Title:

Field margins as substitute habitat for the conservation of birds in agricultural wetlands

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Abstract

Breeding birds in agricultural landscapes have declined considerably since the 1950s and the beginning of agricultural intensification in Europe. Given the increasing pressure on agricultural land, it is necessary to identify conservation measures that consume little productive land. We tested the hypothesis that field margins represent substitute habitats for bird species in agricultural wetlands. We monitored bird species in 86 crop fields in rice paddy landscapes of Camargue (southern France), a wetland of international importance for birds. We investigated whether the area of three types of field margins (grass strips, hedgerows and reed strips) within a 500 m buffer around each studied crop field had an effect on the abundance of three groups of birds defined based on their primary habitat (reedbeds, grasslands, and forest edge species). We controlled for the area of each semi-natural habitat (wetlands, grasslands, and woodlands), crop diversity and mean crop field size. Our study confirms that bird guilds are favored by the cover of their primary habitat but are also influenced by the cover of field margins. Reedbed birds are favored by the cover of wetlands and reed strips, grassland birds are favored by the cover of grasslands and wetlands and negatively impacted by the cover of woodlands and hedgerows, while forest edge birds are favored by the cover of hedgerows and negatively impacted by the cover of reed strips. These results suggest that field margins may represent substitute habitats for reedbed and forest edge bird species and highlight their importance for biodiversity conservation in wetland agricultural landscapes. However, our results also suggest that increasing the area of hedgerows and reed strips may have a negative effect on grassland birds and forest edge birds, respectively. Recommendations for field margin management in agricultural wetlands should therefore be tailored to local conservation priorities.

Keywords: bird conservation, biodiversity, landscape heterogeneity, grassland birds, forest edge birds, reedbed birds, wetland, rice, habitat compensation, land sharing

1 Introduction

Farmland bird populations have experimented a massive decline worldwide over the last decades, primarily due to the loss of semi-natural habitats and intensification of agricultural practices (PECBMS, 2022; Stanton et al., 2018; Sundar and Subramanya, 2010). Agricultural areas represent 37 % of the world terrestrial area and host a large proportion of terrestrial biodiversity (DataBank, 2018; Herzog et al., 2013). It is therefore hopeless to rely solely on the creation of protected areas to compensate for the declines in biodiversity observed in agricultural environments (Li et al., 2020; Margules and Pressey, 2000). Rather, conservation efforts should also target the improvement of the carrying capacity of agricultural landscapes through the adoption of biodiversity-friendly agricultural practices and the protection of non-productive refuge areas, i.e. promote land sharing (Grass et al., 2021).

Patches of semi-natural habitats, such as woodlands, grasslands and wetlands, remaining within agricultural landscapes may provide permanent habitat for wildlife and host a large part of farmland biodiversity (Newton, 2017; Toffoli and Rughetti, 2017). However, these patches are scarce and under increasing pressure due to agricultural intensification which leads to their progressive conversion to arable land despite efforts from the European Union to slow down this trend through agri-environment schemes (Batáry et al., 2015). Hence, in some agricultural landscapes, field margins are the only semi-natural habitats left (Marshall and Moonen, 2002). The habitat compensation hypothesis states that species may compensate for the loss of their primary habitat by using agricultural habitats as a substitute. For instance, Montagu's harrier (*Circus pygargus*) primarily nests in shrublands and grasslands but, in some part of its distribution range, it now relies exclusively on crop fields for breeding and foraging (Norton et al., 2000). It has also been shown that aquatic invertebrates can use drainage ditches as substitute habitats for natural lakes and rivers (Dollinger et al., 2015). The issue of habitat compensation has been addressed in farmland abandonment or dry agricultural areas (e.g. Brotons et al., 2005; Saura et al., 2014; Vallecillo et al., 2008) but rarely in wetland agricultural areas (e.g. Decleer et al., 2015) despite their specific landscape characteristics and biodiversity.

One of the main crop cultivated in wetlands is rice, a flooded cereal which represents 22.8 % of the world cereal surface area (FAO, 2018; Singh et al., 2001). In such rice paddy landscapes, agricultural and semi-natural (wetlands, woodlands and grasslands) areas are generally intermingled with the presence of large field margins around ditches. Biodiversity associated with these rice paddy landscapes includes both waterbirds and terrestrial bird species. While the role of rice paddy landscapes for waterbirds has been largely studied, their

role for terrestrial birds has received much lower attention (Elphick, 2015), whereas they have suffered a very significant decline since the 1950s due to the intensification of agricultural practices and the decrease of landscape heterogeneity (Fraixedas et al., 2019; Sirami et al., 2019). Terrestrial birds using rice paddy landscapes include different ecological guilds: reedbed birds, which are primarily associated with freshwater marshes (Morganti et al., 2019); forest edge species, which are originally associated with forest borders and clearings (Hinsley and Bellamy, 2019; Newton, 2017); and grassland species, which originally live in grassy or shrubby vegetation with no tree cover (Di Giacomo et al., 2010). Field margins could provide resources and nesting habitats for these species (Vickery et al., 2009), e.g. reed strips along ditches for reedbed birds, hedgerows for forest edge species and grass strips for grassland species. However, the role of these landscape features for terrestrial birds has rarely been considered in studies conducted in rice paddy landscapes (King et al., 2010).

