

Extensive sheep grazing and trends of steppe birds in Spain in PAC context: no sheep means no birds (#66525)

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Extensive sheep grazing and trends of steppe birds in Spain in PAC context: no sheep means no birds

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Iberian natural steppes have been traditionally grazed by extensive sheep grazing, which has been mentioned to be positively associated to steppe bird abundance and diversity. Sheep number in Spain, the country harbouring the largest European populations of many steppe bird species, has decreased 9.2 million (37.3%) between 1992 and 2020. Steppe birds in Spain have faced dramatic declines during the same period, but there is a lack of knowledge about the potential association between sheep and steppe birds declines. We used sheep data from the Spanish Ministry of Agriculture and bird data (1998-2018) from the Spanish Common Bird Monitoring Program to assess the association between sheep decline and the Farmland Bird Index (FBI) and the Natural Steppe Bird Index (SBI). We also used an independent dataset about the population trend of the Dupont's Lark (*Chersophilus duponti*) to assess the relationship between sheep number and the decline of such threatened steppe specialist passerine, whose European population is restricted to Iberian natural steppes. In order to avoid spurious relationships between temporal series, variables were tested for cointegration. After confirming cointegration, we found a strong positive relationship between sheep annual change rate and the annual change rate of the FBI and SBI during the period 1998-2018. The association between sheep annual change rate and trend of the Dupont's Lark (2004-2015) was marginally significant. The relationship found, using two independent cointegrated datasets, between the reduction of steppe birds and sheep numbers at the country scale suggests that the decline of steppe birds in Spain could be associated to the decline in sheep numbers. It agrees with previous studies that found a positive relationship between intermediate levels of sheep grazing and steppe bird abundance in Iberian steppes. Our results suggest that the promotion of extensive grazing should be considered as a key factor in future Common Agricultural Policy reforms and conservation programmes in order to protect steppe birds.

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ABSTRACT

Iberian natural steppes have been traditionally grazed by extensive sheep grazing, which has been mentioned to be positively associated to steppe bird abundance and diversity. Sheep number in Spain, the country harbouring the largest European populations of many steppe bird species, has decreased 9.2 million (37.3%) between 1992 and 2020. Steppe birds in Spain have faced dramatic declines during the same period, but there is a lack of knowledge about the potential association between sheep and steppe birds declines. We used sheep data from the Spanish Ministry of Agriculture and bird data (1998-2018) from the Spanish Common Bird Monitoring Program to assess the association between sheep decline and the Farmland Bird Index (FBI) and the Natural Steppe Bird Index (SBI). We also used an independent dataset about the population trend of the Dupont's Lark (*Chersophilus duponti*) to assess the relationship between sheep number and the decline of such threatened steppe specialist passerine, whose European population is restricted to Iberian natural steppes. In order to avoid spurious relationships between temporal series, variables were tested for cointegration. After confirming cointegration, we found a strong positive relationship between sheep annual change rate and the annual change rate of the FBI and SBI during the period 1998-2018. The association between sheep annual change rate and trend of the Dupont's Lark (2004-2015) was marginally significant. The relationship found, using two independent cointegrated datasets, between the reduction of steppe birds and sheep numbers at the country scale suggests that the decline of steppe birds in Spain could be associated to the decline in sheep numbers. It agrees with previous studies that found a positive relationship between intermediate levels of sheep grazing and steppe bird abundance in Iberian steppes. Our results suggest that the promotion of extensive grazing

should be considered as a key factor in future Common Agricultural Policy reforms and conservation programmes in order to protect steppe birds.

Keywords: *Chersophilus duponti*, Farmland Bird Index, Steppe birds, extensive grazing, sheep, steppes, paramo.

INTRODUCTION

European natural and semi-natural open habitats, such as steppes, uplands and moorlands (natural steppes hereinafter) are generally the result of altitudinal/climatic and edaphic tree-limiting conditions, and regular low-intensity human disturbances such as low-yield agriculture, fire or livestock¹. All these factors have shaped the characteristic open, tree-less landscape of such habitats^{2,3}, which harbors high biodiversity values¹.


