Ecological Indicators 45 (2014) 235–244

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Indicators of the impact of land use changes using large-scale bird surveys: Land abandonment in a Mediterranean region

Sergi Herrando[a,b,*], Marc Anton[c], Francesc Sardà-Palomera[c,b], Gerard Bota[c,b], Richard D. Gregory[d], Lluís Brotons[a,b,e]

[a] European Bird Census Council-Catalan Ornithological Institute, Natural History Museum of Barcelona, Plaça Leonardo da Vinci 4-5, 08019 Barcelona, Catalonia, Spain
[b] CEMFOR – CTFC, Centre Tecnològic Forestal de Catalunya, Ctra. St. Llorenç de Morunys km 2, 25280 Solsona, Catalonia, Spain
[c] Catalan Ornithological Institute, Natural History Museum of Barcelona, Plaça Leonardo da Vinci 4-5, 08019 Barcelona, Catalonia, Spain
[d] RSPB Centre for Conservation Science, The Lodge, Sandy, Bedfordshire SG19 2DL, UK
[e] CREAF, Centre de Recerca Ecològica i Aplicacions Forestals, Universitat Autònoma de Barcelona, 08193 Bellaterra, Catalonia, Spain

ARTICLE INFO

Article history:
Received 16 May 2013
Received in revised form 27 February 2014
Accepted 7 April 2014

Keywords:
Bioindicators
Bird monitoring
Land abandonment
Population trend
Composite indices

ABSTRACT

Developing sound indicators of biodiversity impact has been identified as a critical step towards our understanding of how global change components are affecting the environment across the globe. Land abandonment is recognized as a major component of global change in the Mediterranean basin, however, we lack adequate, quantitative, indicators of its impact on biodiversity. An appealing approach to develop biodiversity indicators is the use of large-scale bird monitoring projects, an important source of information that is already available in many countries. In this study we develop a method to quantify the impact of the two main processes associated with land abandonment in the Mediterranean region, namely the abandonment of farmland, which produces a shift from cultivated land to open natural habitats, and the encroachment by vegetation usually associated with reductions in livestock grazing and wood harvesting practices. We used data from bird atlas and monitoring schemes in Catalonia (north-east Iberian Peninsula) to characterize species' population response to these processes by means of detecting quantitative changes in relative abundances along a gradient ranging from habitats not affected by a given driving force to those that arise as a consequence of such force. We then generated multi-species indicators of the impact of these land use changes using these specific population responses to calibrate the relative contribution of each species in the composite index. The temporal patterns depicted by the two indicators in the period 2002–2011 show that vegetation encroachment did have a significant impact on bird communities, whereas any noticeable effect of farmland abandonment on bird populations was observed. The methodology proposed here could be employed to develop indicators capable to track biological impacts of land use change on an annual basis and inform decision-makers about the rate of increase or decrease on wildlife populations.

1. Introduction

A general consensus exists that anthropic alterations of ecosystems are dramatically affecting biodiversity and that as a result there is a need to establish indicators that can measure the rate of biodiversity loss and determine the effectiveness of actions aimed at halting and reversing it (Landres et al., 1988; Noss, 2005; Collen et al., 2008; Butchart et al., 2010). One of the main approaches to generate these summary statistics is to use population trends from existing wide-scale monitoring schemes (Buckland et al., 2005; Gregory et al., 2005; van Swaay and van Strien, 2005). Unlike the classical focus of conservation that centres on rare and localized species, common species usually reported in monitoring schemes can be very appropriate to produce indicators of biodiversity change at large scale due not only to practical reasons but also to their importance in ecosystem structure, functioning and services (Gaston and Fuller, 2008).

Within this context, birds are undoubtedly the taxonomic group that has spawned most research (e.g. Gregory et al., 2005; Devictor et al., 2008; Gregory et al., 2009; Butler et al., 2012; Le Viol et al.,

* Corresponding author at: Catalan Ornithological Institute, Natural History Museum of Barcelona, Plaça Leonardo da Vinci 4-5, 08019 Barcelona, Catalonia, Spain. Tel.: +34 932565991.
E-mail address: ornitologia@ornitologia.org (S. Herrando).

http://dx.doi.org/10.1016/j.ecolind.2014.04.011
1470-160X/

2012). A number of reasons exist that make birds good candidates for generating these indicators: they are very sensitive to environmental change, bird data can be obtained 'low-cost' (particularly when volunteer ornithologists are involved), recognized field and analytical methods exist to handle data on birds, birds play important roles in ecosystem services for humans and, finally, the ease with which birds can be used as communication tools (Gregory and van Strien, 2010). In addition, the existence of well-established, large-scale monitoring projects covering many countries and even continents – in Europe tens of thousands of survey plots in up to 25 countries currently produce data (PECBMS, 2012) – is another very practical reason for attempting to generate sensitive indicators using bird data. These monitoring projects allow reliable annual population indices and trends for common species at national and European level to be obtained, from which several multi-species indicators can be generated on a regular basis (Gregory et al., 2008; PECBMS, 2012).

Wild-bird composite indicators derived from large-scale monitoring data have recently become a tool of political relevance in many EU countries. In particular, the farmland bird index, a multi-species indicator that summarizes population trends for the avifauna of agricultural areas across Europe on the basis of data generated by the Pan-European Common Bird Monitoring Scheme (PECBMS, 2012), has been adopted by the European Union as a baseline indicator under its Rural Development Regulations and as a Sustainable Development and Structural Indicator (European Environmental Agency, 2007; Gregory and van Strien, 2010). This is actually the first indicator based on species' population trends to be included in EUROSTAT (http://epp.eurostat.ec.europa.eu). Indicators based on data from bird monitoring schemes have also been developed at European, national and regional level for evaluating the general state of non-farmland ecosystems such as woodland, urban and wetland habitats (e.g. Gregory et al., 1999; DEFRA, 2002; Zbinden et al., 2005; Gregory et al., 2008; Herrando et al., 2012). Nevertheless, information obtained by state indicators could be complemented by means of indicators of impact of specific pressures, which would allow for better (1) understanding of the underlying processes affecting biodiversity, (2) quantifying its impact, (3) development of tools for communication and decision-making (Gregory et al., 2005; Mace and Baillie, 2007).

Land-use change has been identified as a major driver behind biodiversity changes worldwide (Sala et al., 2000). In the Mediterranean basin, land abandonment in less productive areas has been one of the most relevant changes in land use in recent decades and the footprint on ecosystems of decreased human activity has been reported to affect dramatically biodiversity (Ostermann, 1998; Blondel and Aronson, 1999; Suarez-Seoane et al., 2002; Sirami et al., 2008). However, despite the fact that evidence of the effect of this process has been reported from numerous locations, only a few quantitative meta-analyses have been conducted at regional level (Sirami et al., 2008), and no attempt has ever been made to generate indicators capable of monitoring the impact of this change on biodiversity on an annual basis and a large scale. Therefore, developing these indicators could be particularly interesting in the Mediterranean basin, which is one of the biodiversity hotspots in the world (Myers et al., 2000), and where birds may have a great potential for such purpose because they constitute the taxonomic group with the highest number of monitoring schemes (EuMon, 2014).

In this study, we analyze the impact of land abandonment by splitting this driving force into two different but related processes. First, we defined agriculture abandonment as the process whereby active crop production breaks down and leads to the spontaneous transformation of farmland into wild open habitats such as grassland and low shrubland (Bonet and Pausas, 2007). Then, we defined vegetation encroachment as the increase in density, cover and biomass by indigenous woody or shrubby plants that induce the maturation of vegetation into forest cover. In the Mediterranean basin, vegetation encroachment seems to be closely associated with reductions in livestock grazing and activities related to woody fuel extraction (Lasanta-Martínez et al., 2005). These two processes have occurred mainly in mountain Mediterranean areas in which income from the land has progressively fallen and, consequently, has led to greater rural depopulation (Blondel and Aronson, 1999; Pinto-Correia and Vos, 2004).

