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Between and within-year effects of haying on grassland bird populations and spatial dynamics

Nuno Faria[a,*], Manuel B. Morales[a], João E. Rabaça[b,c]

[a] Grupo de Ecología Terrestre (TEG), Departamento de Ecología, Universidad Autónoma de Madrid 28049 Madrid, Spain
[b] LabOr—Laboratório de Ornitologia, ICAAM-Instituto de Ciências Agrárias e Ambientais Mediterrânicas, Universidade de Évora, 7002-554 Évora, Portugal
[c] Departamento de Biologia, Universidade de Évora, 7002-554 Évora, Portugal

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ABSTRACT

In recent years, haying has extended to Iberian Mediterranean dry grasslands potentially threatening grassland birds. We evaluate the between and within-year effects of haying on grassland birds in Alentejo region, Portugal. Our main goals were: (1) to investigate variations on bird abundance and species richness in the fields hayed, with respect to past haying events occurred in a field and its surroundings and; (2) to investigate the shifts in bird abundance, species richness and spatial dynamics resulting from haying a field and its surrounding area in a given year. We conducted grassland bird censuses during the breeding season through point counts from 2012 to 2015. The relationship between bird abundance/richness and past haying events was investigated using Generalized Linear Models whereas within-year effects of haying were analysed using Generalized Additive Models. Bird abundance in a field was positively related with the surface hayed in the vicinity of that field in the previous year. However, contrasting yearly effects were found for non passerines. Also, some species prefer fields with less haying events or surface hayed, whereas others occur mostly in fields frequently managed for haying. Haying a field leads, in the short term, to its abandonment by birds, and thus to a decrease in bird abundance and, for some species, to spatial concentration in surrounding fields offering suitable habitat. We conclude that within-year effects of haying have higher impact on grassland birds than between-year effects. Maintaining haying at low levels by rotating haying yearly through the different fields in each farm and using partial haying may be an adequate way to ensure an effective management of grassland bird populations.

1. Introduction

Grasslands in Western Europe are mainly secondary and anthropogenic (both semi-natural and artificial). They have replaced forests after centuries of low-intensity agricultural use (Bredenkamp et al., 2002; Suárez et al., 1991). In the last decades, European grassland habitats have experienced strong changes resulting from shifts in agriculture priorities and European Union policies (Huyghe et al., 2014). In Mediterranean environments these changes have resulted mainly from land use modification (specially, due to olive plantation; see Beaufoy, 2001) and grassland management intensification (Correal et al., 2006). Iberian agricultural landscapes were during centuries predominantly used for extensive cereal production and sheep rearing, but in the last decades cattle farms have spread across Mediterranean landscapes favouring the appearance of different grassland management options. For instance, in south Portugal, bovine numbers experienced a 107% increase between 1989 and 2013 (INE, 2014). Also, the surface of the main crops used for haying (forage oats, grass-legume crops or pure legume crops) increased 34% between 1989 and 2009.

Under adequate soil and hydrological conditions, Iberian dry grasslands can produce moderate to high primary production for hay or silage (Carpintero et al., 1991; Hernández et al., 1994; Rodríguez et al., 2006; San Miguel, 2009). New infrastructures and technological solutions, such as irrigation perimeters, new fertilizers and more effective agriculture machinery have generalized the use grassland for hay and silage production. Nowadays, Iberian farmers are no longer willing to take risks because of the droughts that often occur under Mediterranean climate, storing biomass reserves that provide a feeding alternative in periods where grassland biomass production in farms is insufficient to ensure livestock needs, or when animal products are obtained from stabled livestock.

* Corresponding author.
E-mail address: farnuno@gmail.com (N. Faria).