The Camargue (Rhône delta) is a biologically rich area listed in the Ramsar Convention and classified as a Biosphere Reserve by UNESCO (Blondel et al., 2019). It is also the fifth European rice production area (FAO, 2018). If agriculture plays a critical role in the hydrosaline equilibrium of the delta by pumping freshwater from the Rhône River, farmland birds have shown the highest rate of decline in the last 50 years (Fraixedas et al., 2019; Galewski and Devictor, 2016). Hence, it is critical to better understand how field margins and semi-natural habitats remaining within agricultural landscapes may contribute to the restoration of biodiversity.

In this paper, we evaluated the ability of field margins to support the habitat compensation hypothesis for three ecological bird guilds (reedbed birds, forest edge birds and grassland birds) in the rice paddy landscapes of Camargue. We conducted bird surveys in 86 crop fields and tested the hypothesis that field margins provide substitute habitat for bird species in Camargue. More specifically, we predicted that (i) reedbed birds would be positively influenced by semi-natural wetland areas and reed strips; (ii) grassland birds would be positively influenced by grasslands and grass strips and (iii) forest edge species would be positively influenced by woodlands and hedgerows.

2 Material and methods

2.1 Study area

Our study was conducted in the Rhône River delta, a 180,000 ha polderized flood plain located in Southern France and known as “Camargue”. Warm summers typical of the Mediterranean climate (average monthly temperature between May and October above 15°C; Blondel et al., 2019), as well as fresh water pumped from the Rhône River allows rice cultivation. This flooded crop is essential for washing out salt-rich soils and allows rotation with dry crops. Field margins in these rice paddy landscapes are often wide (> 3 m) to be waterproof and keep the rice fields flooded, and structurally complex. Several types of vegetation can therefore co-occur on the same field margin such as reed strips, hedgerows or grass strips. In Camargue, the area of semi-natural habitats decreased from 67 % to 39 % between 1942 and 1984 and is now stable around 58,000 ha (Tamisier and Grillas, 1994). These semi-natural areas are spatially segregated in the delta; woodlands are mainly restricted to riparian areas along the Rhône River, wetlands occupy depressions and cover large areas in the center and south of the delta while grasslands (mostly constituted of meadows and salt steppes) surround the wetlands on slightly elevated areas (Appendix A).

2.2 Study design

We selected 86 organic crop field (Fig. 1) along the gradients of semi-natural cover and hedgerow cover while ensuring their statistical independence according to the methodology developed by Pasher et al., (2013). To do so, we measured semi-natural and hedgerow areas in a 500 meters square moving window with a step size of 100 meters around every agricultural lands of Camargue thanks to land use data from 2019 of the BD TOPO®, OSO Land Cover Map and the Regional Natural Park of the Camargue. Hedgerow was the only field margin layer available on the different land cover map. We checked for uncorrelation between the different field margins types and landscape variables after the crop field selection and the accurate landscape description (see below). We selected only organically managed crop fields in order to limit potential biases associated with variations in the intensity of agricultural practices. We selected crop fields covered by the main five crops types, representative of the main agricultural production in the Camargue (rice, wheat, alfalfa, rape, and market gardening).