As a means of developing indicators of the effects of agricultural abandonment and vegetation encroachment on birds at a large scale, we combined species' population responses to these driving forces with species' population trends in order to establish composite ecologically meaningful indexes. We developed an analytical framework to obtain these species' population responses based on the generation of spatially explicit hypotheses relating habitat data with either abundance data from a common bird monitoring scheme or presence/absence data from a bird atlas. We then adapted the methodology developed by Gregory et al. (2009) to generate multi-species indicators that measure the impact that farmland abandonment and vegetation encroachment have had on the avifauna of a Mediterranean region in recent years.

We used data from Catalonia, a Mediterranean region in which farmland, shrubland and forest state indicators based on bird monitoring projects are updated on an annual basis following the principles adopted in other European countries (Gregory and van Strien, 2010). During the period 2002–2011 the farmland and the forest indicators were roughly stable, while the trend of the shrubland indicator, assessed as the geometric mean of the population indices of 15 species associated with natural open habitats, was clearly negative (ICO, 2012). Hence, this represents an interesting study area, for which indicators of the effects of land abandonment may potentially allow a better understanding of patterns shown by its biodiversity.

2. Methods

2.1. Study area

This study was carried out in Catalonia, a region of c. 32,000 km^2 situated in the north-east of the Iberian Peninsula in which farmland and areas of natural vegetation each cover almost half of its surface area (Fig. 1).

2.2. Data sources

2.2.1. Bird data

Both long-term monitoring data and atlas data, based on the surveillance of breeding bird populations, were employed in this study. The Catalan Common Bird Survey (SOCC) is an ongoing monitoring scheme that was started in spring 2002. It collates data from around 300 monitoring transects (each with a length of 3 km) scattered throughout Catalonia that are walked twice in each breeding period (from April 15 to June 15); the maximum number of individuals in the two censuses was retained as an estimate of relative bird abundance for each species. This scheme embraces two types of field methodology, standard (35%) and extended (65%) transects. In extended SOCC transects collaborators place all birds observed in one of three bands (0–25 m, 25–100 m or >100 m from the line transect), while in the standard SOCC no distance allocation is attempted. Although we analyzed both standard and extended SOCC data to assess annual population indices and trends for each bird species (see Section 2.4), we only used data from the more spatially explicit extended SOCC to derive estimates of the response by bird populations to the processes of farmland abandonment and

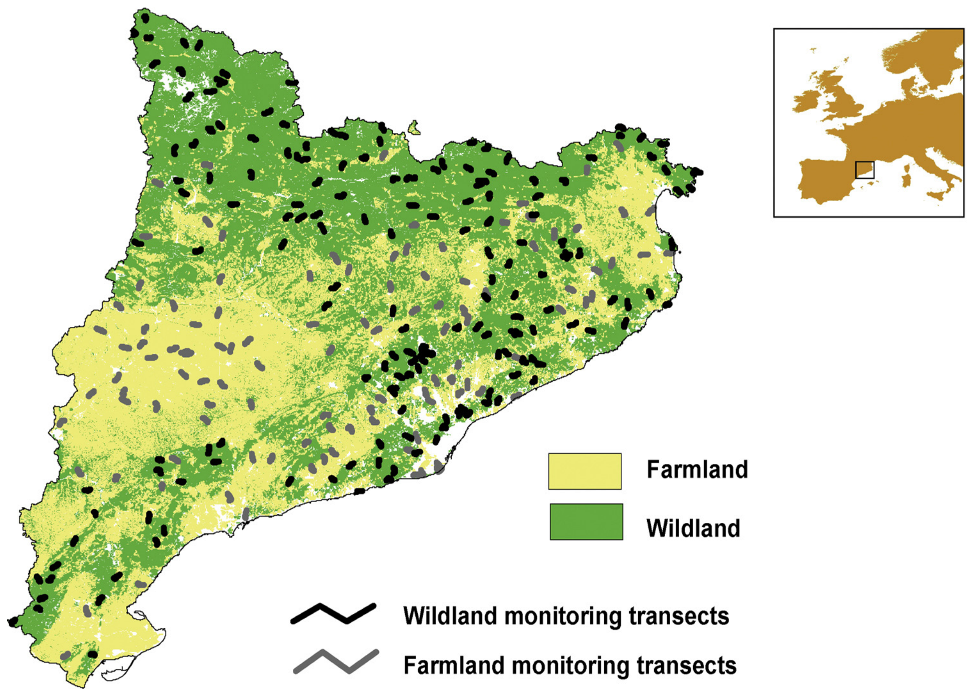

Fig. 1. Study area. Locations of farmland and wildland in Catalonia and of the bird monitoring plots included in the temporal trends shown in this study. The monitoring plots selected to analyze trends under the hypothesis of farmland abandonment ($n = 138$) were those for which farmland categories were present in >60% of a buffer zone of 350 m around each plot; monitoring plots situated in rice fields in the Ebro delta (southern Catalonia) were excluded because of the highly singular characteristics of both the avifauna and agricultural processes of this wetland area. Likewise, the monitoring plots selected to analyze trends under the hypothesis of vegetation encroachment ($n = 174$) were those for which wildland categories were present in >60% of a buffer zone of 350 m around each plot.

vegetation encroachment (see Section 2.3). The Catalan Breeding Birds Atlas (CBBA, Estrada et al., 2004) was a large-scale survey (1999–2002) that covered the whole of Catalonia and for which a total of 3077 1 km × 1 km were surveyed in a stratified fashion (approximately 9% of the total surface area of Catalonia). Two one-hour surveys were conducted for each of the selected 1 km × 1 km during which every square was thoroughly surveyed and every detected species recorded. In this study CBBA data were employed as an alternative source that enabled us to derive a second set of estimates of bird population responses to the driving forces related to land abandonment (see Section 2.3).

2.2.2. Land-use data

Farmland abandonment can be described on a gradient ranging from cultivated areas to open natural habitats (grasslands and low shrublands). On the other hand, vegetation encroachment can be described on a gradient ranging between open natural habitats and tall shrublands and forests. Land-use data for the analyses of bird-habitat relationships were obtained from the Catalan Habitat Cartography (www.ub.edu/geoveg/en/mapes.php) that was completed in the period 1999–2010 using the CORINE land cover categories (www.eea.europa.eu/publications/COR0-landcover) with a minimum polygon size of 150 m × 150 m. The original 289 CORINE categories were reclassified to obtain GIS data for (i) Farmland, which includes arable land (mainly annual cereal crops), vineyards, tree crops (dry tree-crops such as olive and almonds and irrigated orchards), (ii) grasslands and shrublands, which include different types of brushwood from low grassland to shrubland up to 60-cm tall and, lastly, (iii) forests, including, among others, Mediterranean maquis and broadleaf evergreen, deciduous and coniferous forests.

2.3. Species' population responses to drivers

In order to develop indicators of the impact of farmland abandonment and vegetation encroachment, we quantified the responses of bird species populations to these two processes as the changes in their relative abundances that occur in relation to a habitat gradient ranging from habitats not affected by a given driving force to the habitats that arise consequently. The statistical analysis of the specific response to each driving force was the basis for the selection of the set of species to be included in the indicators and of the relative contribution of each selected species to the final index. This approach to analyze species' response to the studied driving forces is the main dissimilarity between our methodology and that proposed by Gregory et al. (2009), who used the differences between current climatic ranges and ranges predicted under forecasted climatic scenarios as a means of evaluating species' population response to climate change. In our case, no predicted scenarios of species distribution as a result of land abandonment were available and hence that approach could not be used. In absence of these future scenarios, current patterns of species occurrence or abundance become an alternative in the quantification of species' population responses to particular driving forces since they can be associated to landscape patterns derived from particular pressures.

