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Is there an optimum scale for predicting bird species' distribution in agricultural landscapes?

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ABSTRACT

Changes in forest cover in agricultural landscapes affect biodiversity. Its management needs some indications about scale to predict occurrence of populations and communities. In this study we considered a forest cover index to predict bird species and community patterns in agricultural landscapes in south-western France. We used generalized linear models for that purpose with prediction driven by wooded areas' spatial distribution at nine different radii.

Using 1064 point counts, we modelled the distribution of 10 bird species whose habitat preferences are spread along a landscape opening gradient. We also modelled the distribution of species richness for farmland species and for forest species. We used satellite images to construct a 'wood/non-wood' map and calculated a forest index, considering the surface area of wooded areas at nine radii from 110 m to 910 m. The models' predictive quality was determined by the AUC (for predicted presences) and ρ (for predicted species richness) criteria.

We found that the forest cover was a good predictor of the distribution of seven bird species in agricultural landscapes (mean AUC for the seven species = 0.74 for the radius 110 m). Species richness of farmland and forest birds was satisfactorily predicted by the models ($\rho = 0.55$ and 0.49, respectively, for the radius 110 m). The presence of the studied species and species richness metrics were better predicted at smaller scales (i.e. radii between 110 m and 310 m) within the range tested.

These results have implications for bird population management in agricultural landscapes since better pinpointing the scale to predict species distributions will enhance targeting efforts to be made in terms of landscape management.

1. Introduction

In an agricultural environment, patches of woody vegetation play a key role owing both to their presence for forest-habitat specialist species, and to their absence for open-habitat specialist species (Balent and Courtiade, 1992; Bennett, 1999; Bonthoux et al., 2012). Any change in patchy or linear forest elements is therefore likely to affect biodiversity in agricultural landscapes (Baz and Garcia-Boyero, 1996; Geertsema et al., 2002; Holzkämper and Seppelt, 2007; Jokimäki and Huhta, 1996; Renfrew and Ribic, 2008). Changes in forest cover in an agricultural landscape occur on different scales. Mobile animals, such as birds, can react quickly to such multi-scale modifications since they are likely to appraise habitat features at a variety of scales (nest sites, territory, wider landscape) (Skórka et al., 2006).

In order to conserve biodiversity in agricultural landscapes, it is important to know on what scales the occurrence of targeted species are best explained and predicted by forest cover (Coreau and Martin, 2007) and whether the predictions vary according to the scale at which habitat variables are measured (Grand and Cushman, 2003; Pickett and Siriwardena, 2011). Is the optimum scale for predicting species distribution different from one species to another or does it exist a unique scale of prediction for the whole community?

To evaluate the impact of the modification in forest cover on biodiversity, we have to be able to measure the influence of this discontinuous forest patches at any point in a territory in a continuous way. To assess the effects of forest fragments on species'

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Table 1
(a) Latin and common names of bird species, habitat type (open, forest or intermediate), occurrences, and mean AUC values for the best radius and (b) species richness for the farmland and forest birds and mean Rho values for the best radius.

(a)

Latin species name	Common species name	Occurrence number	Type of habitat	Mean AUC value
Alauda arvensis	Skylark	356	Open	0.71
Emberiza calandara	Corn bunting	314	Open	0.68
Erithacus rubecula	European robin	651	Forest	0.81
Fringilla coelebs	Common chaffinch	535	Forest	0.73
Lullula arborea	Woodlark	66	Intermediate	0.65
Phylloscopus collybita	Common chiffchaff	663	Forest	0.71
Sylvia communis	Common whitethroat	347	Intermediate	0.71
Saxicola torquata	European stonechat	212	Open	0.70
Turdus philomelus	Song thrush	205	Forest	0.81
Troglodytes troglodytes	Eurasian wren	693	Intermediate	0.73

(b)

Community species richness	Mean (min; max)	Mean Rho value
Farmland birds	2.72 (0; 10)	0.55
Forest birds	3.05 (0; 8)	0.50

distribution the authors generally use landscape indicators that involve several forest cover components, e.g. patch area and morphology, between patches connectivity and isolation. These indicators often produce redundant information owing to the crossed correlations between these environmental variables (Lescourret and Genard, 1994). In this study, we used the Neighbouring Forest Cover (NFC index) proposed by Lauga and Joachim (1992) and Lauga et al. (1996). The NFC includes the main characteristics of the wooded islets: the extent of the forest patches' and the distance between the patch and the calculation point.

