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Bird occupancy in intensively managed agroecosystems under large-scale organic and conventional farming in Argentina: A multi-species approach

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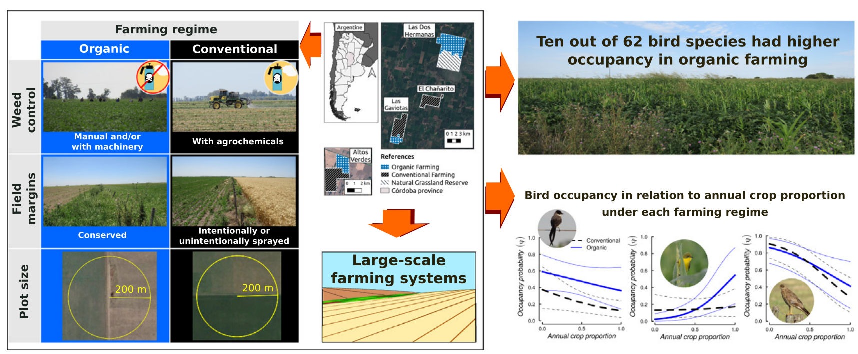
HIGHLIGHTS

- Bird occupancy in large-scale organic farms varied by groups, species, and seasons.
- Ten out of 62 bird species had higher occupancy in large-scale organic farming.
- Bird occupancy increased with annual crops in organic but not in conventional farms.

GRAPHICAL ABSTRACT



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ABSTRACT

Several studies in European and North American agroecosystems conclude that organic farming benefits birds compared to conventional farming. Nevertheless, there are some biases toward these geographic regions and farm size. Argentinian agroecosystems are particularly homogeneous with large arable fields and sparse uncultivated field margins (i.e. large-scale homogenous cropping systems). In Argentina only 0.55% of the total farmland is under organic farming. Thus, our aims were to assess differences in bird occupancy between organic versus conventional farming regimes, and whether bird occupancy varied in relation to annual crop proportion in both farming regimes in central Argentina agroecosystems. We surveyed 156 points in farms under conventional and 154 in organic farming regimes during two bird-breeding seasons. We used multi-species occupancy models with a Bayesian approach to estimate bird occupancy. We observed that the type of farming regime (organic in relation to conventional) had a weak effect on avian occupancy, varying by species and groups. Probability of occupancy was higher for a few insectivorous and omnivorous species but lower for carnivores in organic farms in relation to conventional ones. The proportion of annual crops was positively correlated with occupancy of an insectivore aerial forager, some insectivore foliage gleaners, a granivore, and some omnivorous species in organic farms, but not conventional farms. This work contributes to reducing geographic and small-scale heterogeneous cropping system biases in the avian agroecological literature. Our results, together with future studies needed to assess landscape configuration and composition, and resource availability for birds in each farming regime, will

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allow the evaluation of organic farming as a tool for the conservation of bird species in large-scale homogeneous cropping systems in temperate regions.

1. Introduction

The worldwide loss of biodiversity and related ecosystem services is mainly attributed to agricultural expansion and intensification (Benton et al., 2003; IPBES, 2019). Agricultural intensification includes changes from heterogeneous landscapes with diverse cover types and land uses to homogeneous landscapes. These changes are the consequence of enlarged crop fields, continuous cropping with increased dependence on agrochemicals, loss of natural and semi-natural land covers (i.e., field margins, grasslands, and wetlands), increased mechanization, and changes in timing of farming activities (Gomez et al., 2018; Stanton et al., 2018). The result has been a simplification of agroecosystems in space and time (Benton et al., 2003).

Since biodiversity loss is occurring at an accelerated rate, we should not only consider conservation efforts that exclude human activity, such as networks of protected areas (Chazdon et al., 2009; Fahrig et al., 2011; Garibaldi et al., 2020; Kremen and Merenlender, 2018). Currently, agriculture covers 38% of the Earth's terrestrial surface (Foley et al., 2011) making conservation efforts in farmlands necessary (Quinn et al., 2012). Organic agriculture is considered an alternative to mitigate the biodiversity loss caused by agricultural intensification (Feber et al., 2019; Hole et al., 2005). Unlike conventional farming, which is mainly dependent on external inputs for crop and animal productions, organic farming follows a set of practices such as the non-use of agrochemicals and inorganic fertilizers, a strict crop rotation, and in some regions promotes the maintenance of different cover types (annual crops, pasture, and patches of semi-natural vegetation). These practices contribute to maintain the heterogeneity of agroecosystems, improving habitat quality for birds by supporting higher invertebrate diversity and weed seed availability, increasing foraging and nesting opportunities (Chamberlain et al., 1999).