Species' population responses to drivers were analyzed using two independent bird datasets, the SOCC and CBBA, to produce two alternative values for each combination of species and driving forces. To do so we first characterized the habitat along the extended SOCC transects and in each of the 1 km × 1 km CBBA squares. For each SOCC transect, we calculated the percentage of cover for each habitat in a buffer zone of 100 m, while for the atlas dataset, habitat percentages were calculated within each surveyed 1 km × 1 km. In order to focus on each studied ecological gradient, we only selected those SOCC transects and CBBA squares in which the sum of the coverage of habitats of interest (farmland, grassland and shrubland for agriculture abandonment, and grassland, shrubland and forests for vegetation encroachment) was at least 75%. In the case of farmland abandonment, 110 SOCC transects and 1671 CBBA squares were selected, whereas in the case of vegetation encroachment, 106 transects and 1803 CBBA squares were chosen. Hence, the SOCC transects or CBBA squares in which habitats other than the studied habitats were dominant were excluded from the analyses carried out to calculate species' population responses to the driving forces.

Given that the data for the Catalan Habitat Cartography was obtained between 1999 and 2010, we used the mean number of individuals observed along each SOCC transect over the studied period (2002–2011) in order to maximize the similarity between the periods of the two datasets. The most distant records (>100 m) were excluded from these calculations in order to match the spatial structure of habitat data in subsequent analyses. In the case of the CBBA, species presence data for a given square was obtained in only one of the four years of fieldwork.

To quantify the species' population responses to each driver we carried out generalized linear models (GLM) for the SOCC (monitoring) and CBBA (atlas) datasets. In the analyses carried out with the SOCC dataset, the GLM were run with a Poisson error distribution and a log link function, the abundance of the species was used as the response variable and the percentage of a habitat as the independent factor for each species found along the transect. In the analyses carried out with the CBBA dataset, GLM were run with a Binomial error distribution and a logit link function, the occurrence of the species was used as the response variable and the percentage of a habitat as the independent factor for each species found in a 1 km × 1 km. We selected species with significant models at $p < 0.05$ and then used the obtained model parameter as an estimation of their affinity to the focal gradient.

As in the approach employed by Gregory et al. (2009), two subgroups (+ and −) of species were defined according to whether their response to the driver was positive or negative. Species with a high estimated value (either positive or negative) have a greater weight in the final indicator, whereas species with an estimate close to 0 were unaffected by the driver. These statistical analyses were carried out using the R package (R Development Core Team, 2008).

Land use change and climate change can have interacting effects on biodiversity and this may influence our ability to detect their specific consequences through biodiversity indicators (Clavero et al., 2011). Therefore, we investigated the potential interaction between the species' population responses obtained in this study for land use changes and the responses of the same set of species for climate change. This was addressed by correlating species' population responses to farmland abandonment and vegetation encroachment with the climatic responses at European level (CLIMENS) reported by Gregory et al. (2009).

2.4. Species' annual indices and trends

Large-scale bird monitoring schemes may provide a valuable framework for studying the changes revealed by the studied indicators over time but it should be taken into account that temporal changes in population counts may vary among survey areas for ecological reasons (Amano et al., 2012). Therefore, we focussed our analyses of temporal patterns in the specific habitats in which each particular driving force could potentially have a role. Thus, in order to analyze trends in the indicators of the impact of farmland abandonment, we selected monitoring plots for which farmland land-use categories were present in >60% of the area in a buffer zone of 350 m around each transect. Similarly, we selected transects in areas with more >60% of natural vegetation to analyze trends in the indicators of the impact of vegetation encroachment (Fig. 1). Using data from selected transects, we estimated annual population indices and trends (period 2002–2011) for the common bird species that showed a significant population response to drivers. These values were assessed using the time-effects model of TRIM, a software package based on the analyses of time series of counts using a Poisson regression (Pannekoek and van Strien, 2005). Species present in fewer than 10 selected transects were rejected; in these cases no population indices were calculated and they were excluded from the indicators.

2.5. Calculation of indicators

The indicators generated in this study were based on the geometric mean of abundance indices across species, and were computed by taking the average of the log of the annual indices of n species followed by a back-transformation. This type of index satisfies the majority of the desirable mathematical properties for indicators of biodiversity change (Buckland et al., 2005; Lamb et al., 2009; van Strien et al., 2012).

For each of our two studied driving forces we calculated two multi-species indicators, one derived from the SOCC data and the other from the CBBA data. In each case the two subgroups of species (+ and −) were determined according to the sign of the estimate in the corresponding regression models (see Section 2.3). These multi-species indicators were calculated using geometric means, but with a weight (Wi) for each species obtained from its position in the gradient under study (species estimate/sum of all estimates of the group (either + or −)), which enabled the concept of the unequal relative contribution of each species to the indicator to be introduced into the procedure (Buckland et al., 2005; van Strien et al., 2012).

For each species we used the annual index obtained by TRIM (see Section 2.4) as the population index for year a (I_a). Then, we obtained a value of change (X_{ab}) between years a and b, where $b = a + 1$, using the formula $X_{ab} = \log(I_b/I_a)$. Subsequently, we calculated the sum of $Wi \times X_{ab}$ for i species, where Wi is the weight of each species in the indicator (considered constant over the study period). The value obtained for this sum represents the logarithm of the proportional change in the index between two consecutive years for a given set of species. We then applied the anti-logarithm to obtain the annual index value. By establishing an initial value of the indicator at 100 for the first year (2002), we used the previously calculated values of annual change to calculate the annual values of the indicator. With this procedure we obtained the indicator values for species that respond favourably to each driving force (+), as well as the indicator for species that respond adversely to each driving force (−). We were able to generate an overall index of the change by calculating the ratio between the index for all species that respond favourably to farmland abandonment or vegetation encroachment (+) and the index for all species that respond negatively to these driving forces (−). The 95% confidence limits and standard deviation were obtained using a bootstrap method (Gregory et al., 2009).

We performed a randomization test to obtain the statistical significance of the trends in the two indicators during the period 2002–2011, as described by Gregory et al. (2009). This procedure consisted of obtaining a series of 10,000 indicators by reassigning at random the species estimates to the population data for a given species, and then calculating the difference in the regression coefficients between the models obtained with the real and random indicators. We took the proportion of repetitions in which the regression coefficient was as positive as or more positive than that observed from the real data as the probability of the observed trend of the indicator with calendar year having occurred by chance.

3. Results

Generalized linear models carried out with the SOCC dataset showed that the abundance of 63 species responded significantly to farmland abandonment (33 positively and 30 negatively, Table 1).

Table 1

Population response of bird species to the studied gradients of farmland abandonment (positive values for species linked to low shrubland and grassland, negative values for species linked to farmland) and vegetation encroachment (positive values for species linked to forests, negative values for species linked to low shrubland and grassland). Models were generated using two independent datasets, the Catalan Common Bird Survey (SOCC) and the Catalan Breeding Bird Atlas (CBBA). For analyses using the SOCC dataset, values correspond to the estimates of the generalized linear model with a Poisson error distribution and a log link function specified with the abundance of the species as the response variable and the percentage of a target habitat (% of grassland and low shrubland in the case of farmland abandonment and % of forest in the case of vegetation encroachment) as independent factors. For the analysis with the CBBA dataset generalized linear models were conducted with a Binomial error distribution given that only presence/absence data was available. Only estimates for significant models ($p < 0.05$) are shown.