Bird species represent good model organisms sensitive to changes in forest cover (Cushman and McGarigal, 2003) and are likely to respond differently to the NFC calculated at different radii, representing different spatial scales of potential species' responses to forest spatial distribution. Balent and Courtiade (1992), Berg (2002) or Moreira et al. (2005) have shown that wooded elements are major factors for explaining the assembly of bird species in agricultural habitats. Lauga and Joachim (1992) showed that NFC was a good predictor of three species of forest birds: the song thrush (*Turdus philomelos*), the common chaffinch (*Phylloscopus collybita*) and the European robin (*Erithacus rubecula*).

Here we tested the validity of the NFC as a good predictor of (i) the distribution of 10 agricultural landscape species positioned along a forest to open landscape gradient and (ii) the species richness of farmland and forest birds. Using this index measured at nine different radii we estimated the predictive performance of the individual species and species richness distribution models to determine whether there was an optimum radius for predicting the distribution of ten bird species found in the study area and two species richness metrics using the NFC.

2. Methods

2.1. Study area, sampling design and bird species

The study area is located on the "Vallées et Coteaux de Gascogne" Long Term Ecological Research (LTER) site in South West France centred on the point with geographic coordinates N43°15′53″, E0°51′50″. It is a hilly region where agriculture is devoted to mixed crop-livestock systems and landscapes are a mosaic of diversified land uses including forest patches and hedgerows. We carried out three bird survey campaigns, in 1990, 1995 and 1998, in a zone made up of wooded and unwooded areas (Appendix 1). Bird sampling consisted of 1064 point counts (676 point counts in 1990, 280 in 1995 and 108 in 1998), using 125 m point count radius which corresponds to the extent of the home range for most species of passerine birds (East and Hofer, 1985; Naefdaenzer, 1994). This large sample is well adapted to the building of predictive models (Wisz et al., 2008).

Point counts were stratified according to the agricultural landscapes' forest cover gradient (from 0 to 100% of forest cover, mean = 23%). The dominance of open spaces was linked to the fact that this is an agricultural area with a dispersion of small wooded fragments. Furthermore, because of the spatial resolution of the Spot 4 satellite image used (20 m), the smallest wooded elements and some hedgerows were under-represented. We continued to use this map dating from 1998 with this resolution because we wanted to be as synchronous as possible with the bird data dating from the 90s. We checked that the forest cover in the study area had remained stable between 1990 and 2000, corresponding to the sampling period (Guyon et al., 1999; European forest map available for these two 2 dates and Pekkarinen et al., 2009; <http://forest.jrc.ec.europa.eu/forest-mapping/forest-cover-map).

The bird presence–absence data were taken from 20-min point counts carried out each sampling year in the month of May between 6 and 11 a.m., during the peak of vocal activity, in the absence of heavy wind and rain. Counting only began 3 min after arrival at the point in order to limit the disturbances caused by the observer to the detection of individuals.

We selected 10 species (Table 1) on the basis of their preference along the forest to open landscape gradient (see Balent and Courtiade, 1992), which made it possible to choose species associated with open, forest, and intermediate habitats. All the selected species have an occurrence of more than 20 (Table 2) which is sufficient to avoid problems of modelling rare species (Stockwell and Peterson, 2002). We also calculated species richness for the 1064 point counts as the sum of all present species, excepted large species (e.g. raptors, corvids) with home range larger than the point count area, and human-related species (e.g. sparrows, swallows) because they are gregarious and closely related to human settlements. Because all bird species were not expected to respond uniformly to the wooded gradient, we calculated separately richness for forest bird species (as identified in Balent and Courtiade, 1992) and for farmland bird species (as identified in Filippi-Codaccioni et al., 2010). All scientific bird names are available in Appendix 2.

2.2. Calculation of the forest influence index at different smoothing radii

For each point count, we calculated the NFC, varying between 0 and 1, from the area of all the forest patches present in a given radius, weighting it in inverse proportion to the distance of each forest patch to the calculation point by means of a decreasing exponential function (Lauga and Joachim, 1992). This is a continuous variable that can be calculated at every point of the territory (Lauga et al., 1996). The NFC is calculated using a binary classification of a Spot 4 image taken from a satellite in 1998. Each pixel (20×20 m) takes the value 1 or 0 depending on whether or not the pixel is wooded. A layer with the 1064 georeferenced point counts is superimposed to the classified image. We obtained these maps using the Idrisi software after a supervised image classification. The radius referred to the shortest distance (i.e. in an orthogonal direction) between the focal cell and the side of the square window. We calculated the NFC for nine different concentric radii (Table 2).