Birds are ideal model organisms to assess the effects of environmental perturbations because they are relatively easy to survey and respond rapidly to changes, compared to other vertebrate groups (Goijman et al., 2015). Many bird species provide ecosystem services for agriculture, such as pest control, pollination and seed dispersal (Kross et al., 2016; Sekercioglu, 2006), while others are considered pests (Bernardos and Farrell, 2012; Calamari et al., 2018; Zufiaurre et al., 2017). For these reasons great research efforts have been focused on assessing how agriculture affects birds. In Europe and North America farmland bird declines have been attributed to agricultural intensification (Askins et al., 2007; Chamberlain et al., 2000; Murphy, 2003; Stanton et al., 2018), in some cases related to pesticides (Geiger et al., 2010; Mineau and Whiteside, 2013; Stanton et al., 2018). Several studies in these regions conclude that organic farming benefits birds compared to conventional farming (Batáry et al., 2010; Goded et al., 2018; Kirk and Lindsay, 2017; Kirk et al., 2020; Quinn et al., 2012; Smith et al., 2010; Tuck et al., 2014). Although the effect of organic farming on bird populations has been identified as positive, it could differ among species or groups. Smith et al. (2010) found higher abundances of passerines that feed on arthropods in organic farms than in conventional ones, and attributed this to the effects of pesticides on invertebrate densities. In addition, McKenzie and Whittingham (2009) observed that the amount of non-cropped habitats is another important feature for maintaining higher bird abundances in organic farms.

Intensively managed Argentine agroecosystems are characterized by extensive and homogeneous cropland mosaics, consisting in large arable fields and sparse linear features (Baldi et al., 2006; Gomez et al., 2018). Increased rates of agricultural expansion and intensification in Argentina have been evident since the 1990s due to various factors, mainly market conditions and technological changes, among others (Paruelo et al., 2005). In the central region, many studies have shown how an increase in the number of farmlands under conventional farming negatively affects avian communities (Codesido et al., 2008, 2011; Filloy and Bellocq, 2007; Gavier-Pizarro et al., 2012; Goijman et al., 2015; Schrag et al., 2009). In particular, granivorous gleaners, ground insectivores, and omnivores are negatively affected by extensive areas of soybean maybe related to the low availability of vegetated borders; while insectivorous gleaners and aerial foragers seem more tolerant (Goijman et al., 2015). Some life history traits of the species, such as feeding habits or habitat specialization, can explain the response diversity to agricultural changes (Codesido et al., 2013).

In a review, Tuck et al. (2014) highlighted that there is a geographical bias toward studies in Europe and North America that evaluated the effects of organic farming on biodiversity, and that there is limited data from South America. However in agroecosystems of central Argentina, some studies found that organic farming benefits abundance, occupancy, and species richness of some vertebrate groups such as small mammals (Coda et al., 2015; Gomez et al., 2018; Serafini et al., 2019). However, to our knowledge, few studies have compared the effects of organic versus conventional farming on birds in large-scale homogeneous cropping systems such as those in central Argentina, where the main difference between the two farming regimes is almost exclusively the non-application of pesticides. Overall, most studies compare the two farming regimes in small-scale heterogeneous cropping systems (Batáry et al., 2010; Genghini et al., 2006; Goded et al., 2018; Kragten and de Snoo, 2008; Smith et al., 2010). Therefore, we aim to contribute to the reduction of these geographic and farmland configuration biases by presenting bird occupancy results from homogeneous large-scale farms in Argentina. To achieve this, we: 1) compared the occurrence of bird species between organic and conventional farming, and 2) determined if species occupancy varied in relation to crop proportion within organic and conventional farming by looking at the interaction between farming management and annual crop proportion. Based on the increased abundance, occupancy and species richness of small mammals observed in the same study area, and the positive effects of organic farming on bird species in other regions, we predict that occupancy probabilities of groups and species of birds will be higher in organic than conventional farming regime, and that annual crops under organic farming will support higher occupancy probabilities than annual crops under conventional farming. We also predict that these effects will be stronger on insectivorous birds compared to granivores, omnivores and carnivores (cf. Goded et al., 2018), and that this effect will be higher in summer when conventional farms receive more amounts of insecticides (Goijman et al., 2020).