English name	Latin name	Farmland abandonment		Vegetation encroachment	
		Monitoring data (SOCC)	Atlas data (CBBA)	Monitoring data (SOCC)	Atlas data (CBBA)
Mallard	*Anas platyrhynchos*		−0.013		
Red-legged Partridge	*Alectoris rufa*	0.006		−0.010	
Common Quail	*Coturnix coturnix*	−0.019	−0.016		−0.014
Little Egret	*Egretta garzetta*		−0.016		
Grey Heron	*Ardea cinerea*		−0.008		
Common Buzzard	*Buteo buteo*		−0.005		
Common Kestrel	*Falco tinnunculus*		−0.003		−0.015
Common Moorhen	*Gallinula chloropus*	−0.083	−0.024		
Little Bustard	*Tetrax tetrax*	−0.115	−0.062		
Stone Curlew	*Burhinus oedicnemus*	−0.045	−0.038		
Rock Dove	*Columba livia*		−0.021		
Stock Dove	*Columba oenas*	−0.019			
Woodpigeon	*Columba palumbus*	−0.018	−0.010	0.020	0.024
Collared Dove	*Streptopelia decaocto*	−0.037	−0.022		
Turtle Dove	*Streptopelia turtur*	−0.019	−0.010	0.030	0.022
Great Spotted Cuckoo	*Clamator glandarius*		−0.010		
Common Cuckoo	*Cuculus canorus*		0.008	0.012	0.004
Little Owl	*Athene noctua*	−0.021	−0.015		
European Bee-eater	*Merops apiaster*	−0.009	−0.015	−0.011	0.015
European Roller	*Coracias garrulus*		−0.031		
Eurasian Hoopoe	*Upupa epops*	−0.012	−0.017	−0.012	0.005
Eurasian Wryneck	*Jynx torquilla*		0.009		
Eurasian Green Woodpecker	*Picus viridis*	−0.007	−0.006		0.006
Great Spotted Woodpecker	*Dendrocopos major*		0.009	0.009	
Calandra Lark	*Melanocorypha calandra*	−0.201	−0.056		
Crested Lark	*Galerida cristata*	−0.030	−0.032		
Thekla Lark	*Galerida theklae*	0.016	0.004		
Woodlark	*Lullula arborea*	0.006	0.006	−0.007	
Eurasian Skylark	*Alauda arvensis*	0.013		−0.027	−0.032
Eurasian Crag Martin	*Ptyonoprogne rupestris*	0.025	0.026		−0.004
Barn Swallow	*Hirundo rustica*	−0.023	−0.025		0.004
Red-rumped Swallow	*Cecropis daurica*		0.012		
Northern House Martin	*Delichon urbicum*		−0.007	0.006	
Tawny Pipit	*Anthus campestris*	0.027	0.019	−0.017	
Tree Pipit	*Anthus trivialis*	−0.018		−0.018	−0.021
Water Pipit	*Anthus spinoletta*	−0.064		−0.064	−0.052
Grey Wagtail	*Motacilla cinerea*		0.008	−0.014	−0.005
White Wagtail	*Motacilla alba*	−0.010		−0.015	
Winter Wren	*Troglodytes troglodytes*	0.008	0.015	0.015	0.018
Hedge Accentor	*Prunella modularis*			−0.022	−0.024
European Robin	*Erithacus rubecula*	0.004	0.012	0.017	0.013
Common Nightingale	*Luscinia megarhynchos*	−0.006	−0.010	0.011	0.016
Black Redstart	*Phoenicurus ochruros*	0.020	0.022		
Common Stonechat	*Saxicola torquatus*	0.012	0.009	−0.010	
Northern Wheatear	*Oenanthe oenanthe*			−0.066	−0.048
Black-eared Wheatear	*Oenanthe hispanica*	0.014	0.008	−0.020	0.018
Rock Thrush	*Monticola saxatilis*			−0.019	−0.021
Blue Rock Thrush	*Monticola solitarius*	0.034	0.026		0.025
Ring Ouzel	*Turdus torquatus*				−0.023
Eurasian Blackbird	*Turdus merula*	0.001	0.019	0.011	0.033
Song Thrush	*Turdus philomelos*				0.009
Mistle Thrush	*Turdus viscivorus*	0.005		−0.010	−0.013
Cetti's Warbler	*Cettia cetti*	−0.020	−0.018		0.024
Fan-tailed Warbler	*Cisticola juncidis*	−0.073	−0.029		
Reed Warbler	*Acrocephalus scirpaceus*	−0.030	−0.032		
Great Reed-warbler	*Acrocephalus arundinaceus*	−0.029	−0.033		
Melodious Warbler	*Hippolais polyglotta*		−0.005	0.015	0.019
Blackcap	*Sylvia atricapilla*		0.005	0.010	0.013
Garden Warbler	*Sylvia borin*	0.028	0.014		
Orphean Warbler	*Sylvia hortensis*	0.019	0.010		
Common Whitethroat	*Sylvia communis*				−0.009
Dartford Warbler	*Sylvia undata*	0.043	0.030		
Subalpine Warbler	*Sylvia cantillans*	0.014	0.007	0.014	0.015
Sardinian Warbler	*Sylvia melanocephala*	0.010		0.025	0.036
Bonelli's Warbler	*Phylloscopus bonelli*		0.006		0.014
Chiffchaff	*Phylloscopus collybita*	0.013	0.015		
Goldcrest	*Regulus regulus*				−0.010

Table 1 (*Continued*)

English name	Latin name	Farmland abandonment		Vegetation encroachment	
		Monitoring data (SOCC)	Atlas data (CBBA)	Monitoring data (SOCC)	Atlas data (CBBA)
Firecrest	*Regulus ignicapilla*	0.005	0.011	0.023	0.021
Spotted Flycatcher	*Muscicapa striata*		0.005		
Long-tailed Tit	*Aegithalos caudatus*		0.008	0.026	0.019
Marsh Tit	*Poecile palustris*			−0.013	
Crested Tit	*Lophophanes cristatus*		0.015	0.010	0.018
Blue Tit	*Cyanistes caeruleus*		0.003	0.017	0.013
Great Tit	*Parus major*		0.006	0.009	0.025
Nuthatch	*Sitta europaea*			0.023	
Short-toed Treecreeper	*Certhia brachydactyla*		0.003	0.015	0.022
Penduline Tit	*Remiz pendulinus*	−0.078	−0.042		
Golden Oriole	*Oriolus oriolus*		−0.003		0.015
Red-backed Shrike	*Lanius collurio*	0.007	0.033	−0.018	−0.024
Southern Grey Shrike	*Lanius meridionalis*	0.012	0.008		
Woodchat Shrike	*Lanius senator*	0.006			
Black-billed Magpie	*Pica pica*	−0.019	−0.026		
Eurasian Jay	*Garrulus glandarius*		0.005	0.015	0.017
Yellow-billed Chough	*Pyrrhocorax graculus*				−0.046
Red-billed Chough	*Pyrrhocorax pyrrhocorax*	0.053		−0.030	
Eurasian Jackdaw	*Corvus monedula*		−0.019		
Carrion Crow	*Corvus corone*		0.008	−0.024	−0.015
Common Raven	*Corvus corax*	0.011	0.012	−0.032	−0.007
House Sparrow	*Passer domesticus*	−0.025	−0.024		0.006
Tree Sparrow	*Passer montanus*	−0.025	−0.030		
Rock Sparrow	*Petronia petronia*	0.008		−0.025	
Eurasian Chaffinch	*Fringilla coelebs*	0.012	0.015		
European Serin	*Serinus serinus*	−0.006		0.009	0.016
Alpine Citril Finch	*Serinus citrinella*			−0.014	−0.024
European Greenfinch	*Carduelis chloris*	−0.006	−0.012		0.014
European Goldfinch	*Carduelis carduelis*	−0.008	−0.003	0.008	0.010
Eurasian Linnet	*Carduelis cannabina*	0.013	0.012	−0.020	−0.017
Red Crossbill	*Loxia curvirostra*			−0.004	−0.006
Eurasian Bullfinch	*Pyrrhula pyrrhula*				−0.021
Yellowhammer	*Emberiza citrinella*			−0.022	−0.031
Cirl Bunting	*Emberiza cirlus*	−0.004	−0.005		0.011
Rock Bunting	*Emberiza cia*	0.022	0.027	−0.012	−0.013
Ortolan Bunting	*Emberiza hortulana*	0.023	0.019	−0.033	−0.010
Corn Bunting	*Emberiza calandra*	−0.013	−0.014		−0.008

Likewise, models generated with the CBBA dataset showed that the occurrence of 78 species showed significant responses to farmland abandonment (39 positively and 39 negatively, Table 1). The Pearson correlation showed that the species' population responses to farmland abandonment calculated with these two independent datasets produced similar results ($r = 0.84$, $P < 0.001$, $n = 51$).