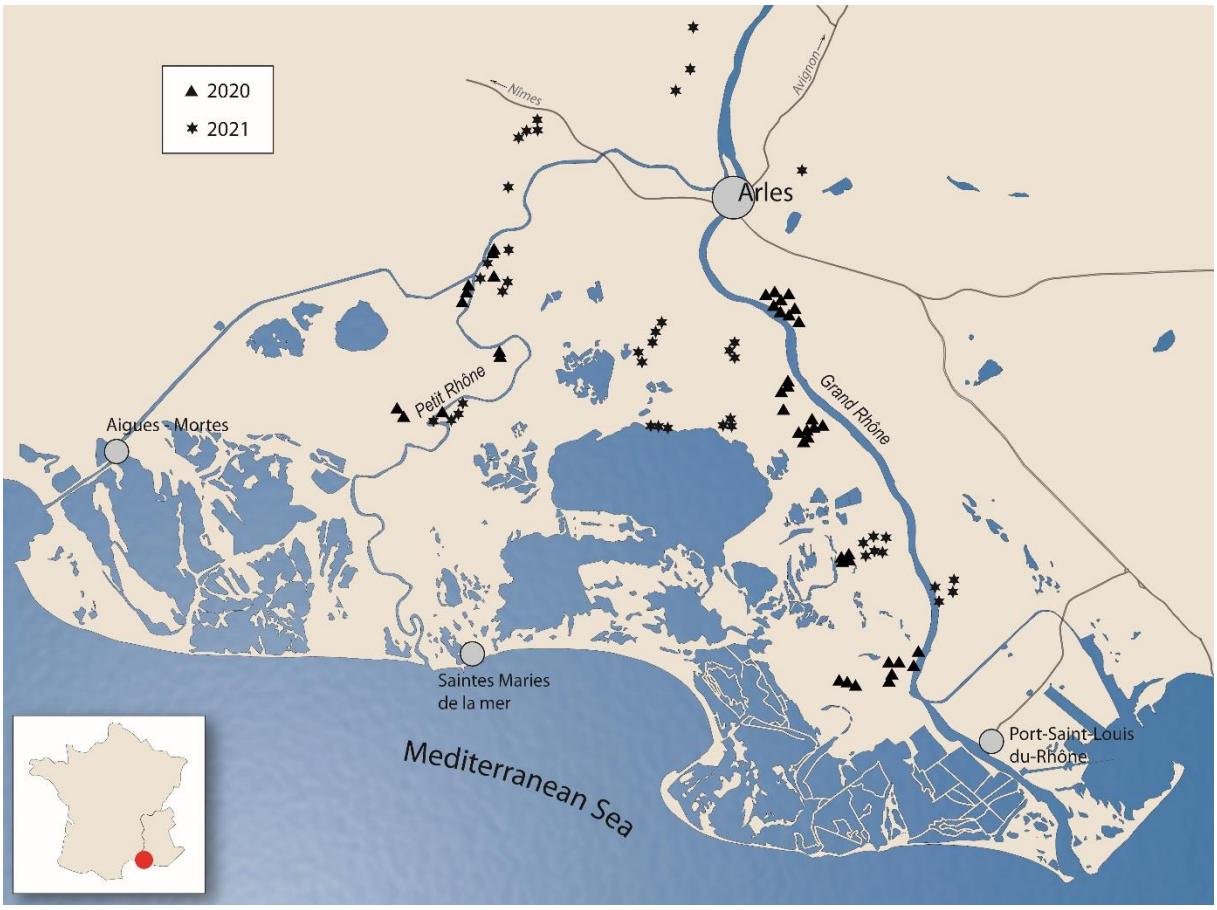

Figure 1. Location of the eighty-six crop fields monitored for birds in the Camargue, Rhône delta. Triangles represent crop fields sampled in 2020 and stars represent crop fields sampled in 2021.

We calculated the area of each type of field margin and semi-natural habitat within a 500 meter buffer around the centroid of each crop field, following Chan et al. (2007). First, we estimated the area of the three field margin vegetation types: (1) hedgerows, tree lines and bushy areas; (2) grass strips, grassy boundaries including grassy tracks or dirt roads used for the moving of agricultural machinery; (3) reed strips that grow in and along irrigation or drainage earthen ditches. Because we aimed at testing the hypothesis that field margins represent substitute habitats whatever its shape, we calculated the area and not the length of field margins. Second, we estimated the area of three categories of semi-natural areas: (1) woodlands (mainly riparian forests dominated by white poplar (*Populus alba*), pinewoods (*Pinus pinaster*), and tamarisk (*Tamarix gallica*) groves) and shrublands dominated by narrow-leaved mock privet (*Phillyrea angustifolia*); (2) grasslands including dry grasslands extensively grazed by free-range cattle, Mediterranean salt meadows and halophilous scrubs and fallow lands; (3) wetlands including freshwater and brackish marshes, reedbeds and ponds. Landscape mapping was based

on field observations done after the bird monitoring in June 2020 and June 2021 (see below) because fine scale assessment was too difficult based on remote sensing approaches, particularly for reed strips. Finally to account for the possible confounding effect of crop field heterogeneity, we also estimated within each 500 meter buffer the mean crop field size and the Shannon diversity index of crop types (*Crop_SHDI* = - $\sum_{i=1}^{n} pi \ln pi$, where *pi* corresponds to the proportion of crop cover type *i* in the landscape), following the method implemented in Sirami et al. (2019). As a result, we obtained values for eight landscape variables for each sampled crop field.

2.3 Bird monitoring and traits

Birds were monitored over 5-minute point counts halfway along the longest margin of each crop field during the breeding period. Two visits were conducted at each site between mid-April and mid-June with at least 4 weeks between the two visits, following the protocol from the French common breeding bird census scheme (Jiguet, 2003). Flying birds were removed from the analyses because they were not interacting with the landscape. Birds landing outside the sampled crop field and its field margins were also removed to avoid detection bias potentially generated by hedgerows preventing the observer to see birds beyond trees. We used the maximum abundance per site between the two visits for each species for further analyses.
We classified each species into one of three guilds according to the primary habitat used for breeding: reedbed, grassland and forest edge birds. Species were assigned to one of three guilds based on the EUNIS habitat classification that describes species related to woodlands, wetlands, grasslands or urban areas (Appendix B). Generalist birds, i.e. not linked to one habitat in particular, or birds using urban areas for breeding were discarded from the analyses. We modulated the EUNIS data with information provided by local experts to take into account ecological particularities of the Camargue. To avoid extreme cases of zero-inflation, we only analyzed species present in more than 15 % of sampled crop fields (Marja and Herzon, 2012). Twelve species were retained for the analyses (Table 1).