2. Materials and methods

2.1. Study area

The study was carried out in an intensively managed agroecosystem in south-eastern Córdoba province, Argentina (Appendix A-Fig. A1). This region is part of the Pampas ecoregion, originally dominated by natural grassland, but is currently embedded in an agroecosystem where part of the original flora is restricted to uncultivated border vegetation. In this agroecosystem, annual crops are mainly under conventional farming where the most frequent crop rotations are wheat-soybean or soybean-maize (as alternate single summer crops per year with a winter fallow), even though the soybean monoculture as a single summer crop per year is a common practice (Puricelli and Tuesca, 2005; Satorre, 2005). The climate is temperate, sub-humid, with a mean annual temperature of 16 °C. The mean annual rainfall is 725 mm; most rainfall is concentrated in spring-summer (October-March) and the winters are dry (Cantero and León, 1999). Soils in the area are Phaeozems, and soil parent material is Aeolian (loess) (IUSS Working Group WRB, 2015).

In Argentina, there are 36 Mha under conventional farming (Aapresid, 2018), with a small proportion dedicated to organic farming. Currently, there are 3.6 Mha under this farming regime, and only 6% of this area is devoted to annual crop production, whereas the rest is dedicated to pastures for cattle production (Bedano and Domínguez, 2016; SENASA, 2019). In these agroecosystems both organic and conventional farms are intensively managed, differing almost exclusively in the application or not of pesticides.

Our study included the entire surface of large-scale homogenous cropping systems under an organic farming regime in south-eastern Córdoba province. We sampled 2707 and 3216 ha of fields under organic and conventional farming respectively. These fields were located on four farms: Las Dos Hermanas (DH) (Foundation Rachel and Pamela Schiele, 2031 ha), Las Gaviotas (LG) (Postel S.A., 1689 ha), Altos Verdes (AV) (Huanqui S.A., 1010 ha) and El Chañarito (CH) (1193 ha). Argencert (Argencert, 2018), or Organización Internacional Agropecuaria (OIA, 2017), certified all organic farms. Las Dos Hermanas also included a 1922 ha natural grassland reserve; and LG and AV had both organic and conventional farming regime (for details of farm size, see Appendix D - Table A1). All organic fields have been under this farming regime for more than 15 years (Coda et al., 2015).

2.2. Data collection

We surveyed birds during two breeding seasons, in spring and summer (November-December, February), from 2016 to 2018. We surveyed 310 points in total (154 and 156 in organic and conventional farming regime respectively), and the location and number of the points varied between breeding seasons (2016-2017, 2017-2018; Appendix B – Table A2). The points were located on the margins of the field, considered as the strip of uncultivated vegetation located on the inner margin of the fields. We randomly allocated points for each breeding bird season using QGis 2.7 (QGIS Development Team, 2017). We separated points by at least 400 m to ensure independence of the observations, and to reduce the possibility of chemical contamination in farms under an organic regime from adjacent conventional farms. For that reason, we also ensured that the points were located at least 200 m from their outer boundaries.

We recorded all bird species seen or heard during 5 min within 200 m of each survey point (observational unit). We conducted surveys between 0600 and 1100 (first daily visit) and 1500-2000 (second daily visit). We repeated surveys at each point in three consecutive occasions (the same or next day) to increase detection probabilities of most species and taking into account the fulfillment of the assumption of closed populations necessary in occupancy models. We rotated the order of the visits to minimize possible bias caused by the time of day (e.g. morning day 1, evening day 1, morning day 2, or evening, morning, evening).

We quantified the proportion of farmland by setting up a polygon vector layer digitizing land use and land cover within a 200 m radius (~12.6 ha), centered on each survey point (Gavier-Pizarro et al., 2012; Goijman et al., 2015; Schrag et al., 2009). We drew maps at 1:1250 scale from Google Earth images corresponding to a date close to the field surveys, using the OpenLayer plugin within QGIS 2.7 (QGIS Development Team, 2017). We classified as annual crops the following crop types and considered them as a single category: soybean, corn, sunflower, wheat, and peanut; we did not include pasture (alfalfa and other pastures) because annual crops have more machinery passes and greater inputs of pesticides and fertilizers (Kirk et al., 2020). In order to show the differences between organic and conventional farming we display the different types of land cover in Appendix A-Fig. A2.