In the case of vegetation encroachment, generalized linear models carried out with the SOCC dataset showed that 52 species responded significantly to this process (24 positively and 28 negatively, Table 1), while the CBBA dataset showed that 59 species responded significantly (33 positively and 26 negatively, Table 1). The Pearson correlation showed that the species' population responses derived from these two independent datasets also produced similar results ($r = 0.88$, $P < 0.001$, $n = 40$).

No significant correlation between the estimates of impact of climate change (CLIMENS) and the species' population responses to farmland abandonment or vegetation encroachment (Table 1) was found for both datasets, CBBA and SOCC (Pearson correlations $P > 0.1$ for all the four comparisons with CLIMENS).

Indicators of the impact of farmland abandonment on bird populations were calculated in parallel using the two different types of species' estimates (derived from the SOCC and the CBBA datasets) as weightings of each species' contribution to the composite indices. For each dataset, two multi-species indicators were calculated, one for the species positively affected by this driving force and one for the species negatively associated (Fig. 2). Bird assemblages did not change during the study period according to the hypothesis of an effect of farmland abandonment on birds since, as a whole, populations of species expected to be positively affected by this process did not increase and those expected to be negatively affected did not decrease. Consequently, the indicator of the impact of farmland abandonment on bird populations, calculated as the ratio between the positive and the negative composite species trends, did not show any clear temporal trend during the study period (Fig. 2). Although greater fluctuations were observed in the indicator calculated with the SOCC dataset than with the CBBA dataset, results were in general very similar irrespective of the dataset used for the species weighting procedure. In the case of the SOCC dataset, the randomization test indicated a probability of 0.336 of obtaining as positive or more positive linear trend at random over the whole period. This probability was 0.769 when using the CBBA dataset.

Exactly the same procedures were carried out to obtain the indicators of the impact of vegetation encroachment on bird populations. However, in this case the composite indices of the species predicted to be positively and negatively associated to this driver diverged; the first composite index increased during the study period, while the second decreased (Fig. 3). In other words, bird assemblages changed during the study period according to the hypothesis of an effect of vegetation encroachment on birds since, as a whole, populations of species expected to be positively affected by this process increased while those expected to be negatively affected decreased. Consequently, the indicators of the impact of vegetation encroachment on bird populations showed a clear temporal trend during the study period (Fig. 3). In addition, the randomization tests indicated, for the SOCC dataset, a probability of 0.025 of obtaining as positive or more positive linear trend of the indicator on year over the whole period. This probability was 0.010 when using the CBBA dataset.

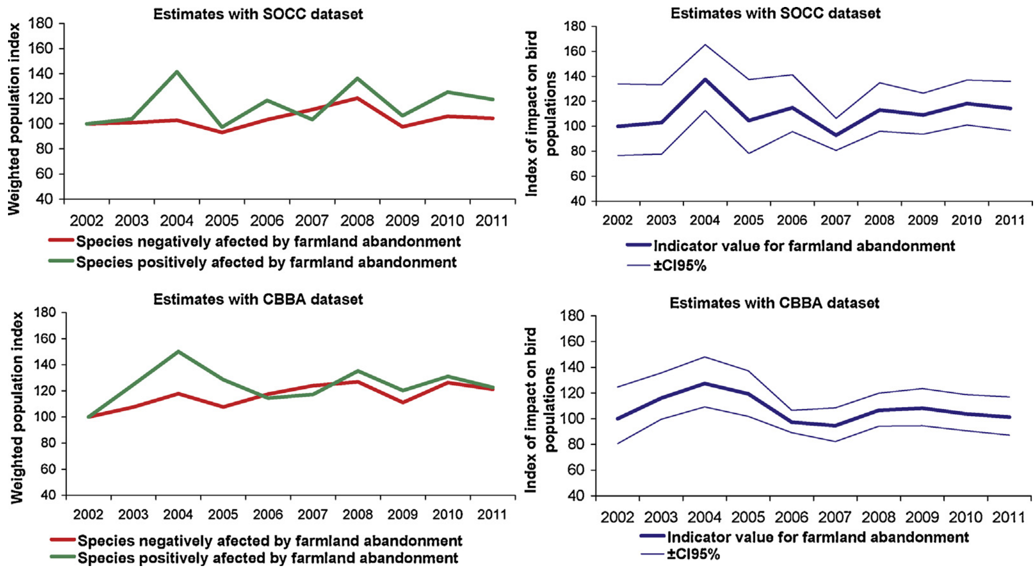

Fig. 2. Indicators of the impact of farmland abandonment on bird populations. The graphs on the left show the weighted temporal changes in the composite indices for the set of species affected positively and negatively by the abandonment of cultivated areas in the study area. The composite indices were calculated separately using species' population responses according to the SOCC and CBBA datasets. The graphs on the right show the resulting indicators of the impact of farmland abandonment for each dataset (SOCC and CBBA), which correspond to the ratios of the indices positively and negatively affected by this driving force. The indicators were set to 100 in 2002. Thin discontinuous lines show 95% bootstrap confidence intervals for annual values from 10,000 bootstrap replicates.

These results indicate that the impact of vegetation encroachment in Mediterranean wild areas on bird populations was significant during the period 2002–2011, a finding that contrasts with the lack of response regarding the abandonment of cultivated lands during the same period.

4. Discussion

4.1. Methodological approach

As far as we know, in this study we have developed a new methodological approach whose aim was to quantify the effects that a particular change in land use induces on bird species. In order to quantify the species' population responses to predicted climate change, Gregory et al. (2009) used differences between current and predicted European ranges according to forecasted climatic scenarios depicted in Huntley et al. (2007). However, these authors dealt with a very particular driving force which, due to its global dimension, has allowed the development of robust predicted scenarios of change in distribution for organisms such as birds. This methodological framework based on the existence of predictions of species distribution driven by a given pressure cannot always be easily implemented for land use change because of its higher complexity both in spatial and temporal dimensions (e.g. Rindfuss et al.,

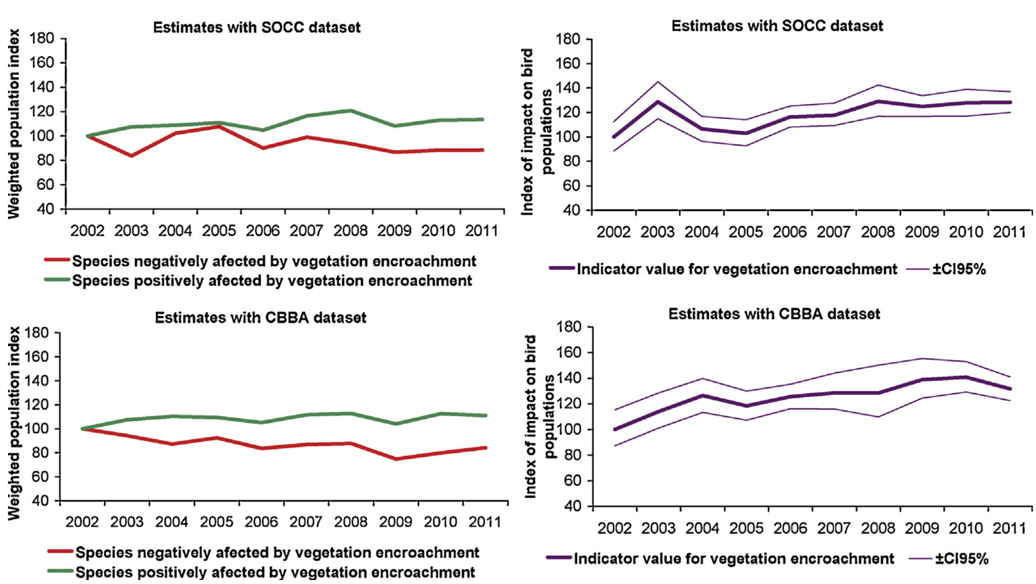

Fig. 3. Indicators of the impact of vegetation encroachment on bird populations. The graphs on the left show the weighted temporal changes in the composite indices for the set of species affected positively and negatively by vegetation encroachment in the study area. The composite indices were calculated separately using species' population responses according to SOCC and CBBA datasets. The graphs on the right show the resulting indicators of the impact of vegetation encroachment for each dataset (SOCC and CBBA), which correspond to the ratios of the indices positively and negatively affected by this driving force. The indicators were set to 100 in 2002. Thin discontinuous lines show 95% bootstrap confidence intervals for annual values from 10,000 bootstrap replicates.