Table 1. Lists of species studied within the three guilds- based on the EUNIS database combined with information provided by local experts to take into account ecological particularities of the Camargue (Appendix B).

Reedbed birds	Grassland birds	Forest edge birds
Eurasian reed warbler (*Acrocephalus scirpaceus*)	Crested lark (*Galerida cristata*)	European greenfinch (*Chloris chloris*)
Great reed warbler (*Acrocephalus arundinaceus*)	Corn bunting (*Emberiza calandra*)	Carrion crow (*Corvus corone*)
	Eurasian skylark (*Alauda arvensis*)	Melodious warbler (*Hippolais polyglotta*)
		Common nightingale (*Luscinia megarhynchos*)
		Great tit (*Parus major*)
		Eurasian magpie (*Pica pica*)
		European green woodpecker (*Picus viridis*)
		Eurasian blackcap (*Sylvia atricapilla*)
		Eurasian hoopoe (*Upupa epops*)

In order to check for the completeness of our data, we calculated the coverage of our sampling, which is defined as the proportion of the total number of individuals in an assemblage that belong to the species present in the sample (Chao and Jost, 2012). The overall coverage of our sampling was 73.5 %, which reflects no undersampling issue (Mallet et al., 2022). The sampling completeness per crop field was not correlated with any explanatory variable (Pearson coefficient < 0.24, Appendix C), which suggests that the study design was robust and not biased toward one or several landscape variables.

2.4 Data analysis

We ran one linear mixed-effect model per guild. We used species abundance as the response variable, while fixed effects were the area of the three field margin types (hedgerows, grass strips and reed strips), the area of the three semi-natural habitat types (woodlands, grasslands and wetlands), crop diversity and mean crop field size. All explanatory variables were centered and scaled. Crop type and site identity were added as random effects. We added species as fixed effect for reedbed birds (2 species) and grassland birds (3 species) and as

random effects for forest edge birds (9 species) to respect the condition that a random factor should have more than 5 levels (Kery and Schaub, 2012). We did not include variable 'year' in our final models because this variable was never significant and was not relevant to our research question. We accounted for spatial autocorrelation by using an exponential structure on crop field coordinates, and checked for the absence of autocorrelation in the residuals. We used a negative binomial error distribution (type 2: variance increases quadratically with the mean) to deal with over-dispersion of forest edge birds abundance and a Poisson distribution for reedbed and grassland birds. We ran models with a log-link and a random zero inflation to describe the probability of observing an excess of zeros not generated by explanatory variables (Zuur and Ieno, 2016).

We ran models with all combinations of effects which could be derived from this general model thanks to the dredge function in R (Barton, 2020). We ranked these models using the Akaike information criterion for small samples (AIC_c; Burnham & Anderson, 2002). Then, we averaged parameters across all models with a delta AIC_c smaller than two. We discussed the effect of variables when confidence intervals of their estimate did not overlap zero.

We used a jackknife analysis to identify which species contributed most to the effect detected (Crowley, 1992). We iteratively recalculated the estimate of the average model after removing species one by one from the data set. For each species, we calculated the percentage difference between the estimate from the average model and the jackknife models. A positive species contribution to a positive estimate means that the species abundance increases more than the other species in average when the value of the variable increases. When discussing our results, we focused on the most influential species, i.e. species for which removing them modified the estimate by at least 10 % compared to a model including all species (Princé and Zuckerberg, 2015). Statistical analyses were run using glmmTMB (Magnusson et al., 2020), entropart (Marcon and Hérault, 2015) and MuMin (Barton, 2020) in R 4.0.5 (R Core Team, 2017).

3 Results

The spatial variation in field margin area around the 86 organic crop fields was similar across the three vegetation types; hedgerows (median = 3.67 ha; range: [0; 17.47]), reed strips (median = 3.60 ha; range: [1.46; 8.72]) and grass strips (median = 3.29 ha; range: [0; 6.27]). The dominant type of semi-natural habitat was grassland (median = 7.38 ha; range: [0; 45.23]),

followed by wetland (median = 1.37 ha; range: [0; 48.15]) and by woodland (median = 0.71 ha; range: [0; 20.78]). Crop diversity was on average 0.93 ± 0.04 (median = 0.98; range: [0; 1.6]). Crop mean field size was on average 2.32 ± 0.10 ha (median = 2.27 ha; range: [1.09; 5.85]). There was no correlation among explanatory variables since all Pearson correlation coefficients were under 0.45 (Appendix C).

The abundance of reedbed birds was positively related to both reed strip margins (Table 2, Fig. 2A) and wetland area (Table 2, Fig. 2B). The abundance of the Eurasian reed warbler was more positively impacted by reed strip margins than the abundance of the great reed warbler, but less positively impacted by wetland area than the abundance of the great reed warbler.