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In the Iberian Peninsula haying is not confined to cereal and legume forage crops or wet meadows, occurring frequently on semi-natural spontaneous dry grasslands (grazed or not). These semi-natural habitats hold important populations of threatened or near-threatened birds at European or global level, such as the great bustard (*Otis tarda*), the little bustard (*Tetrax tetrax*) or the Montagu's harrier (*Circus pygargus*). However, mowing machinery and mowing timings are likely to threaten grassland bird populations by causing reproductive failure through loss of nests and eggs, chick mortality or adult mortality (Grüebler et al., 2008; Vickery et al., 2001). Indeed, in temperate areas of central Europe and North America several authors suggested a link between important declines in grassland bird populations and changes in timing and frequency of hay (Green et al., 1997; Grüebler et al., 2008; Herkert, 1997).

Few links between hay management and changes in wildlife populations have been established (see Perlut et al., 2006) and the knowledge on the relative importance of the processes involved is deficient, particularly in Mediterranean environments. Furthermore, there is a general lack of evidence-based landscape-scale conservation strategies that consider alternative grassland management techniques, such as rotational mosaic mowing (Buri et al., 2013). Socher et al. (2012) showed that low-intensity mowing (once a year or less) favours plant species richness in a greater degree than grazing, although at higher cutting frequency, richness dropped dramatically, while higher grazing intensity had little effect on plant diversity. Differences in the management of cutting frequency and the amount of inputs may thus be responsible directly or indirectly not only for the observed variation in plant diversity, but also for the high spatial variability in arthropod abundance at the landscape scale (Badenhausser et al., 2009; Chambers and Samways, 1998; Humbert et al., 2009), which are important resources for birds in Iberian and other dry grasslands (see Faria et al., 2012).

These complexities of grassland management are likely to determine different responses by bird species. In this study, we evaluate the between and within-year effects of haying on grassland bird diversity, abundance and spatial dynamics during the breeding season in Alentejo region (south Portugal). Our main goals were: (1) to investigate variations on bird abundance and species richness in the fields, with respect to past haying events occurred in a field (number, surface and year of last haying) and its surroundings in the previous year, assessing for differences related with contrasting weather conditions in each year, and with the type of hay, and (2) to investigate the shifts in bird abundance and species richness, due to field abandonment by birds and their subsequent spatial concentration resulting from haying a field and its surrounding area in a given year.

2. Material and methods

2.1. Study area

The study area is located in Évora region (Alentejo province, south Portugal; −7.884902W, 38.533521N), in the Mesomediterranean biogeographic region (Rivas-Martínez et al., 2004). Climate is generally dry, with average annual temperatures ranging from 9.6 °C in winter to 24.1 °C in summer and a annual rainfall average of 586 mm (1981–2010 period; IPMA, 2015a). This area comprises a mosaic landscape dominated by holm oak forested areas or 'montados' and grasslands. Soils are mostly acidic and of low average fertility (own unpublished data). Most important land uses are extensive livestock grazing (mostly cattle) and cereal/leguminous crops for hay production. Cereal crops for grain are nowadays less common due to recent conversion of farms for beef production. Irrigated pastures are also common in this region, although marginal in surface compared to dry grasslands. The mean field size in the study area was around 70 ha.

As mentioned above, there are no official mowing statistics for the region of Évora and therefore the only data available refer to the fields monitored by our team during these four years of study (Table 1). All mown fields during these four years were used for hay production. Both rainfall and temperature were very different between years (IPMA 2015b), potentially affecting the entire process of haying and bird distribution (Table 1).

The study area is partly included in the Special Protection Area for birds of Évora. It holds important populations of protected grassland bird species such as the little and great bustards, Montagu's harrier, black-bellied sandgrouse (*Pterocles orientalis*) and the calandra lark (*Melanocorypha calandra*). No special regulation on mowing is applied inside the Special Protection Area.

2.2. Data collection

We conducted grassland bird censuses through point counts during four consecutive breeding seasons from 2012 to 2015. Bird counts were made in the first three and a half hours after sunrise and in the last two and a half hours before sunset, in the last fortnight of April and repeated in the last fortnight of May. A radius of 250 m around the point count station and a count period of 15 min were assumed, recording for the location and number of individuals of each species displaying clear territorial or nesting behaviour and adjusting if necessary the geographical location of the territories. This procedure is particularly suitable in high density areas were birds spend most of their time chasing each other). The counting period length used minimises potential detectability problems due to between-field differences in

Table 1
Haying and weather statistics for the 2012–2015 period in Évora region.