2004; Rounsevell et al., 2012; Chiron et al., 2013). Consequently, researchers may have difficulties to generate predicted species' population responses based on species range predictions driven by land use changes at large spatial scales. In absence of robust future scenarios, current patterns of species distribution and abundance may become an alternative and often more available tool in the quantification of species' population responses to particular driving forces since species occurrence and abundance can be associated to landscape patterns derived from particular pressures. In our approach the responses of the different bird species populations to driving forces were evaluated by means of identifying the habitats involved in a particular land use change and analysing how their occurrence or abundance changes with the amount of these habitats.

In this study, farmland abandonment was evaluated as a gradient from farmland to grassland and low shrubland. We did not include tall shrublands and forests as an extreme value in this gradient since, while these can also develop as a result of farmland abandonment in the Mediterranean basin, in the short-term this process essentially only induces the growth of open natural areas with a low vertical structure (Bonet and Pausas, 2007). The second driving force, vegetation encroachment, was defined as a gradient from grassland and low shrubland to forest. Although this could be a subsequent process to the farmland abandonment mentioned above, i.e. progressive vegetation encroachment in rangelands in the absence of activities such as grazing or wood fuel collection (Maestre et al., 2009), in some areas it could also be an independent process affecting rangelands that have not been cultivated in recent years (Lasanta-Martínez et al., 2005). The precise reasoning for assigning the habitats associated to each extreme of the gradient mediated by a given driving force is a crucial part of this methodology and depends on available information about habitats and species ecology. In this study, we considered a particular categorisation of the original habitat dataset into a few classes according to previous knowledge on species ecology in the study region (Estrada et al., 2004), and then making decisions such as classifiying plant communities as grasslands and shrublands or forests depending on its height and placing a threshold at 60-cm tall. New approaches following this methodology should exercise great caution in the habitat classifications addressed for each study case to allow consistent interpretations of results.

The quantitative assessment of how each species responds to selected habitat gradients is another critical question. We used a spatially explicit approach, linking species presence or abundance in sampling plots to the composition of selected habitats in a regression approach. As in any other analysis based on a sample of units, species' population responses to a habitat gradient will depend on the possible bias of habitats within the analyzed sample. We used two independent datasets (atlas and monitoring data) that differ in terms of geographical coverage (much greater in atlas) and information quality (counts in monitoring data and presence/absence in atlas data). Despite the fact that the number of species included in the procedure using the atlas dataset was higher than in that of the monitoring dataset (24% more for farmland abandonment and 13% more for vegetation encroachment), similar results were found. This would support the idea that there could be some degree of flexibility in the composition and number of species included in an indicator that performs well (Butler et al., 2012; Renwick et al., 2012).

In this study we employed species-specific estimates of the impact of driving forces at the level of the regional trends of populations to obtain, by means of calculating geometric means of yearly population indices, multi-species indicators of the studied processes. Nevertheless, other approaches for creating indicators based on species population trends are possible. One such technique is based on the application of estimates at community level to each monitored plot to generate indices for particular driving forces; this would be the case of the Community Thermal Index used to evaluate the effects of climate change (Devictor et al., 2008, 2012) or the Community Specialization Index used to analyze biotic homogenization (Doxa et al., 2012; Le Viol et al., 2012). In this study we selected the methodology developed by Gregory et al. (2009) because it explicitly produces indicators for species positively and negatively associated to a driving force and not merely a final index and so allows for a finer interpretation of the patterns affecting the shape of the final indicators. In addition, the applied methodology has advantages regarding the characteristics of the temporal dataset used: it is flexible in its data requirement since no raw data is required (just population indices for a given region or country of interest) and potential problems regarding missing values from particular sampling plots in the time series are accounted for in the TRIM analyses used to obtain regional or national population indices (Pannekoek and van Strien, 2005). However, these community indices can also be explored in the evaluation of the effects of land-use driving forces and future work should focus on the comparison of the indicators of change created by these two different procedures.

We believe that the methodology implemented here provides a more robust basis for evaluating the impact of specific changes in land use than state indicators solely based on aggregations of species in a given habitat lacking explicit hypotheses regarding the changes in land use provoked by a particular driver. The finding of accurate independent data to evaluate the relationship between the annual values of these indicators and variables directly associated to the intensity of land use would provide a robust basis for predictions regarding the impacts under future scenarios derived from these variables, as was carried out by Scholefield et al. (2011) for the European Farmland Bird Indicator.

4.2. Land abandonment and changes in bird populations

A consequence of the shift from the primary to the tertiary sector that took place throughout the Iberian Peninsula (above all in the north-east) during the second half of the last century was the abandoning of traditional and sustainable multifunctional activities and their substitution by more purely production-oriented activities (Casals et al., 2009). Less productive farmland areas such as mountain Mediterranean areas were abandoned and severe emigration rates, farm abandonment and a decrease in both livestock numbers and the use of wood resources followed (MacDonald et al., 2000). The change in land management has resulted in very important transformations in Mediterranean landscapes characterized by the spread of natural vegetation and vegetation encroachment (Debussche et al., 1999; Lasanta-Martínez et al., 2005). These processes have considerable impact on ecosystem functioning and biodiversity (Rey Benayas et al., 2007; Eldridge et al., 2011). The results of our study indicate that the impact of the vegetation encroachment on bird populations has been significant over the last ten years in Catalonia; nevertheless, no major impact can be reported for the abandonment of cultivated land during the same period.

No independent data on the annual changes in farmland and wildland are available at the present to provide more detailed, quantitative data on land use changes in the region. Land-use statistics are only updated approximately every 10 years in Catalonia (www.creaf.uab.es/mcsc). The only information available indicates that the ratio between farmland and wildland decreased by 16% between 1993 and 2005, a period that only partially matches our study period (2002–2011). According to the same data source, the ratio between forest and grassland increased by 18% in Catalonia during the period 1993–2005, an increase in forest cover that occurred despite the large impact of forest fires during this period (above all in 1994 and 1998). Therefore, according to available land-use data, farmland abandonment has probably occurred to some extent in our study area. However, our results do not reveal a clear impact of this driver on bird communities for the whole study period (2002–2011). A deeper look at the temporal changes in the indicators show a non significant increasing trend that can be observed for the beginning of the time series (2002–2004), matching the process of farmland abandonment reported by land use data until 2005. From this year, the land abandonment indicator fluctuates and no defined trend can be detected. Variation in the extent of forests with respect to shrubland and grassland matches the results for our indicator of vegetation encroachment until 2005 and then maintain the increase at a similar annual rate. These interpretations regarding the association between land use data and bird data have obvious limitations regarding the partial overlap of the two study periods. In addition, it should be taken into account that biological responses to driving factors are often not immediate and may also depend on processes occurred in the past (Lindborg and Eriksson, 2004; Aggemyr and Cousins, 2012; Zozaya et al., 2012). Despite all these limitations, our analyses on bird indicators produce consistent results with available land use data and suggest that the indicators developed track appropriately the impact of these land use changes on birds.

Climate change might be considered another potential driving force influencing the outcomes of our composite indicator, and there is a potential for an interaction between Species Thermal Index and land use dynamics in Mediterranean birds (Clavero et al., 2011). However, no relation was found in our study between the specific population responses to climate change (CLIMENS) shown by Gregory et al. (2009) and those reported here for vegetation encroachment and farmland abandonment, suggesting that the patterns shown by our indicators are not essentially affected by climate drivers. Certainly, estimates of the impact of climate change on species employed here were developed at continental scale and no equivalent estimates at the scale of the study area were available for these correlations, which might be interesting to develop in future reseach. Therefore, we are confident that our land abandonment indicators are indeed showing the effects of land use change and not indirect climate change effects on bird communties.