The abundance of grassland birds decreased with hedgerow margins, increased with the area of grasslands (Table 2, Fig. 3A) and wetlands (Table 2, Fig. 3B) and decreased with the area of woodland (Table 2, Fig. 3C). The abundance of the crested lark was less positively related to grassland and wetland areas than other species. The abundance of the corn bunting was more positively related to grassland area than other species, whereas the Eurasian skylark was more positively related to wetlands than other species. The Eurasian skylark was less negatively impacted by woodland than the crested lark. The corn bunting was less negatively impacted by hedgerow than the two other species.

The abundance of forest edge birds was positively related to the area of hedgerows (Table 2, Fig. 4A) and negatively related to reed strip margins (Table 2, Fig. 4B). None of the semi-natural habitats had a significant effect on forest edge bird abundance (Table 2). The common nightingale was less positively impacted by the area of hedgerows than the great tit, the European greenfinch or the Eurasian blackcap. The common nightingale was less negatively impacted by reed strips than the European greenfinch and the melodious warbler.

The area of grass strips, crop mean field size and crop diversity were selected in models for grassland and forest edge bird species but had a non–significant effect after model averaging in all cases (Table 2).

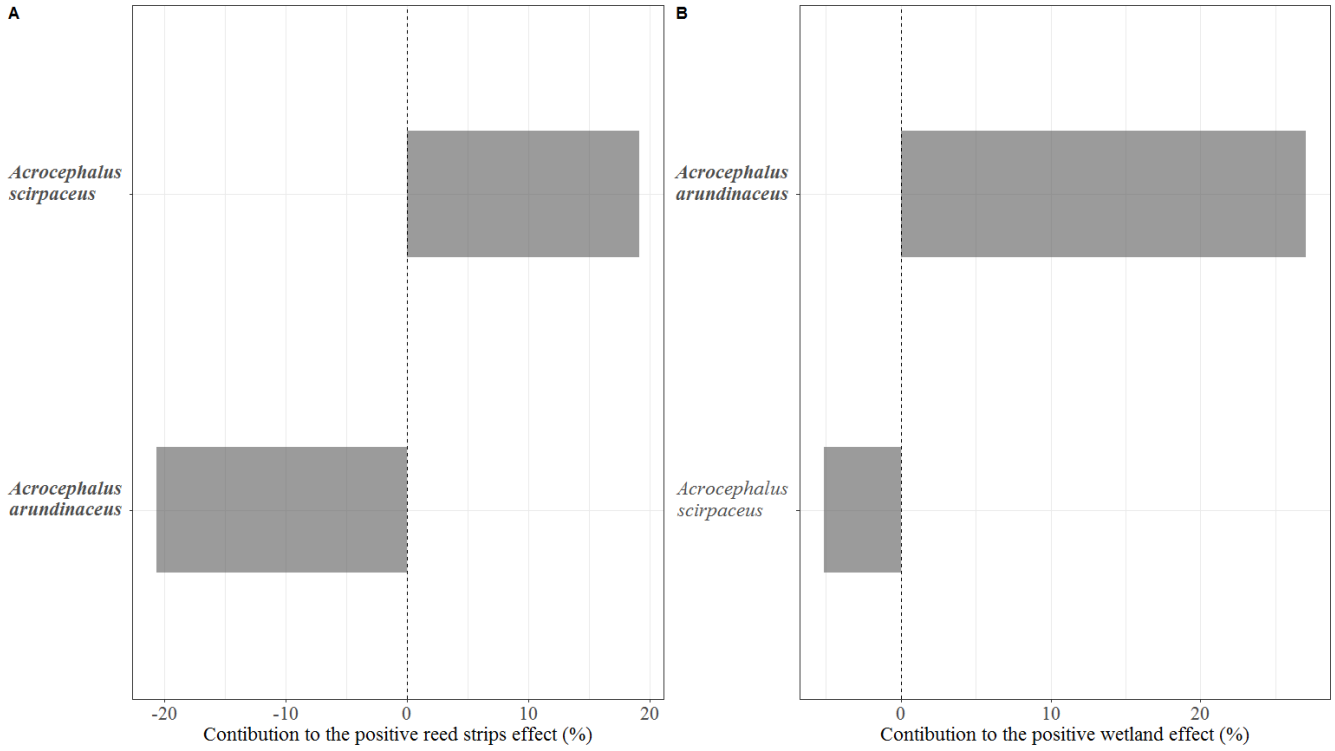

Figure 2. Contribution of reedbed species to (A) the positive effect of reed strips and (B) to the positive effect of wetlands in the average model. Positive contribution means that the species contribute to the effect. Species in bold correspond to species for which removing them modified the estimate by at least 10 % compared to a model including all species.

