow	No. of sampled meadows	Area (ha)	Density (woodcock/ha)
Grazed lowlands	218	679.4	0.3±0.5
Grazed mountain	25	185.7	0.2±0.2
Ungrazed	162	596.3	0.2±0.3

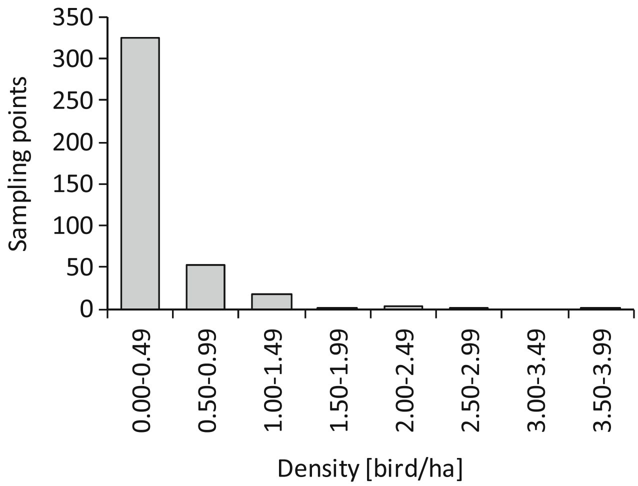

Fig. 3 Frequency distribution of density of woodcocks wintering in Gipuzkoa (north of Spain). Data collected over a period of three consecutive years (winters of 2010 to 2012)

The sampled meadows were situated at a mean altitude of 338±183 m above sea level, with mean winter temperatures of 7.3±1.1 °C and precipitation levels of 343±34 mm.

Habitats (land uses) around the meadows where the birds were surveyed (within a buffer of 1-km radius) mostly consisted of further meadows (43±21 %) and non-native tree plantations (34±20 %) (Table 1). Meadows were mostly found in soils of 0.5 to 1 m (41±34 %) and 1 to 2 m (39±33 %) (Table 1).

We obtained an average density of 0.3±0.4 woodcocks/ha (range 0–3.8 woodcocks/ha; Fig. 3). The model which included an effect of latitude, land use PC1, sampling year, and type of meadow was the one that best fitted our data (Table 3). However, we had two additional models with a ΔAICc <2 in relation to the first one. Overall, such models also included an effect of the soil type and precipitation (Table 3). Having a look at the *B* parameters of these models after the model averaging, however, we detected that the only variables having a significant effect on *W* were latitude, $PC1_{land}$, year, and type of meadow. Overall, *W* tended to be lower in sites from southern Gipuzkoa, in sites where there was a higher proportion of tree plantations, in grazed mountain pastures, and during the winters of 2011 and 2012 in relation to 2010 (Table 4; densities: 2010, 0.4±0.5 woodcocks/ha; 2011, 0.2±0.3 woodcocks/ha; 2012, 0.2±0.4 woodcocks/ha).

Discussion

The sampling year was one of the main variables affecting *W*. Although year-associated random effects cannot be rejected, this result is compatible with the fact that woodcocks' abundance in winter is associated with productivity at breeding quarters and survival during the previous winter (Guzmán 2013). In particular, woodcocks wintering in Iberia tend to be more numerous in years following rainy, cold summers within the circum-Baltic area, this being the origin of most (or many) of them (Guzmán et al. 2011). Abundance is also higher if the preceding winter has been warmer, since cold winters decrease survival prospects in woodcocks (Tavecchia et al. 2002). The inclusion of further years in our model has to be considered a priority, in order to improve its predicting capacity.

Our best models also showed a negative effect of tree plantations (within our region mostly formed by Monterey pine) on *W*. Woodcocks search for forest habitats during the day (Braña et al. 2013; Duriez et al. 2005c) since the vegetation cover allows them to minimize predation (Duriez et al. 2005b). However, in Gipuzkoa, we detected that, within a buffer of 1-km radius around the fields where the birds were found, forests were avoided, or, alternatively, fields surrounded by a high proportion of forest were not able to host densities as high as those found in areas richer in meadows. When foraging, waders have been reported to avoid being close to woodland or forest areas where there would be predators such as sparrowhawks (*Accipiter nisus*) (Whitfield 2003). Along similar lines, increasing distance to cover while foraging could be a factor to keep in mind from the habitat use perspective.