Our results indicate that the impact of the vegetation encroachment on bird populations in Catalonia has been significant over the last decade. These results are consistent with those of the most recent evaluation of IUCN species conservation status in this territory (Anton et al., 2013). Considering the set of species negatively affected by vegetation encroachment according to our estimates, 32–38% (depending on the origin of the estimate, either monitoring or atlas data) are currently considered to be threatened or near threatened, whereas this percentage is just 8–9% for the set of species positively affected by this driving force. Species negatively affected by vegetation encroachment require natural or semi-natural open habitats as nesting or feeding places and many of them will likely deteriorate their conservation status without substantial changes in land management. In order to preserve these species, new open habitats can be created by several management practices such as prescribed burning or promoting grazing by large herbivores or livestock farming (Blondel and Aronson, 1999; Pons et al., 2003).

5. Conclusions

The approach based on the estimation of the strength of the habitat-bird relationship used in this study may provide a robust methodology for obtaining indicators aiming at detecting impacts of land use changes on biodiversity. Data from long-term monitoring based on citizen science projects may represent a good opportunity to generate indicators that can be annually updated at low cost and hence inform periodically social audience and decision makers about these ecological changes. In Catalonia, the results shown by the indicator of the increasing impact of vegetation encroachment on birds suggest that further policies aiming at favouring biodiversity values in open habitat will be required in the near future if the trend is to be reversed.

Acknowledgements

The data analyzed in this study was obtained by volunteer ornithologists, without whom the atlas and bird monitoring in Catalonia would not be possible. Javier Quesada, Dani Villero, Ferran Páramo, Constantí Stefanescu and Àngel Ruiz provided valuable support in data processing and interpretation. Mike Lockwood improved the English. The Catalan Breeding Bird Atlas and the Catalan Common Bird Monitoring Scheme receive support from the Catalan Government and are conducted by the Catalan Ornithological Institute. Partial funding was received from the EU BON project (308454; FP7-ENV-2012, European Comission), TREEBIO 200/2010 (Organismo Autónomo Parques Nacionales), BIOCAT-BB CGL2009-08798, BIONOVEL CGL2011-29539, CONSOLIDER-MONTES CSD2008-00040 projects (Spanish Science and Innovation Secretariat), Fundació Catalunya-La Pedrera, INIA and RURAGRI ERA-NET (TRUSTEE 235175).

References

Aggemyr, E., Cousins, S.A.O., 2012. Landscape structure and land use history influence changes in island plant composition after 100 years. J. Biogeogr. 39, 1645–1656.

Amano, T., Okamura, H., Carrizo, S.F., Sutherland, W.J., 2012. Hierarchical models for smoothed population indices: the importance of considering variations in trends of count data among sites. Ecol. Ind. 13 (1), 243–252.

Anton, M., Estrada, J., Herrando, S., 2013. The red list of Catalan breeding birds (NE Iberian Peninsula). Rev. Catalana Ornitol. 29, 1–19.

Blondel, J., Aronson, J., 1999. Biology and Wildlife of the Mediterranean Region. Oxford University Press, Oxford.

Bonet, A., Pausas, J.G., 2007. Old field dynamics on the dry side of the Mediterranean basin: patterns and processes in semiarid southeast Spain. In: Cramer, V.A., Hobbs, R.J. (Eds.), Old Fields: Dynamics and Restoration of Abandoned Farmland. Island Press, Washington, pp. 247–264.

Buckland, S.T., Marrugan, A.E., Green, R.E., Fewster, R.M., 2005. Monitoring change in biodiversity through composite indices. Philos. Trans. R. Soc. B 360, 243–254.

Butchart, S.H.M., Walpole, M., Collen, B., van Strien, A.J., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.-F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Hernández Morcillo, M., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vié, J.-C., Watson, R., 2010. Global biodiversity: indicators of recent declines. Science 328, 1164–1168.

Butler, S.J., Freckleton, R.P., Renwick, A.R., Norris, K., 2012. An objective, niche-based approach to indicator species selection. Methods Ecol. Evol. 3, 317–326, http://dx.doi.org/10.1111/j.2041-210X.2011.00173.x.

Casals, P., Baiges, T., Bota, G., Chocarro, C., de Bello, F., Fanlo, R., Sebastià, M.T., Taull, M., 2009. Silvopastoral systems in NE of the Iberian Peninsula. A multifunctional perspective. In: Rigueiro, A., McAdam, J., Mosquera, M.R. (Eds.), Advances in Agroforestry. Agroforestry in Europe: Current Status and Future Prospects, vol. 6. Springer Verlag, Berlin, pp. 161–181.

Chiron, F., Princé, K., Paracchini, M.L., Bulgheroni, C., Jiguet, F., 2013. Forecasting the potential impacts of CAP-associated land use changes on farmland birds at the national level. Agric. Ecosyst. Environ. 176, 17–23.

Clavero, M., Villero, D., Brotons, L., 2011. Climate change or land use dynamics: do we know what climate change indicators indicate? PLoS ONE 6 (4), e18581.

Collen, B., Loh, J., Whitmee, S., McRae, L., Amin, R., Baillie, J.E.M., 2008. Monitoring change in vertebrate abundance: the living planet index. Conserv. Biol. 23 (2), 317–327.

Debussche, M., Lepart, J., Dervieux, A., 1999. Mediterranean landscape changes: evidence from old postcards. Glob. Ecol. Biogeogr. 8, 3–15.

DEFRA, 2002. Working with the Grain of Nature. DEFRA Publications, London.

Devictor, V., van Swaay, C., Brereton, T., Brotons, L., Chamberlain, D., Heliölä, J., Herrando, S., Julliard, R., Kuussaari, M., Lindström, Å., Reif, J., Roy, D.B., Schweiger, O., Settele, J., Stefanescu, C., van Strien, A.J., van Turnhout, C., Vermouzek, Z., deVries, M.W., Wynhoff, I., Jiguet, F., 2012. Differences in the climatic debts of birds and butterflies at a continental scale. Nat. Clim. Change 2, 121–124.

Devictor, V., Julliard, R., Couvet, D., Jiguet, F., 2008. Birds are tracking climate warming, but not fast enough. Proc. R. Soc. Lond. Ser. B 275, 2743–2748.

Doxa, A., Paracchini, M.L., Pointereau, P., Devictor, V., Jiguet, F., 2012. Preventing biotic homogenization of farmland bird communities. The role of high nature value farmland. Agric. Ecosyst. Environ. 148, 83–88.

Eldridge, D.J., Bowker, M.A., Maestre, F.T., Roger, E., Reynolds, J.F., Whitford, W.G., 2011. Impacts of shrub encroachment on ecosystem structure and functioning: towards a global synthesis. Ecol. Lett. 14, 709–722.

Estrada, J., Pedrocchi, V., Brotons, L., Herrando, S. (Eds.), 2004. Catalan Breeding Bird Atlas 1999–2002. Institut Català d'Ornitologia (ICO)/Lynx Edicions, Barcelona.

EuMon, 2014. EU-Wide Monitoring Methods and Systems of Surveillance for Species and Habitats of Community Interest. http://eumon.ckff.si/

European Environmental Agency, 2007. Halting the Loss of Biodiversity by 2010: Proposal for a First Set of Indicators to Monitor Progress in Europe. EEA Technical Report No. 11/2007. EEA, Copenhagen.

Gaston, K.J., Fuller, R.A., 2008. Commonness, population depletion and conservation biology. Trends Ecol. Evol. 23, 14–19.

Gregory, R.D., Vořišek, P., Noble, D.G., van Strien, A.J., Klvaňová, A., Eaton, M., Gmelig Meyling, A.W., Joys, A., Foppen, R.P.B., Burfield, I.J., 2008. The generation and use of bird population indicators in Europe. Bird Conserv. Int. 18, 223–244, http://dx.doi.org/10.1017/S0959270908000312.