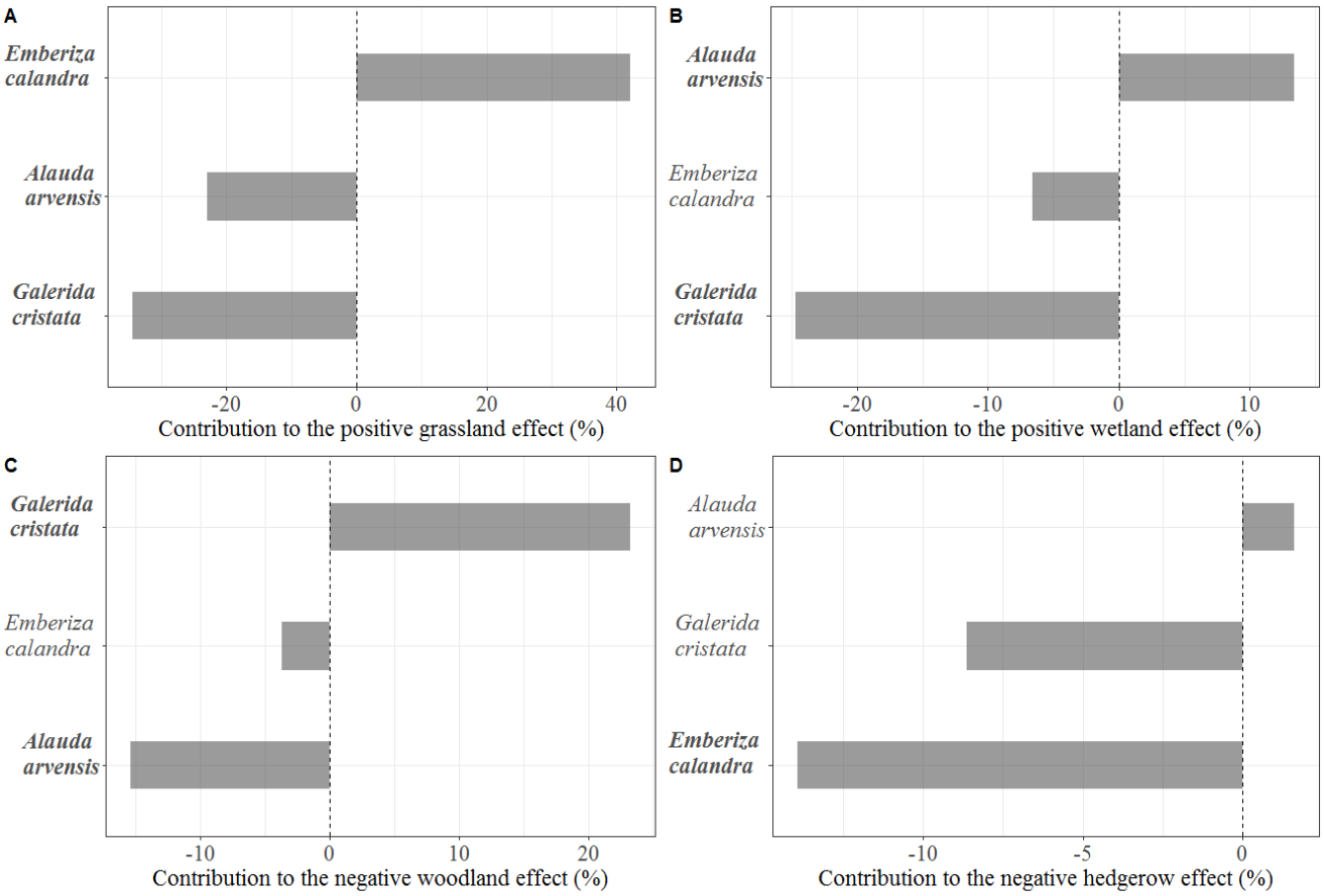

Figure 3. Contribution of grassland species to (A) the positive effect of grasslands, (B) positive effect of wetlands, (C) the negative effect of woodlands, (D) the negative effect of hedgerows for the average model. Positive contribution means that the species contribute toward the effect. Species in bold correspond to species for which removing them modified the estimate by at least 10 % compared to a model including all species.