Several works have suggested the existence of a complex system of multiple interactions where extensive sheep grazing affects plant structure spatial heterogeneity and plant species composition⁴, as well as arthropod abundance both directly through its depositions and indirectly^{5,6,7}. Heavy levels of grazing have proven to be disadvantageous for a large number of steppe birds, due to overconsume of plants and high fertilization⁸. However, light or moderate grazing may have positive effects since grazing decreases vegetation height^{6,9}, facilitate the occurrence of coprophagous^{6,10,11}, and the foraging efficiency of steppe birds increases in more open habitats^{8,12,13}. Moreover, greater visibility in sparser vegetation minimize the risk of predation for ground-standing birds^{13,14}. All these factors may favour the abundance and space use of insectivorous birds^{2,3,15,16}. As a result, numerous threatened bird species have their strongholds in these extensively sheep grazed natural steppes¹⁷. Of particular conservation concern are the Iberian natural steppes (shrub steppes, *sensu*¹⁸), which as many Mediterranean

calcareous grasslands are the consequence of both anthropogenic and natural processes, with a deep importance of spring and autumn extensive grazing by sheep^{19,20}. Iberian natural steppes harbour the main (or the whole) population of several threatened steppe bird species, such as the Dupont's lark (*Chersophilus duponti*), the Greater short-toed lark (*Calandrella brachydactyla*), the Stone curlew (*Burhinus oediconemus*), the Little bustard (*Tetrax tetrax*), both Black-bellied (*Pterocles orientalis*) and Pin-tailed sandgrouses (*Pterocles alchata*), or the tawny pipit (*Anthus campestris*), among many others²¹.

Steppe and farmland birds are the most threatened group of birds in Europe²² and overall 83% of the steppe bird species show an unfavorable conservation status in Europe²³. Agricultural intensification, together with habitat loss and land-use changes have partly caused the large declines detected over the past several decades for open-habitats bird populations^{1,21,24,25}. In marginal regions such as those of Iberian natural steppes, where agriculture income has been traditionally low, agricultural intensification is also occurring at field scale, but the negative trends for several steppe birds that only inhabit primary stages of vegetation succession are especially linked to shrub encroachment^{26,27,28}. The spread of shrubs and dominant graminoids is one of the major consequences of grazing abandonment, altering local floristic and edaphic conditions^{1,29} and finally affecting to the whole animal community²⁶.

During the second half of the XX century, land abandonment due to rural depopulation has generated a parallel reduction of sheep farming in Spain, as well as an increase in stocking rates and, locally, a progressive replacement of sheep by cattle^{30,31}. All these changes have supposed a great impact in land use^{30,32} and lead to an increase of shrub and tree cover in these areas³¹.

While a number of studies have assessed the relationship between grazing pressure and bird abundance in farmlands and uplands in the United Kingdom^{2,3,24}, our current knowledge about

the association between grazing and farmland and steppe birds in Mediterranean landscapes is still reduced (but see^{9,32,33}).  In this study we aimed to assess the variation in steppe bird abundance in relation to changes in sheep abundance in Spain over the period 1998-2018. We estimated the nation-wide relationship between annual changes of sheep abundance with an annual index of population trend estimated for 35 common farmland bird species (Farmland Bird Index, Table S1) and for 20 common natural steppe bird species (Steppe Bird Index, Table S2) to evaluate the potential impact of changes in sheep number with abundance of open-habitat bird species. Additionally, we also tested the relationship between annual change of sheep numbers and population trends of the Dupont's lark (*Chersophilus duponti*). We selected this species because it is a threatened habitat-specialist whose European population is restricted to Iberian natural steppes³⁴, and for which accurate data have been compiled during the last 15 years³⁴. Moreover, the promotion of extensive grazing has been traditionally described as one of the main conservation interventions to maintain optimal vegetation structure for the Dupont's lark (reviewed by³⁵). Based on the assumed positive impact that low-moderate grazing pressure has on steppe bird abundance⁶, we expected to find a close association between the decline of sheep number and those in the population indices estimated for the community of steppe birds, as well as for the Dupont's lark.

MATERIAL AND METHODS

Study area

We focused the study in Spain, since it is the European country hosting the largest proportion of steppe birds²¹ and the second one in number of sheep (ca. 19% of the total³⁶).