Gregory, R.D., van Strien, A.J., 2010. Wild bird indicators: using composite population trends of birds as measures of environmental health. Ornithol. Sci. 9, 3–22.

Gregory, R.D., Gibbons, D.W., Impey, A., Marchant, J.H., 1999. Generation of the Headline Indicator of Wild Bird Populations. BTO Research Report 221. British Trust for Ornithology and Royal Society for the Protection of Birds, Thetford/Sandy.

Gregory, R.D., van Strien, A.J., Voříšek, P., Gmelig Meyling, A., Noble, D., Foppen, R., Gibbons, D., 2005. Developing indicators for European birds. Philos. Trans. R. Soc. B 360, 269–288.

Gregory, R.D., Willis, S.G., Jiguet, F., Voříšek, P., Klvaňová, A., van Strien, A.J., Huntley, B., Collingham, Y.C., Couvet, D., Green, R.E., 2009. An indicator of the impact of climatic change on European Bird populations. PLoS ONE 4 (3), e4678.

Herrando, S., Weiserbs, A., Quesada, J., Ferrer, X., Paquet, J.-Y., 2012. Development of urban bird indicators using data from monitoring schemes in two large European cities. Anim. Biodivers. Conserv. 35, 141–150.

Huntley, B., Green, R.E., Collingham, Y.C., Willis, S.G., 2007. A Climatic Atlas of European Breeding Birds. Durham University, RSPB & Lynx Edicions, Barcelona.

ICO, 2012. Desè informe del Programa de Seguiment d'Ocells Comuns a Catalunya (SOCC). Institut Català d'Ornitologia, Barcelona (in Catalan).

Lamb, E.G., Bayne, E., Holloway, G., Schieck, J., Boutin, S., Herbers, J., Haughland, D.L., 2009. Indices for monitoring biodiversity change: are some more effective than others? Ecol. Indic. 9, 432–444.

Landres, P.H., Verner, J., Thomas, J.W., 1988. Ecological uses of vertebrate indicator species – a critique. Conserv. Biol. 2, 316–328.

Lasanta-Martínez, T., Vicente-Serrano, S.M., Cuadrat-Prats, J.M., 2005. Mountain Mediterranean landscape evolution caused by the abandonment of traditional primary activities: a study of the Spanish Central Pyrenees. Appl. Geogr. 25, 47–65.

Le Viol, I., Jiguet, F., Brotons, L., Herrando, S., Lindström, Å., Pearce-Higgins, J.W., Reif, J., van Turnhout, C., Devictor, V., 2012. More and more generalists: two decades of changes in the European avifauna. Biol. Lett., http://dx.doi.org/10.1098/rsbl.2012.0496.

Lindborg, R., Eriksson, O., 2004. Historical landscape connectivity affects present plant species diversity. Ecology 85, 1840–1845.

MacDonald, D., Crabtree, J.R., Wiesinger, G., Dax, T., Stamou, N., Fleury, P., Gutierrez-Lazpita, J., Gibon, A., 2000. Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response. J. Environ. Manage. 59, 47–69.

Mace, G.M., Baillie, J.E.M., 2007. The 2010 biodiversity indicators: challenges for science and policy. Conserv. Biol. 21 (6), 1406–1413.

Maestre, F.T., Bowker, M.A., Puche, M.D., Hinojosa, M.B., Martinez, I., Garcia-Palacios, P., Castillo, A.P., Soliveres, S., Luzuriaga, A.L., Sánchez, A.M., Carreira, J.A., Gallardo, A., Escudero, A., 2009. Shrub encroachment can reverse desertification in semiarid Mediterranean grasslands. Ecol. Lett. 12, 930–941.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853–858.

Noss, R.F., 2005. Indicators for monitoring biodiversity: a hierarchical approach. Conserv. Biol. 4, 355–364.

Ostermann, O.P., 1998. The need for management of nature conservation sites designated under Natura 2000. J. Appl. Ecol. 35, 968–973.

Pannekoek, J., van Strien, A.J., 2005. TRIM 3 Manual (Trends and Indices for Monitoring data). Statistics Netherlands, Voorburg.

PECBMS, 2012. Population Trends of Common European Birds 2012. CSO, Prague.

Pinto-Correia, T., Vos, W., 2004. Multifunctionality in Mediterranean landscapes – past and future. In: Jongman, R. (Ed.), The New Dimensions of the European Landscape. Springer, Wageningen, pp. 135–164.

Pons, P., Lambert, B., Rigolot, E., Prodon, R., 2003. The effects of grassland management using fire on habitat occupancy and conservation of birds in a mosaic landscape. Biodivers. Conserv. 12, 1843–1860.

R Development Core Team, 2008. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, ISBN 3-900051-07-0 http://www.R-project.org

Renwick, A.R., Johnston, A., Joys, A., Newson, S.E., Noble, D.G., Pearce-Higgins, J.W., 2012. Composite bird indicators robust to variation in species selection and habitat specificity. Ecol. Indic. 18, 200–207.

Rey Benayas, J.M., Martins, A., Nicolau, J.M., Schulz, J.J., 2007. Abandonment of agricultural land: an overview of drivers and consequences. CAB Rev.: Perspect. Agric. Vet. Sci. Nutr. Nat. Resour. 2, 057, http://dx.doi.org/10.1079/PAVSNNR20072057.

Rindfuss, R.R., Walsh, S.J., Turner, B.L., Fox, J., Mishra, V., 2004. Developing a science of land change: challenges and methodological issues. Proc. Natl. Acad. Sci. 101 (39), 13976–13981.

Rounsevell, M.D.A., Pedroli, B., Erb, K.-H., Gramberger, M., Busck, A.G., Haberl, H., Kristensen, S., Kuemmerle, T., Lavorel, S., Lindner, M., Lotze-Campen, H., Metzger, M.J., Murray-Rust, D., Popp, A., Pérez-Soba, M., Reenberg, A., Vadineanu, A., Verburg, P.H., Wolfslehner, B., 2012. Challenges for land system science. Land Use Policy 29 (4), 899–910.

Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, R., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M., Wall, D.H., 2000. Global biodiversity scenarios for the year 2100. Science 287, 1770–1774.

Scholefield, P., Firbank, L., Butler, S., Norris, K., Jones, L.M., Petit, S., 2011. Modelling the European farmland bird indicator in response to forecast land-use change in Europe. Ecol. Indic. 11 (1), 46–51.

Sirami, C., Brotons, L., Burfield, I., Fonderflick, J., Martin, J.L., 2008. Is land abandonment having an impact on biodiversity? A meta-analytical approach to bird distribution changes in the north-western Mediterranean. Biol. Conserv. 141 (2), 450–459.

Suarez-Seoane, S., Osborne, P.E., Baudry, J., 2002. Responses of birds of different biogeographic origins and habitat requirements to agricultural land abandonment in northern Spain. Biol. Conserv. 105, 333–344.

van Swaay, C.A.M., van Strien, A.J., 2005. Using butterfly monitoring data to develop a European butterfly indicator. In: Kuhn, E., Thomas, J.A., Feldman, R., Settele, J. (Eds.), Studies in the Ecology and Conservation of Butterflies in Europe. , pp. 106–108.

van Strien, A.J., Soldaat, L.L., Gregory, R.D., 2012. Desirable mathematical properties of indicators for biodiversity change. Ecol. Indic. 14, 202–208.

Zbinden, N., Schmid, H., Kéry, M., Keller, V., 2005. Swiss Bird Index SBI – Kombinierte Indices für die Bestandsentwicklung von Artengruppen regelmässig brütender Vogelarten der Schweiz 1990–2004. Der Ornithologische Beobachter 102, 283–291 (in German).

Zozaya, E.L., Brotons, L., Saura, S., 2012. Recent fire history and connectivity patterns determine bird species distribution dynamics in landscapes dominated by land abandonment. Landsc. Ecol. 27 (2), 171–184.