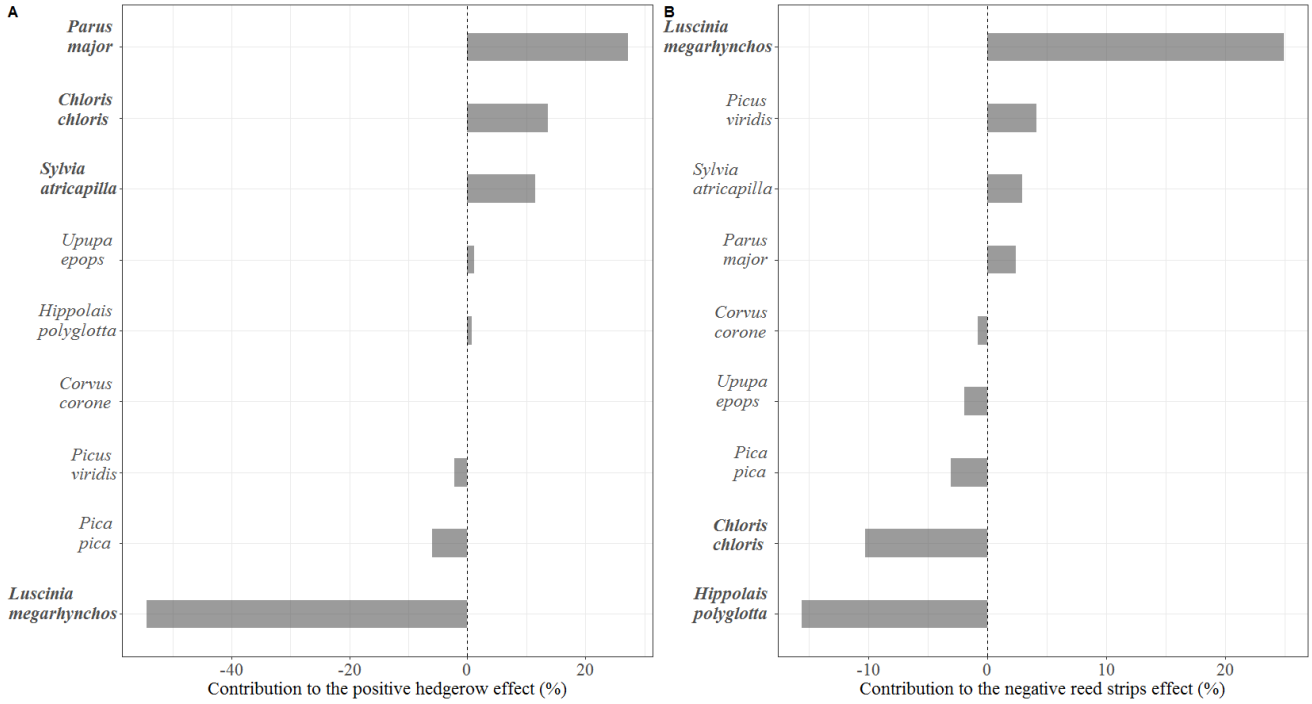

Figure 4. Contribution of forest edge species to (A) the positive effect of hedgerows and (B) the negative effect of reed strips for the average model. Positive contribution means that the species contribute toward the effect. Species in bold correspond to species for which removing them modified the estimate by at least 10 % compared to a model including all species.

Table 2. Averaged estimates of the effects of landscape variables for the three bird guilds monitored in agricultural crop fields of the Camargue. Confidence intervals are in brackets. Values in bold indicate significant effects: *p < 0.05, **p<0.01, ***p<0.001.

	Reedbed birds	Grassland birds	Forest edge birds
Hedgerow	-0.92 [-0.77 ;0.04]	**-0.40** **[-0.74 ;-0.05]***	**0.19** **[0.05 ;0.33]****
Grass strip		0.14 [-0.18 ;0.46]	
Reed strip	**0.58** **[0.13 ;1.04]***	-0.29 [-0.73 ;0.14]	**-0.21** **[-0.35 ;-0.06]****
Woodland area		**-1.00** **[-1.85 ;-0.15]***	0.08 [-0.44 ;0.21]
Grassland area	-0.27 [-0.64 ;0.10]	**0.32** **[0.03 ;0.61]***	

Wetland area	**0.79** **[0.38 ;1.19]*** **	**0.32** **[0.05 ;0.58]***	-0.06 [-0.20 ;0.08]
Crop diversity		0.18 [-0.11 ;0.46]	
Mean crop field size		-0.23 [-0.52 ;0.06]	0.05 [-0.72 ;0.18]

4 Discussion

Our results show that reed strips and hedgerows represent substitute habitats for both reedbed and forest edge species, in line with the habitat compensation hypothesis. However, we did not find any evidence for the habitat compensation hypothesis for grassland birds, for which the abundance was not related to the area of grass strips. The abundance of reedbed (wetlands) and grassland (grasslands) species was strongly related to the area of their primary habitat, but this was not the case for forest edge species. Finally, neither crop field size nor crop diversity had a significant effect on species guild abundance.

Our study shows that reedbed birds are positively impacted by the amount of their primary habitat. They are also positively impacted by reed strips. This result confirms that reed field strips represent substitute habitat for reedbed birds in Camargue. Moreover, our results suggest that the effects of the area of reed strips and the area of wetland on reedbed birds abundance are of the same order of magnitude. This means that an increase in reed strips area may have a similar effect on the abundance of reedbed species than an increase in wetland area (Riva and Fahrig, 2022). It is however important to underline that some passerines specialist of these habitats were not contacted at all during our surveys, e.g., the moustached warbler (*Acrocephalus melanopogon*) or the bearded reedling (*Panurus biarmicus*) even though they are breeding in the Camargue. This suggests that the reed strips we studied may not be used as substitute habitat by all reedbed birds. This may be partly explained by the quality of ditches found in Camargue and the ecological preferences of species. Indeed, ditches are increasingly being lined with concrete or buried in Camargue as in other rice paddy landscape, in Japan for example (Yamada et al., 2011). Some studies have highlighted that earthen ditches host much more aquatic fauna and flora than concrete ones (Katoh et al., 2009). Lining ditches with concrete leads to important differences in their use by birds. For example, the density of intermediate egrets (*Egretta intermedia*) was twice as high in rice fields with shallow earthen