Estimation of change rate in sheep number

Annual data of total number of sheep in Spain were obtained from the General Directorate of Agricultural Productions and Markets (GDPME), of the Spanish Ministry of Agriculture, Fisheries and Food MAPA³⁷, for the period 1992–2020. Data come from surveys collected for all the country’s agrarian districts, and later scaled up to the province level. This is the only nationwide exhaustive information on livestock numbers and change. We restricted our analyses to sheep husbandry and did not include goat husbandry, as the number of goats in Spain is much reduced when compared to sheep (ca. 17% in respect to sheep farming for the year 2020) and mainly restricted to certain regions³⁷. We estimated the overall annual change rate in sheep number in Spain by calculating the yearly rate of change (%) since: a) 1992, for the whole time period, b) 1998, for comparisons with Farmland and Steppe Bird Indices (see below), and c) since 2005 for comparisons with Dupont’s lark trends, using each mentioned year as the reference value (cero) in each analysis.

Estimation of change rate in bird populations

For estimating farmland and steppe birds trends we used bird data from the Spanish Common Breeding Bird Monitoring Program (SACRE), which is hosted by the Spanish partnership of BirdLife (SEO/BirdLife). SACRE data is provided by volunteers who perform bird censuses in a set a 10 x 10 km cells distributed across the country (see Supplementary Fig. 1). These sites are sampled annually, during the breeding season, following a standardized methodology. The program currently involves over 1,000 sites³⁸. Although the SACRE started in 1996 we selected data for the period 1998-2018, since during the first two years of the program the data referred to a reduced number of sites.

Census data are analysed by SEO/BirdLife, which provides a bird population abundance index for each species and year, estimated using the Trend and Indices for Monitoring data (TRIM) software by fitting log-linear regression models to count data with Poisson error terms³⁹. These indices were converted on an annual change rate (%) following the same method described to estimate yearly change rate of sheep number. The change rate of the TRIM population index can be used as an estimate of annual changes in the abundance of bird species^{38,40} (see²⁵ for a similar procedure). Indeed, the SACRE program provides the best information of population trends for common breeding bird species in Spain^{41,42}. The indices of a group of species can be summarized into a single estimate to analyze trends of related bird species⁴³. Among these multi-species indices stands out the Farmland Bird Index (FBI), which is a summary population index that includes information of species classified as common farmland birds (e.g⁴⁰). The FBI is an official index, adopted by the European Union, of the quality of EU's agroecosystems for biodiversity and the effectiveness of agri-environmental interventions applied under European CAP³⁶. We used the official data provided by SEO/BirdLife for the FBI index in Spain, which comprised data for 35 common farmland bird species (see Table S1). Complementarily, we built a combined population index for a subset of 20 common species typical of Iberian natural steppes (Steppe Bird Index, SBI, see Table S2; for species selection see^{18,21,44}), in order to further explore the relationship of steppe-specialist birds with the variation in sheep number. The data about bird population index for each species and year was also provided by SEO/BirdLife.

Finally, we used the Dupont's Lark (*Chersophilus duponti*), as a threatened habitat-specialist of Mediterranean natural steppes, to evaluate the relationship between the abundance of this strong steppe-specialist lark and changes in sheep number. Due to its difficulty to be

censused using traditional surveys applied during the SACRE ⁴⁵, and thus the uncertainty in SACRE Dupont's lark data, we used an independent dataset collected using a standardized, species-specific, counting method. Annual change rate of Dupont's Lark population was estimated by Gómez-Catasús et al.³⁴ over the period 2004-2015 in Spain. This dataset comprised 42% of the Spanish populations of the species, which can be considered as representative of the population trends of the species in Spain ³⁴. Annual change rates were also estimated using the software TRIM³⁴, similarly to the method described for the SACRE program.

Statistical analyses

The application of regression models to time series can generate spurious relationships between the considered variables, which although statistically related, they might be purely coincidental⁴⁶. If no causal relationship between the variables in a regression does exist, the variance increases over time (non-stationarity) and affects the Durbin Watson statistic, whose low values may be due to this problem, and the coefficient of determination, which may reach high values, close to 1⁴⁶. In order to deal with these problems, we have carried out cointegration analyses between variables in the regressions described below. Two variables are cointegrated when they increase or decrease synchronously and maintain their relationship over time, suggesting a causal relationship⁴⁷. That is, when subtracting its expected value from the dependent variable, it is stationary (that is, mean value is stable along the time series)⁴⁷. We have used Johansen's method to assess the effect of order of causality between variables⁴⁸. Once determined if two temporal series are cointegrated, traditional regression methods can be interpreted. We fitted a linear regression to estimate the change rate of sheep number over the period 1998-2020. We fitted independent linear regressions to assess the relationship between bird population

trends (FBI, SBI) and sheep number, using change rates of bird population trends as variable response and the change rate in sheep numbers as independent variable over the period 1998-2018. Finally, we assessed the relationship between the Dupont's lark index and sheep number through linear regression. We used the overall annual change rate of Dupont's lark as variable response and the change rate in sheep number as independent variable over the period 2004-2015, using the year 2004 as reference value (0).