2.3. Classification of avian groups

We classified species into groups according to their main foraging resource and taxonomy following the approach of Goijman et al. (2015). We considered four groups: 1) insectivores (Passeriformes, including a few species from Cuculidae, Picidae, and Trochilidae families–species that feed mainly on arthropods in the breeding season, as well as on seeds); 2) granivores (Columbidae and Psittacidae families–some of them considered as agricultural pests in Argentina); 3) omnivores (Tinamidae, Ardeidae, Laridae, Scolopacidae, and Charadriidae families–species that consume seed, leaves and arthropods on the ground); and 4) carnivores (Accipitridae, Falconidae and Strigidae families–diurnal and nocturnal birds of prey). Information about foraging resources were taken from de la Peña (2015). For details, see Appendix C.

2.4. Occupancy analysis

We used hierarchical multi-species occupancy models with a Bayesian approach based on survey-specific detection/non-detection data to estimate the influence of farming regime and proportional area of annual crops on birds occupancy probability (Dorazio and Royle, 2005; Kéry and Royle, 2016; Royle and Dorazio, 2008). These models allow for inference at individual species level and at group level (Kéry and Royle, 2016). By sharing information across species (governed by higher level parameters from a common distribution), we were able to increase the precision of parameter estimates and enhance our understanding of both species-specific and group occupancy probabilities (Ruiz-Gutiérrez et al., 2010; Sauer and Link, 2002). Since we were interested in examining potential differences in occupancy probabilities among main groups of species, and we assumed that the parameter estimates for each individual species may be more closely related to those of its group, we separated the analysis into the previously described groups.

Occupancy estimation accounts for imperfect detection probabilities of each species ($p < 1$). Site-occupancy models can be formulated as a hierarchical model, linking two binary regression models: a state process model for occupancy of each species and an observation process model for detection, conditional on occupancy (Royle and Dorazio, 2008). Our state process model assumes occupancy as a binary state $z_{j,i,e}$ for each species $i = 1,2, \ldots, N$ at point $j = 1,2, \ldots J$ and farm $e = 1,2,3,4$; where $z_{j,i,e} = 1$ when the species is present, and zero otherwise. $z_{j,i,e}$ is a latent variable that represents the true state of occurrence of each species i at point j in farm e; and the Bernoulli parameter ψ is the expected value of z, called the probability of occupancy. Due to the fact that true occurrence is imperfectly observed, this is incorporated through the observation process model $Y_{j,k,i,e} \sim \text{Bern}(p_{j,k,i,e}; z_{j,i,e})$, where $p_{j,k,i,e};$ is the probability that species i at point j in farm e is detected at repetition $k = 1,2,3$; and $p_{j,k,i,e}; = 1$ when the species is detected, and zero otherwise. We analyzed data corresponding to spring and summer separately to improve parameters estimation.

We modified the model proposed by Kéry and Royle (2016) to incorporate farm as a random effect. Because the location of survey points was randomly allocated each breeding season, we did not consider a year effect as a source of variation, and considered points from different years as independent observations. Our occupancy model was:

$$\text{logit}\,\Psi_{j,i,e} = \beta 0_{i,e} + \beta 1_i * cov1_{j,e} + \beta 2_i * cov2_{j,e} + \beta 3_i * cov1_{j,e} * cov2_{j,e}$$

where $\beta 0$ is estimated for each species i and farm e; $cov1$ and $cov2$ correspond to annual crop proportion and farming regime of each point survey j and farm e respectively. We considered that the best approach was to construct a single model and make inferences based on 95%

Bayesian credible intervals (95% CRI). We considered as strong effects those in which zero was not included in the 95% CRI, because we can be confident that the parameter is either positive or negative. However we also present and discuss the effect of those parameters with 95% CRI those that slightly overlapped zero (i.e., $f > 0.95$, f being the proportion of the posterior with the same sign as the mean). We modeled detection for each species without specific covariates. We used a Bayesian approach in R 3.1.2 (R Development Core Team, 2018) and JAGS software, through package jagsUI (Kellner, 2016), which uses Markov chain Monte Carlo to find the posterior distribution of the parameters of interest. We ran three chains of length 300,000 each and discarded the first 150,000 as burn in, with a thinning rate of ten to avoid computer memory and storage limitations. We used weakly informative priors for all parameters (for details, see Appendix D). We assessed convergence by visual inspection of the chains and using the Gelman and Rubin diagnostic (Gelman and Rubin, 1992).