Statistics	2012	2013	2014	2015
Haying				
Number of sampling fields	45	45	47	39
Fields with tall/dense vegetation with potential for haying	10	17	23	16
Fields partly or fully hayed	3	12	15	11
Haying start date	16-May	06-May	06-May	05-May
Weather				
Winter[a] rainfall (mm)	25.3	168.3	291.8	89.2
Spring[b] rainfall (mm)	46.9	225.3	160.0	77.4
Winter average minimum temperature (°C)	2.5	7.8	5.2	3.6
Winter average maximum temperature (°C)	14.9	11.0	14.5	14.2
Spring average maximum temperature (°C)	6.5	7.7	7.6	7.8
Spring average minimumtemperature (°C)	19.1	17.8	19.4	20.9

[a] Winter (December–February).
[b] Spring (March–April).

vegetation height. Raptors hold large territories, in some cases outside sample field boundaries. Therefore, we only considered observations of raptors hunting or perched in the sampled field. The species and bird groups considered are presented in Table 2.

In order to obtain homogenous sampling areas, counts were made only in fields large enough to fit the whole counting area. In total we performed censuses in 45 fields in 2012, 45 fields in 2013, 47 fields in 2014 and 39 fields in 2015. Due to limitations on the cartography available for haying (notably the dates of mowing), we only analysed within-year effects of haying in 35 fields in 2012, 37 fields in 2013, 37 fields in 2014 and 35 fields in 2015. In order to avoid spatial autocorrelation of the data, sample fields were widely distributed around the city of Évora out of 15 farms evenly distributed in the north and south plains. In addition, the main land uses in these grasslands, and specifically the fields used for haying, are not concentrated in any particular sector of the study area.

Information on haying was mostly collected during field work or provided by land managers. If necessary, the surface mown in each field was corrected using the aerial photos of the region. Two types of hay were considered: cereal-based crops and pastures/ fallow land. Both vegetation types are managed during winter and spring for haying using livestock exclusion and soil fertilization. Their use for haying or alternatively for grazing depends mostly on winter rainfall. At the time of haying these two habitats are fairly similar in sward structure, presenting tall and dense vegetation and absence of woody plants, but differ in plant composition (own unpublished data) and possibly in arthropod diversity. Fields sown with grasses such as raygrass and alfalfa/clover are quite rare in Évora region and thus were not considered.

Vegetation surveys were conducted after bird counts, in the same day or at most 2 days later. Vegetation height was measured within a $50\,cm \times 50\,cm$ square, using 18 random sampling replicates disposed around each point count station. All remaining independent variables collected are presented in detail in Table 3.

2.3. Data analyses

2.3.1. Between-year effects

The relationship between bird abundance and richness and past haying events was investigated using Generalized Linear Models (GLM, McCullagh and Nelder, 1989), considering a Poisson distribution for the data. When overdispersion was detected in models, the standard errors and *p*-values estimates were corrected using quasi-GLM models. The variance in quasi-GLM models is given by $\varphi \times \mu$, where μ is the mean and φ the dispersion parameter. Following the recommendation of Zuur et al. (2009) the models with φ over 1.3 were corrected for overdispersion. The dependent variables used were (a) the territory abundance of each species and of specific groups of birds (passerines, non-passerines, ground-nesting birds, non ground-nesting birds and all species), and (b) the species richness of those groups. The maximum abundance/richness values between April and May counts were chosen for the analyses. We defined a priori five independent variables of interest, four variables describing haying events at the field level: (1) the last year of haying (LastHayF), (2) the number of years of haying in the previous three-year period (NHayF3Y), (3) the surface used for haying in the previous three-year period (PHayF3Y) and (4) the surface used for haying in the previous year (PHayF1Y); and one variable describing haying events in the surroundings of a field (5) the surface used for haying in the previous year within a buffer of 300 m around the field (PHayS1Y; see Table 3 for variable names and descriptions).