All statistics were performed under R 3.6.2⁴⁹, using package *lme4*⁵⁰ for linear regressions and packages *vars* and *urca* for cointegration analyses⁵¹. The level of significance was $P < 0.05$.

RESULTS

Sheep numbers have significantly declined in Spain during the period 1992-2020 (Fig. 1). In

2020 sheep number declined in 37.3% in respect to 1992 data (-9,175,782 sheep;

Linear regression, F-statistic = 128.2.10, df= 27, adjusted $R^2=0.82$; $p<0.001$, Fig. 1).

Johansen test showed significant cointegration between bird indices and sheep trends, which

indicates that posterior regression results can be considered as non-spurious: Spanish farmland

birds' trend (FBI) vs. Sheep trends Johansen test = 26.82; $p<0.01$; Spanish steppe birds' trend

(SBI) vs. Sheep trend: Johansen test = 27.31; $p<0.01$; Dupont's lark trend (FBI) vs. Sheep trend:

Johansen test = 25.02; $p<0.01$.

We found a strong, positive and significant relationship between the annual change rate of

Spanish farmland birds (FBI) during the period 1998-2018 and sheep trend (Linear regression, F-

statistic = 39.85, df= 19, adjusted $R^2 = 0.66$, $p<0.001$, Fig. 2A). Similarly, a positive and

significant association was found between the annual change rate of natural steppe birds (SBI)

and sheep trend for the same period (Linear regression, F-statistic = 27.4, df= 19, adjusted $R^2 =$

0.57, $p < 0.001$, Fig. 2B). The linear relationship between Dupont's lark annual change rate and sheep trend over the period 2004-2015 showed a positive and marginally-significant relationship (Linear regression, F-statistic = 4.44, $df = 9$, adjusted $R^2 = 0.26$, $p = 0.06$, Fig. 3).

DISCUSSION

Our results show a strong decline in sheep number in Spain during the last three decades, which is in agreement with the decreasing number of sheep husbandry in many European countries: for the period 2002-2018^{36,52,53,54,55}. Nonetheless, the sheep decline detected in Spain was especially steep since 2007, firstly, and especially since 2009, when the number of sheep drastically declines (Fig. 1). After controlling for spurious correlations, we found a very strong and positive relationship between the reduction in sheep number and the decline of farmland and natural steppe birds at national scale. The relationship between sheep number and population trend of the Dupont's Lark, a strong habitat specialist of Mediterranean natural steppes⁵⁶, was just close to significance ($p = 0.06$). This result was obtained using an independent dataset³⁵ and at shorter temporal scale (11 vs. 20 years) than FBI and SBI analyses. The lack of significant relationship for the Dupont's Lark case might be partly related to the more restricted distribution range of the species, which may difficult the possibility of detecting nation-wide changes. Likewise, the decline of the Dupont's Lark has also been associated to other land-use changes due to human activity, such as habitat loss due to ploughing⁵⁷ and the development of wind farm³⁵ which may have created confusion into the data analyzed.

We are aware that the decline of steppe birds in Spain is not exclusively explained by the decline in sheep number, but our results and previous studies strongly suggest that the significant relationships found are not simple casuistic correlations. It is well known that the negative

trends of steppe birds in Europe are mainly related to agricultural intensification and land use changes, such as the decline of fallow lands^{25,58}, which traditionally were an important grazing source⁵⁹, as well as to the increase in the use of pesticides and herbicides^{60,61}, higher mechanization⁶², or the increase of trellis vineyards or irrigated woody crops, which are large unsuitable habitat for steppe birds^{63,64}, for cite a few. Velado-Alonso et al.¹⁸ have recently found strong geographical associations between steppe bird richness and local sheep breed richness, which may be interpreted as an indicator of the intensity of extensive sheep grazing. Though these relationships are probably mediated by other environmental gradients, sheep grazing could have effects on increasing habitat heterogeneity, which could help to promote steppe bird richness and abundance¹⁸.