3. Results

We observed 62 bird species (51 in spring; 57 in summer) belonging to 11 orders; 42 of these species were classified as insectivores, 5 as granivores, 7 as omnivores, and 8 as carnivores (Appendix B). Detection probabilities for each species were generally below 50% ($p < 0.5$). *Leistes superciliaris*, *Zonotrichia capensis*, *Ammodramus humeralis*, *Patagioenas picazuro* and *Vanellus chilensis* were the only species with $p > 0.5$ in both seasons (Appendix A-Fig. A3).

At a group level, the proportional area of annual crops had a negative effect on omnivores' occupancy probabilities in spring (β = -0.661; 95% CRI = (-1.165, -0.197)) and in summer (β = -0.615; 95% CRI = (-1.349, 0.106)), and on insectivores only in summer (β = -0.231; 95% CRI = (-0.458, -0.020)) (Appendix A-Fig. A4). Organic farming, with respect to conventional, affects occupancy probabilities of each group differently. It had a negative effect

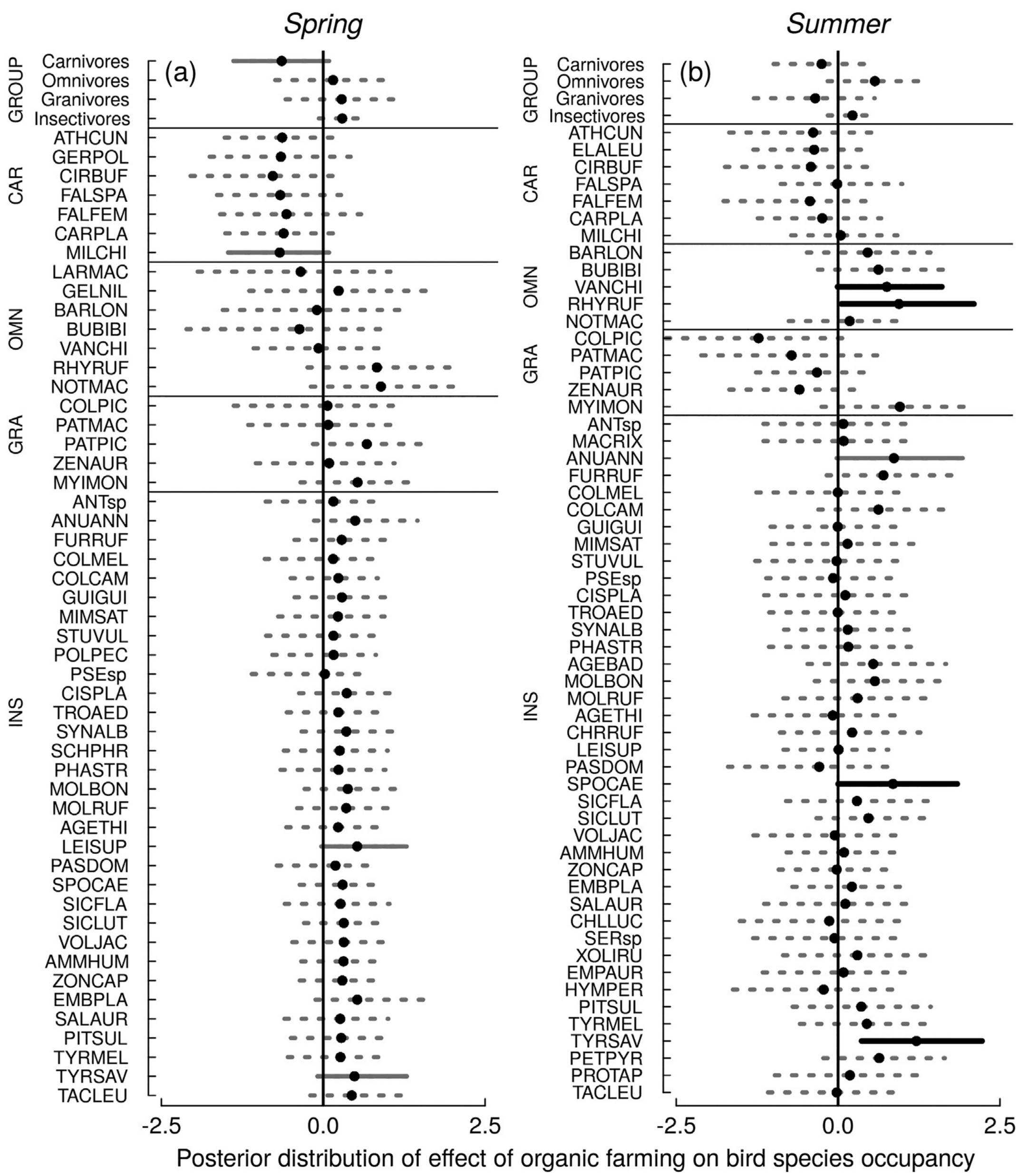

Fig. 1. Effect of organic farming (relative to conventional) on bird species and groups occupancy (posterior means and 95% CRI). Posterior distributions to the right of zero represent species or groups for which occupancy was higher under organic farming. Solid black lines, 95% CRI that not overlap zero. Solid grey lines, 95% CRI that slightly overlaps zero (refer to the methods section for more details).

on carnivores' occupancy probabilities in spring (β = -0.642; 95% CRI = (-1.386, 0.091)), while it had positive but weak effects on insectivores in spring (β = 0.294; 95% CRI = (-0.068, 0.649)) and omnivores' occupancy probabilities in summer (β = 0.569; 95% CRI = (-0.161, 1.297))(Fig. 1). Interaction between annual crop proportion and organic farming affected positively occupancy probabilities of granivores in spring (β = 0.644; 95% CRI = (-0.034, 1.387)) and insectivores in summer (β = 0.304; 95% CRI = (-0.022, 0.620)) (Appendix A-Fig. A5). In general, and regardless of the strength of the effect, group occupancy probabilities tend to decrease with the increase in annual crop proportion under conventional farming in all groups of birds, while the responses of the groups were variable to increases of annual crop proportion under organic farming (Appendix A-Fig. A6).