ditches than in rice fields with deep concrete-lined ditches (Katayama et al., 2012). In the present study, the positive effect of reed field margins was greater for the Eurasian reed warbler than for the great reed warbler, the latest requiring wetter and larger patches of reedbeds than the Eurasian reed warbler (BirdLife International, 2022). The absence of the bearded reedling is also consistent with the fact that it requires larger areas of reedbeds and is not encountered in reed strips along artificial ditches (PM pers. obs.). Further research is needed to confirm the value of reed strips and the role of their quality for the conservation reedbed bird species. Moreover, it would be important to compare the demographics of *Acrocephalus spp.* in this substitute habitat and in natural reed beds to ensure that reed strips are not ecological traps (Horne, 1983).

Our results support the hypothesis that hedgerows represent substitute habitat for forest edge birds (Batáry et al., 2010; Wilson et al., 2017). Indeed, we observed a positive effect of the area of hedgerows on the abundance of forest edge birds. This effect is primarily driven by the response of three species (the great tit, the European greenfinch and the Eurasian blackcap), which all require a clump of trees to breed. In contrast, the common nightingale responded less positively to the presence of hedgerows, which is consistent with the fact that it is able to breed in bushes without tree cover (BirdLife International, 2022). Surprisingly, we did not find any positive effect of woodland area on the abundance of forest edge birds, which contrasts with other studies on this specific guild (e.g. Melin et al., 2018; Sasaki et al., 2020). This lack of significant effect could be due to the use of woodland area, while woodland perimeter might be more important to forest edge birds (Wilkin et al., 2007). However, in our study these two variables were strongly correlated (Pearson $r = 0.80$). We ran the same model with woodland perimeter instead of woodland area but this did not change the outcome. Another reason for the lack of relationship between the area/perimeter of woodland and the abundance of forest edge species may be due to the quality of these habitats (Preiss et al., 1997). Our results also show that forest edge bird species are negatively impacted by the presence of reed strips.

As predicted, our results show that grassland birds are positively impacted by the area of grasslands and wetlands, which offer suitable nesting and feeding sites (With et al., 2008; Zmihorski et al., 2016). These species were also negatively impacted by the area of hedgerows and woodland. These results add support to previous studies that observed a similar negative effect of wooded habitats on different species of grassland birds (e.g. Ellison et al., 2013; Wilson et al., 2014). Woodland patches usually do not offer resources for grassland birds and could also be a source of avian and mammalian predators (Burger et al., 1994). In Camargue, grassland species can be tolerant to trees depending on their behavioral ecology. For instance,

corn bunting is known to use isolated trees as singing places and is therefore more tolerant to hedgerows than Eurasian skylark and crested lark (Ellison et al., 2013). Unlike Josefsson et al. (2013), we did not find a positive effect of grass strips on grassland birds. Our study therefore does not provide evidence of the habitat compensation hypothesis for grassland birds in Camargue. This absence of significant effect could be due to the large amount of grassland in the sampled or to the fact that these strips are frequently used by farmers to move around the crop fields, which causes disturbances that might prevent nesting (Vickery et al., 2009). Further research should explore the role of these grassy margins and their quality for the conservation of grassland species.

Our results highlight that field margins are important landscape components to improve biodiversity conservation while keeping sufficient area dedicated to food production in rice paddy landscapes. Recommendations for the management of these field margins should however consider potential antagonistic effects, e.g. the opposite effect of hedgerows on forest edge species and grassland species. Moreover, they should also consider the quality of these habitats (Horne, 1983). In Camargue, current conservation priorities concern the disappearance of wetlands and grasslands as well as the degraded conservation status of species associated with these habitats. There is however less concern for forest edge birds, which can be found in other agricultural landscapes. Our study therefore suggests that conserving and restoring reed and grass strips may constitute key levers to increase biodiversity in the Camargue agricultural landscapes. Hedgerows have positive effects on forest edge birds but negative effects on grassland birds, as well as on waterbirds (Tourenq et al., 2001). Moreover, they can host a diversity of auxiliary species as well as taxa of high conservation importance in the Camargue and other wetlands such as bats (Mas et al., 2021). Hedgerows have also been shown to limit the presence of greater flamingos (*Phoenicopterus roseus*), considered as a pest in rice fields. The action of replanting hedgerows carried out locally by the Regional Natural Park of the Camargue must therefore be optimized in order to limit their negative impact on bird species associated with high conservation value. Land use planning studies could be a good way to propose management actions to farmers and stakeholders, maximizing both long-term agricultural benefits and biodiversity conservation.

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Conflict of interest disclosure

The authors declare they have no conflict of interest relating to the content of this article.

Data, script and code availability

Supplementary information, dataset and statistical scripts are available here: https://doi.org/10.5281/zenodo.6521956

Supplementary information

Appendix A: Map of habitat localization in Camargue

Appendix B: Table of species guilds

Appendix C: Correlation table between landscape explanatory variables and sampling completeness (Cn).

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