The associations found between the decline of both sheep number and steppe birds in Spain are in agreement with the well-recognized positive impact that extensive grazing has on the distribution and abundance of steppe birds^{3,8,12,18,65} (but see^{8,66} for a negative effect of both heavy or very low levels of grazing in steppe birds). Steppe birds are adapted to open habitats, which are partly maintained by light or moderate grazing⁸. Grazing plays an important role by decreasing vegetation height and increasing spatial heterogeneity⁶⁶, which may increase the foraging efficiency of steppe birds by foraging in more open habitats^{8,9,13,67} and minimize their predation risk while foraging on the ground^{13,14}. Traditional sheep grazing has been described a main driver of these habitats, as it may favor open, creeping plant phenotypes, which disperse their seeds through the livestock dungs^{68,69}. Plant consume by sheep in Mediterranean shrub steppes under an extensive grazing has been estimated at around 1500 kg/ha/year (dry weight), while dung producing is around 600 kg/ha/year⁷⁰. Besides, sheep dung is twice as attractive to Mediterranean dung beetles as cattle dung, three times more than red deer pellets, and four times

more than horse dung⁷¹. Thus, extensive sheep grazing will reduce plant structure and density⁴ and facilitates the occurrence of dung-processing arthropods⁷², an important food source for some steppe birds^{6,7,10}. These areas might be, finally, preferred for birds feeding on insects and, especially on dung beetles and other coprophagous arthropods^{9,11,15,16}.

Goat abundance was around six times lower than sheep abundance in Spain in 2018, and especially linked to specific regions, then in this work we have only considered trends in sheep number. Nonetheless, the negative relationship between Iberian steppe birds and sheep numbers was maintained once included the trend of goat numbers in Spain, which was around -10% during the period 2002-2018 according to official data³⁷. Besides sheep number decline, during the last decades there has been also a great change in the livestock husbandry towards a higher intensification^{32,51} that may alter the role that sheep play in natural steppes and other plant communities. For example, in recent times sheep are more often kept indoors than free-ranging³¹ and the proportion of pregnant and lactating ewes, which are usually hosted, has been increased^{31,32,73}. These changes in sheep husbandry imply a substantial reduction of the workload and may maximize the farmers income, but reduce the intensity and duration of outdoors grazing^{30,32}, besides its larger inefficiency in extracting energy than that of native sheep breeds when grazing and exploiting resources in harsh environments that cannot be used otherwise³¹.

Under these circumstances, extensive sheep grazing in Spain has practically disappeared³¹, and the role of sheep as ecosystem engineer species has disappeared⁷³ or even is negative due to pollution or overgrazing and soil degradation around intensive farms^{74,75}. In Spain, shrub- and tree-encroachment has steeply increased in areas considered as transitional from former extensive grazing to current land abandonment³¹, and consequences of this functional change are still to be fully determined.

Our results suggest that the alarming decline of Iberian steppe birds might be, at least partly, associated to the sharp decline in sheep livestock occurring in Iberia. Further research is needed to understand the mechanisms behind the associations found in that study, but meanwhile there is a need to reverse the negative effect that this trend in sheep number may suppose on habitat heterogeneity and quality for steppe birds. Thus, the conservation of steppe birds seems to be linked to that of extensive grazing, and benefits for one component probably have benefits on the other¹⁸. According to that, the promotion of extensive grazing should be considered as a key factor in future Common Agricultural Policy reforms and conservation programs in order to maintain steppe bird populations. As the same grazing pressure may be favorable for some species of conservation concern but detrimental to others^{9,33}, we encourage researchers to estimate the adequate grazing intensity for protecting most of steppe birds, as well as to perform species-specific studies for proposing a concrete grazing intensity to protect the most threatened ones. These studies would provide scientific evidence to managers and therefore increase the implementation of extensive grazing as conservation intervention⁷⁶. Extensive sheep grazing should be considered as a low impact-practice, which may contribute to reverse shrub encroachment while avoiding other resources-consuming practices as mowing, manual shrub-clearing and/or controlled burning¹. In a climate change scenario, natural steppe habitats may need habitat management actions addressed to improve habitat quality for open-habitat bird species^{9,76,77,78,79}.