At the species level, we only report the species that showed occupancy probabilities strongly affected by some of the covariates considered (Fig. 1 and Appendix A-Figs. A3 and A4). *Tyrannus savana* was the only insectivore with a repeated response pattern in occupancy probabilities in both seasons. Although this species was negatively affected by the increase of annual crop proportion, its occupancy was always higher in organic than in conventional farms (Fig. 2a and b). *Sporophila caerulescens*, *Synallaxis albescens*, *Pseudocolopteryx* sp., *Sicalis luteola* and *Molothrus bonaeriensis* showed a positive interaction effect between annual crop proportion and organic farming in summer. Occupancy probabilities of these species increased with annual crop proportion under organic farming and remained constant or decreased with annual crop proportion under conventional farming (Fig. 2c, d, e, f and g). Occupancy probabilities of most omnivorous species responded negatively to annual crop proportion (Fig. 3); however, in spring, *Nothura maculosa*'s and *Rhynchotus rufescens*' occupancy probabilities increased with annual crop proportion in organic farms and decreased with annual crop proportion in conventional ones (Fig. 3a and b). The granivorous species *Columbina picui* also showed a positive interaction effect between annual crop proportion and organic farming in spring (Fig. 4a). Among carnivores, only *Milvago chimango* showed a negative response to annual crop proportion in both farming regimes in summer (Fig. 4b).

4. Discussion

In large-scale homogeneous cropping systems of Argentina, occupancy probabilities are not consistently higher for all bird species and groups in organic compared to conventional farming as predicted. Only ten of the 62 species showed higher occupancy probabilities under organic than conventional farming. Moreover, our results indicated that the effect magnitude of organic farming regime on occupancy probabilities varied according to avian group, species, and season. For example, at the group level, occupancy of insectivores, granivores, and omnivores, in at least one season, was higher under organic compared to conventional farming with different magnitude, while occupancy was lower for carnivores. When we consider the effects on occupancy at a species level, three out of seven omnivores evidenced positive responses to organic farming (*V. chilensis* in summer, *N. maculosa* in spring, and *R. rufescens* in both seasons), while only six insectivores out of 42 (*S. caerulescens*, *S. luteola*, *Pseudocolopteryx* sp., *S. albescens*, *M. bonaeriensis* in summer and *T. savana* in spring and summer) and one granivorous species (*C. picui* in spring) benefited from organic farming. Lastly, *M. chimango*, a carnivore, was negatively affected by this farming regime in spring.