We examined the potentially different responses of birds to haying of different types: cereal-based crops and pasture/fallow land. To do this, we introduced in the models, the surface of hay crops and the surface of pastureland/fallow land in the surroundings as independent variables.

Although the descriptive variables collected at field level have different biological meaning and management application, they showed non-negligible levels of collinearity (correlation values between 0.65 and 0.85). To overcome this problem we restricted model ranking/selection to four GLM models and respective submodels:

$$M1: \text{maxBirdAprilMay} \sim (\text{LastHay} + \text{PHayS1Y}) \times \text{Year}$$

$$M2: \text{maxBirdAprilMay} \sim (\text{NHayF3Y} + \text{PHayS1Y}) \times \text{Year}$$

$$M3: \text{maxBirdAprilMay} \sim (\text{PHayF3Y} + \text{PH PHayS1Y}) \times \text{Year}$$

$$M4: \text{maxBirdAprilMay} \sim (\text{PHayF1Y} + \text{PHayS1Y}) \times \text{Year},$$

where, maxBirdAprilMay represents the maximum abundance or richness of the species and groups considered recorded in April or May. These models allowed us to investigate the response of each bird species/group to haying both at field and surroundings levels

Table 2
Species considered for the study, respective phenology status and bird groups. The species analysed individually (representative in the sample) are presented.

Species	Fenology status	Bird group[a]	Representative in the sample
Montagu's Harrier *Circus pygargus*	Breeding	NP,GN	
Black-shouldered Kite *Elanus caeruleus*	Resident	NP,NGN	
Lesser Kestrel *Falco naumanni*	Breeding	NP,NGN	
Common kestrel *Falco tinnunculus*	Resident	NP,NGN	•
Red partridge *Alectoris rufa*	Resident	P,GN	
European quail *Coturnix coturnix*	Breeding	NP,GN	•
Little bustard *Tetrax tetrax*	Resident	NP,GN	•
Great bustard *Otis tarda*	Resident	NP,GN	
Eurasian stone-curlew *Burhinus oedicnemus*	Resident	NP,GN	
Black-bellied sandgrouse *Pterocles orientalis*	Resident	NP,GN	
Calandra lark *Melanocorypha calandra*	Resident	P,GN	•
Short-toed lark *Calandrella brachydactyla*	Breeding	P,GN	
Crested lark *Galerida cristata*	Resident	P,GN	•
Thekla lark *Galerida theklae*	Resident	P,GN	•
Tawny pipit *Anthus campestris*	Breeding	P,GN	
Zitting cisticola *Cisticola juncidis*	Resident	P,GN	•
Southern grey shrike *Lanius meridionalis*	Resident	P,NGN	•
Corn bunting *Emberiza calandra*	Resident	P,GN	•

[a] Passerine (P), non-passerine (NP), ground-nesting (GN) and non ground-nesting (NGN).

Table 3
Variables used to model dry grassland bird response to haying management at two temporal scales (inter-annual and intra-annual).

Variable	Description	Average (+SD)	Range
Between-year			
Year	Factor variable indicating the year where field works took place	–	2012–2015
LastHayF	Year of last haying in the field. Varying from 0 if last haying occurred in the previous year, to 3, if last haying occurred four years ago or more	1.13 ± 1.30	0–3
NHayF3Y	Number of years that the field was hayed in the previous three-year period	0.72 ± 0.88	0–3
PHayF3Y	Average percentage of field that was hayed in the previous three-year period	0.15 ± 0.23	0–0.86
PHayF1Y	Percentage of field that was hayed in the previous year	0.15 ± 0.30	0–1
PHayS1Y	Percentage of a 300 m buffer around a field that was hayed in the previous year	0.15 ± 0.14	0–0.51
–			
Within-year			
PHayField	Percentage of the counting area that was hayed	0.11 ± 0.28	0–1
PHaySurr	Percentage of a 500 m buffer around the counting area that was hayed	0.08 ± 0.11	0–0.48
VegHeig	Mean vegetation height measured at a field within a 50 × 50 cm square, using 18 sampling replicates randomly disposed around each point count station. Factor variable with four vegetation classes: (1) 0–15 cm, (2) 15–30 cm, (3) more than 30 cm and (4) vegetation hayed	–	–

considering both temporal effect of the number of years to last haying, (model M1) and spatial variation. More specifically, we assess the effect of the number of haying events (model M2) and the surface mown using a time window of one and three years (models M4 and M3, respectively).