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Author Contributions

J.T. conceived the idea and lead data collection and formal analysis. J.T. and C.P-G. contributed equally to the design and writing.

Competing Interests:

The authors declare no competing interests.

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Figure 1

Temporal trend in the number of sheep in Spain during the period 1992-2020.

The linear regression is shown in blue, and 95% Confidence Intervals in grey (linear regression: adjusted $R^2 = 0.82$; $p < 0.0001$).

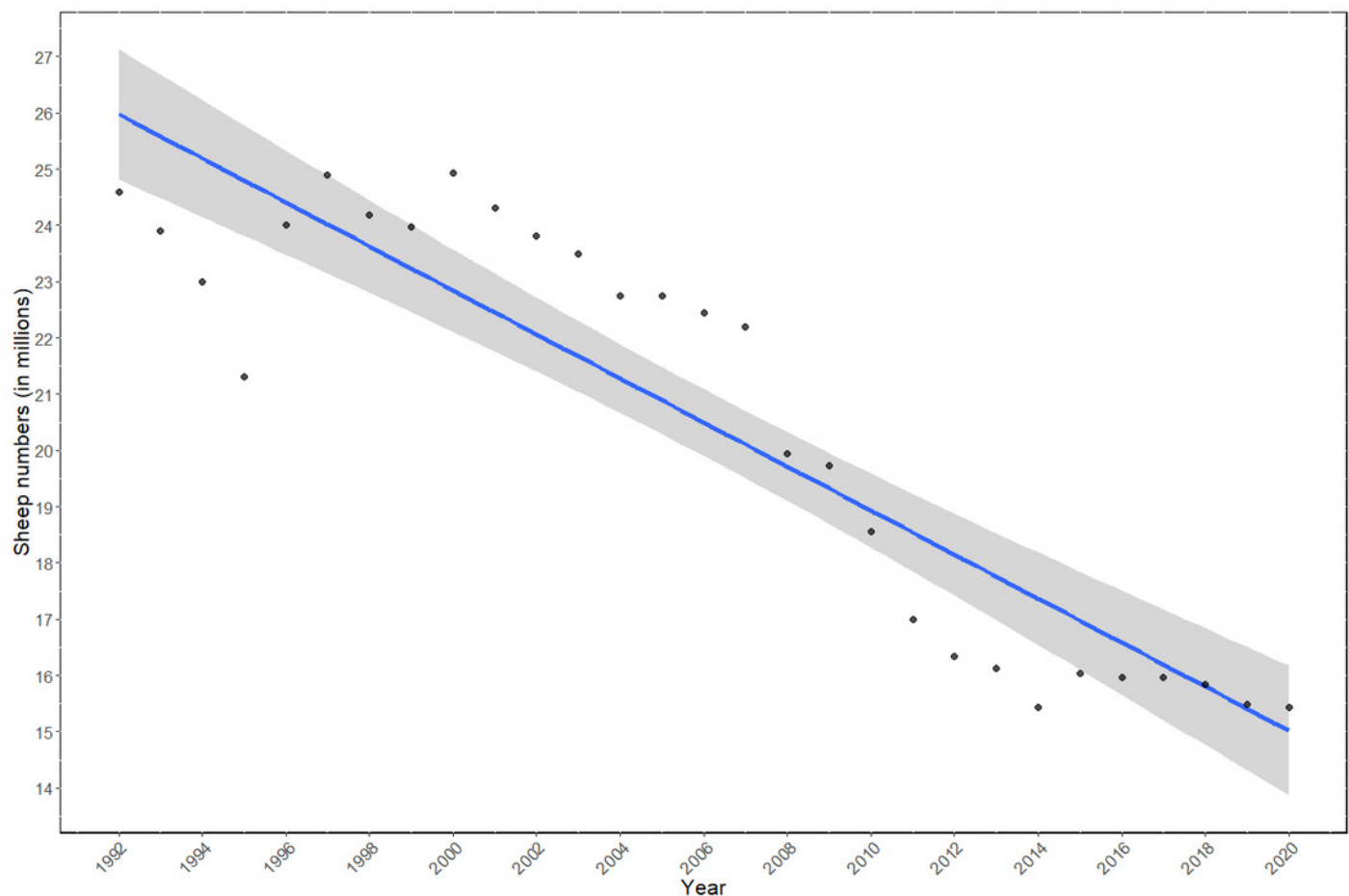


Figure 2

Linear relationship between annual change rates of bird communities and annual change rate of sheep numbers in Spain during the period 1998-2018.