In other wintering areas, the species has been observed to concentrate along the coast during cold spills (Gossmann and Ferrand 2000; Hoodless and Coulson 1994; Péron et al. 2011b). In our case, we also found a clear effect of geographic

Table 3 Rank of the models with an AICc difference <2 in relation to the first one. We also show the null model

Models	AICc	ΔAICc	AICc weight	*df*
1. Lati+Long+$PC1_{land}$+Year+Mead	1504.3	0.0	0.310	9
2. Lati+Long+$PC1_{land}$+$PC1_{soil}$+Year+Mead	1505.0	0.7	0.216	10
3. Lati+Long+$PC1_{land}$+Prec+Year+Mead	1506.1	1.9	0.122	10
4. Null	1601.0	96.7	0.000	2

All models included site as a random factor and the log of the area of the meadow and the number of visits each year as offset variables

Abbreviations: *AICc* small sample sizes-corrected Akaike values, *ΔAICc* AICc difference in relation to model 1, *df* degrees of freedom. Variables: *Lati* latitude, *Long* longitude, $PC1_{land}$ PC1 from the PCA on land uses, $PC1_{soil}$ PC1 from the PCA on soil type, *Year* sampling year, *Mead* type of meadow

Table 4 Model averaged coefficients (*B* parameters±SE, *P*-associated values) obtained from a GLMM (log-linear link function) on number of woodcocks wintering in Gipuzkoa in relation to the geographic location (longitude and latitude), precipitation (Prec.), land uses ($PC1_{land}$), soil type ($PC1_{soil}$), sampling year, and type of meadow. Apart from this, each model included these variables: number of visits to the meadow and meadow area as offset variables and sampling site as a random factor

Variable	*B*	SE(*B*)	*P*
Long[a]	−0.38	0.32	0.264
Lati[a]	+1.20	0.27	<0.001
Prec[a]	+0.02	0.11	0.846
$PC1_{land}$[a]	−0.49	0.23	0.034
$PC1_{soil}$[a]	+0.13	0.26	0.621
Year			
2010	0[b]	–	–
2011	−1.12	0.15	<0.001
2012	−0.87	0.14	<0.001
Meadow			
Ungrazed	0[b]	–	–
Grazed	+0.56	0.49	0.255
Grazed mountain	−3.03	1.01	0.003

[a] Standardized variables

[b] Reference values

location on *W*, even once cold spills were removed from our data set. Particularly, we observed that the species was more abundant in the north, which in our region limits with the coastline. This result agrees with both the studies carried out in other areas and a previous work where the species was found to be more abundant along the coast of Gipuzkoa (Mendiburu and Arizaga 2010). The woodcock occupies areas where, due to the warm, oceanic coast-associated clime and lack of ice in winter (Cramp and Simmons 1980), access to earthworms is easier (Granval 1986; Hoodless and Hirons 2007). This highlights the importance of Gipuzkoa, and particularly of its coast and other similar areas along the coast of northern Spain, for the conservation of woodcocks wintering in Iberia.

Woodcocks were also observed to be less abundant in grazed mountain pastures. Likely, a combination of several factors could explain this result: (1) the cattle densities across these elevated zones are lower than those in the lowlands and also the soil is much less deep, so the woodcocks may prefer to exploit those meadows richer in feeding sources, mostly earthworms, situated in the lowlands; (2) the mountain pastures suffer more frosts than the meadows located in valleys, so food access in these mountainous areas would be hampered more often than in the meadows located at lower altitudes where frosts are occasional.

The sampled meadows in Gipuzkoa hosted a woodcock density ranging from 0.2 to 0.4 wintering woodcocks/ha. Although it would be possible to calculate the wintering population size based on these figures using a predictive model over the area combining our land use and our results-associated spatial variables, this was beyond the scope of this paper. If doing that, however, it would be important to remember that some woodcocks stay in the forest even at night (Duriez et al. 2005b, c), so this should be also considered in the estimations.

In conclusion, we obtained a model found to predict the density of woodcocks wintering in a region of northern Iberia (Gipuzkoa) in relation to latitude, land uses, sampling year, and type of meadow. The variance due to the "year" effect would include several potential explanatory variables, so future research should try to add more variables, such as year-associated meteorological conditions, at both breeding and non-breeding quarters (Guzmán 2013). Locally, a mosaic of some forest/woodland with abundant meadows would allow numbers of woodcocks to reach an optimum within the region.

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Conflict of interest No potential conflicts of interest have been identified.

Compliance with ethical standards This study was carried out with the authorization of the Environmental Department of the Gipuzkoa Administration.

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