Model ranking and selection was performed by calculating Akaike's Information Criterion corrected for small sample size (AICc) or Akaike ~ s Information Criterion for overdispersed count data, corrected for small sample (QAICc), for all possible combinations of variables of M1 to M4 models. Models with the lowest AICc/QAICc and within less than 2 units of ΔAICc/ΔQAICc were selected as best models and considered similar in performance (Burnham and Anderson, 2002).

2.3.2. Within-year effects

The spatial dynamics of bird abundance and richness resulting from haying were investigated using Generalized Additive Models, (GAM; Wood, 2008) to account for non-linear responses revealed by previous univariate analyses. Generalized additive models are a modification of GLMs where each predictor is included in the

Table 4
Best GLM models for the response of grassland bird groups to the inter-annual management of haying.

Bird group	Model	Year	PHayS1Y	LastHayF	PHayF3Y	PHayF1Y	PHayS1Y:Year				LastHayF:Year				pseudo-R^2	Information theory		
							12	13	14	15	12	13	14	15		(Q) AICc	Δ(Q) AICc	Weight
Bird abundance (overall)	1	•*	0.53*												0.08	713.80	0.00	0.18
	2	•*	0.51*	0.03											0.09	714.00	0.20	0.17
	3		0.40												0.03	714.70	0.84	0.12
	4		0.37	0.03											0.04	715.10	1.23	0.10
	5	•	0.47*								−0.05	0.12	0.12*	0.10	0.13	715.20	1.37	0.09
	Null														0.00	716.40	2.57	0.05
Passerine abundance	1	•**	0.46	0.04											0.12	672.30	0.00	0.26
	2	•**	0.48*												0.11	672.40	0.13	0.24
	3	•**		0.04											0.10	673.80	1.58	0.12
	Null														0.00	678.00	5.78	0.01
Non-passerine abundance	1	•*	1.03*		−0.58										0.10	520.40	0.00	0.26
	2		1.17**		−0.56										0.06	521.40	1.05	0.16
	3	•			−0.57		1.71*	−0.68	−2.84*	−0.01					0.12	521.60	1.21	0.14
	4	•*	1.09*												0.08	522.00	1.65	0.12
	Null														0.00	528.00	7.62	0.01
Ground-nesting abundance	1	•***	0.59*	0.04											0.25	660.90	0.00	0.39
	2	•***	0.62**												0.24	661.90	0.99	0.24
	3	•***		0.05*			1.03*	−0.40	−1.16	0.06					0.28	662.80	1.85	0.16
	Null														0.00	686.30	25.42	0.00
Non ground-nesting abundance	1	•*				−0.66	−5.66**	7.39*	1.72	2.99					0.24	331.10	0.00	0.30
	2	•					−5.51**	7.23**	1.20	2.63					0.23	331.30	0.20	0.27
	3	•**	−2.82**			−0.63									0.20	331.80	0.70	0.21
	4	•**	−2.93**												0.19	331.90	0.84	0.19
	Null														0.00	361.40	30.30	0.00
Non ground-nesting richness	1	•*	−2.89**			−0.64									0.16	303.70	0.00	0.27
	2	•*	−3.00**												0.15	303.70	0.00	0.27
	3	•*				−0.67	−5.66**	7.20*	1.74	3.30					0.19	304.10	0.40	0.22
	4	•*					−5.51**	7.03*	1.20	2.94					0.17	304.20	0.53	0.21
	Null														0.00	323.10	19.47	0.00

The coefficients, the (Q)AICc for each model and the statistical significance for each variable and are presented (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$). The models shown are those with $\Delta(Q)AIC_c < 2$ and the corresponding null models.