(A) Farmland Bird Index (adjusted $R^2 = 0.66$; $p < 0.0001$). (B) Steppe Bird Index (adjusted $R^2 = 0.56$; $p < 0.001$).

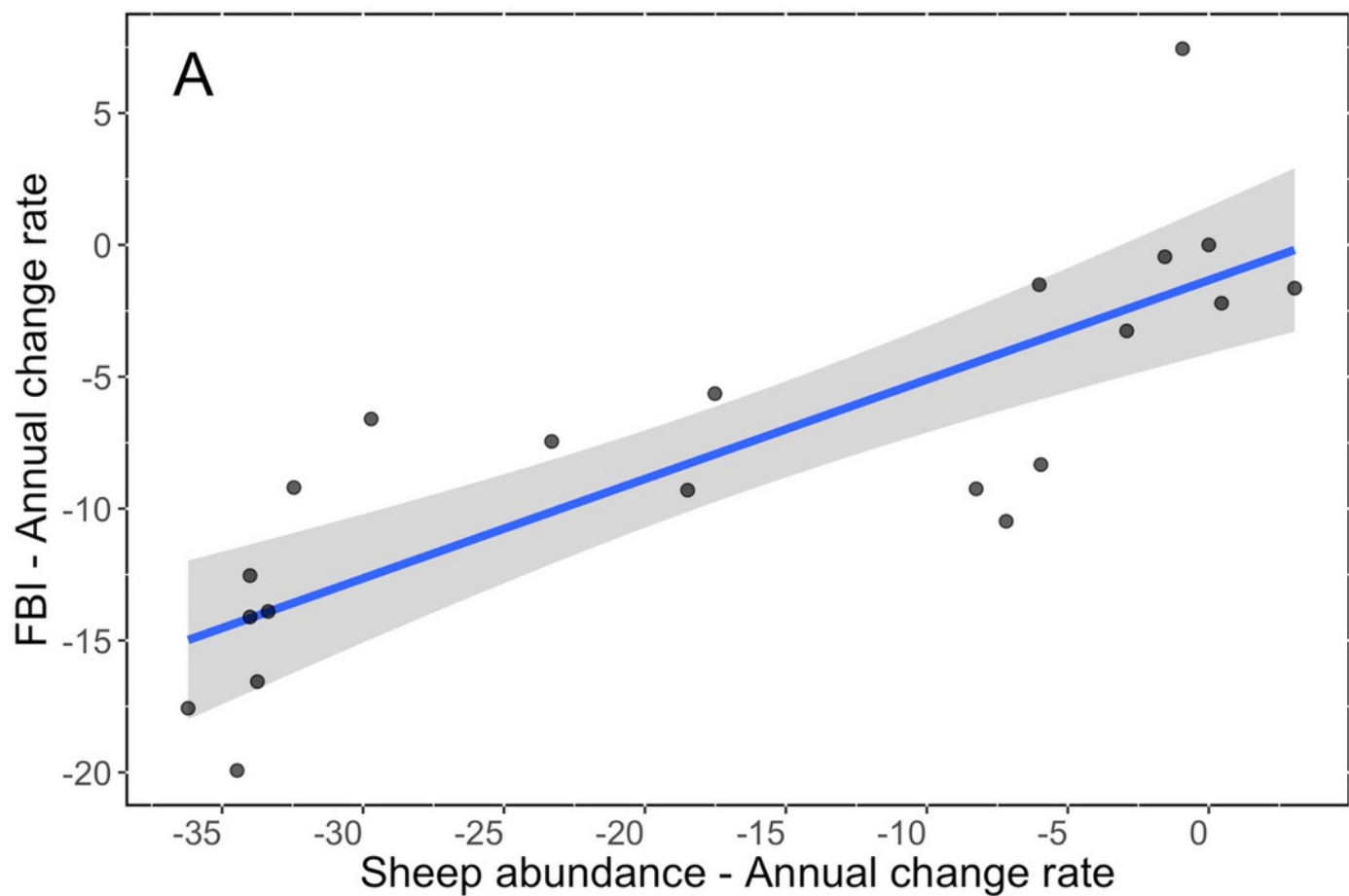


Figure 3

Figure 2b (to be placed below figure 2a)

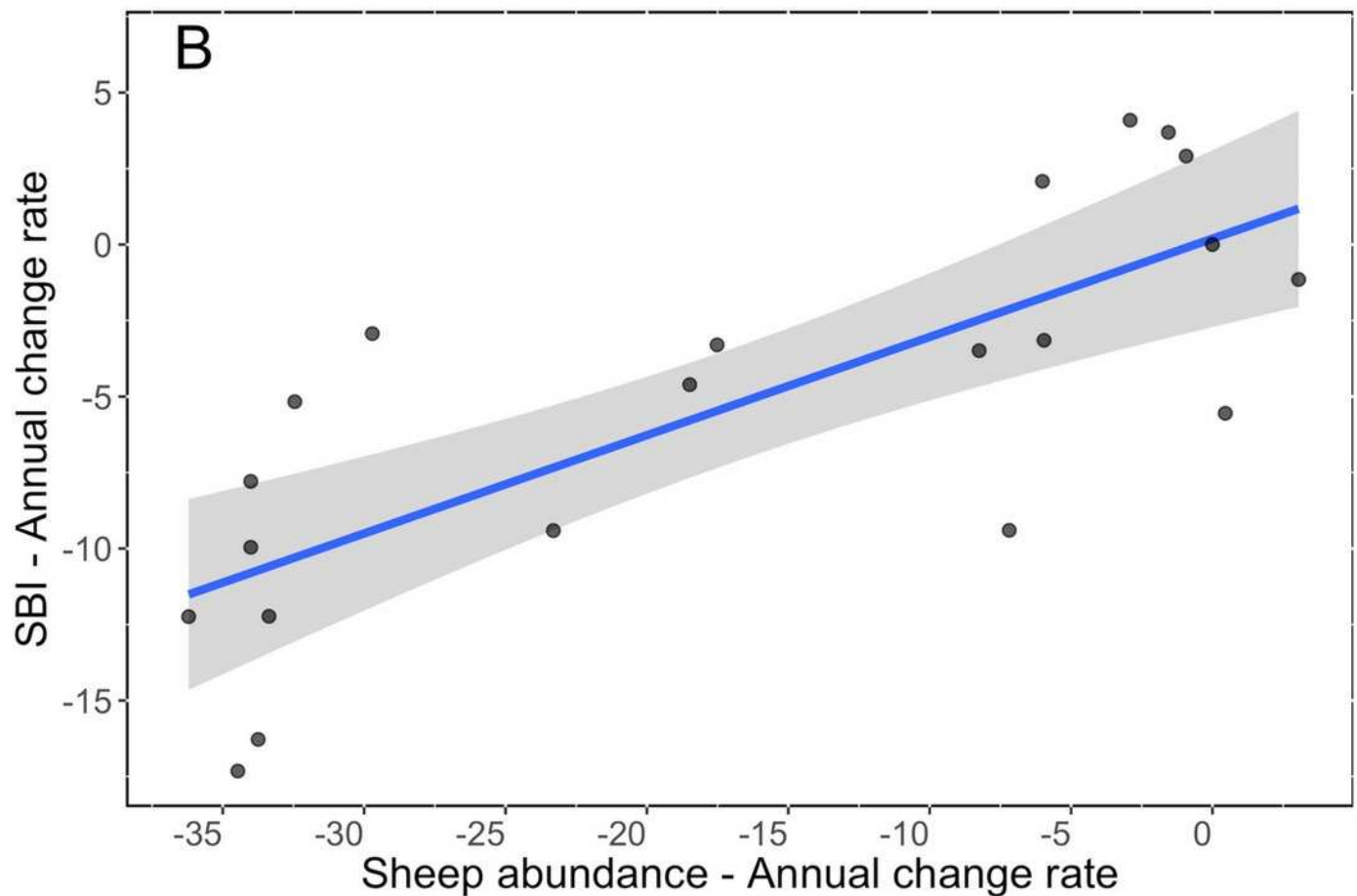


Figure 4

Linear relationship between Dupont's Lark annual change rate and annual change rate of sheep numbers in Spain during the period 2004-2015 (adjusted $R^2 = 0.25$; $p < 0.0649$).