Our results agree with those in agroecosystems in Europe and North America, where organic farming affects positively the abundance and/or species richness of farmland birds, but this effect also varies between seasons (e.g. Goded et al., 2018) and functional groups (e.g. Kirk and Lindsay, 2017). This effect is even stronger in regions with more intensive agriculture in North America (Kirk et al., 2020), and in simple landscapes than in complex ones in Europe (Batáry et al., 2010; Smith et al., 2010). Comparisons between our agroecosystem and those of North America and Europe should be made with caution. Particularly, European agroecosystems differ from Argentine ones in the configuration and composition of the landscape, which is composed of an extensive matrix of large-scale arable fields, surrounded by narrow and low quality border vegetation, and few patches of semi-natural vegetation (Coda et al., 2015; Serafini et al., 2019). Fuller et al. (2005) reported that organic farms tend to have smaller fields compared to conventional ones, which is another difference with our study area where organic

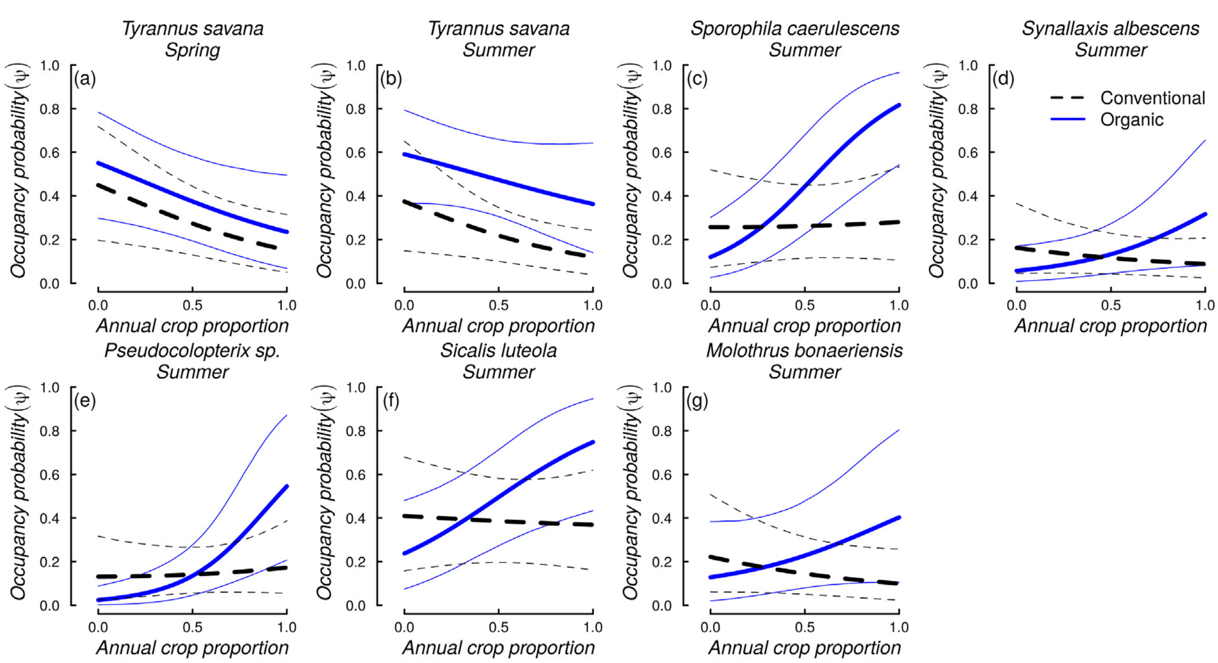

Fig. 2. Occupancy probabilities and annual crop proportion for each insectivore species and farming practice (organic farming and conventional farming). Thick lines: predicted occupancy probabilities, thin lines: 95% CRI.

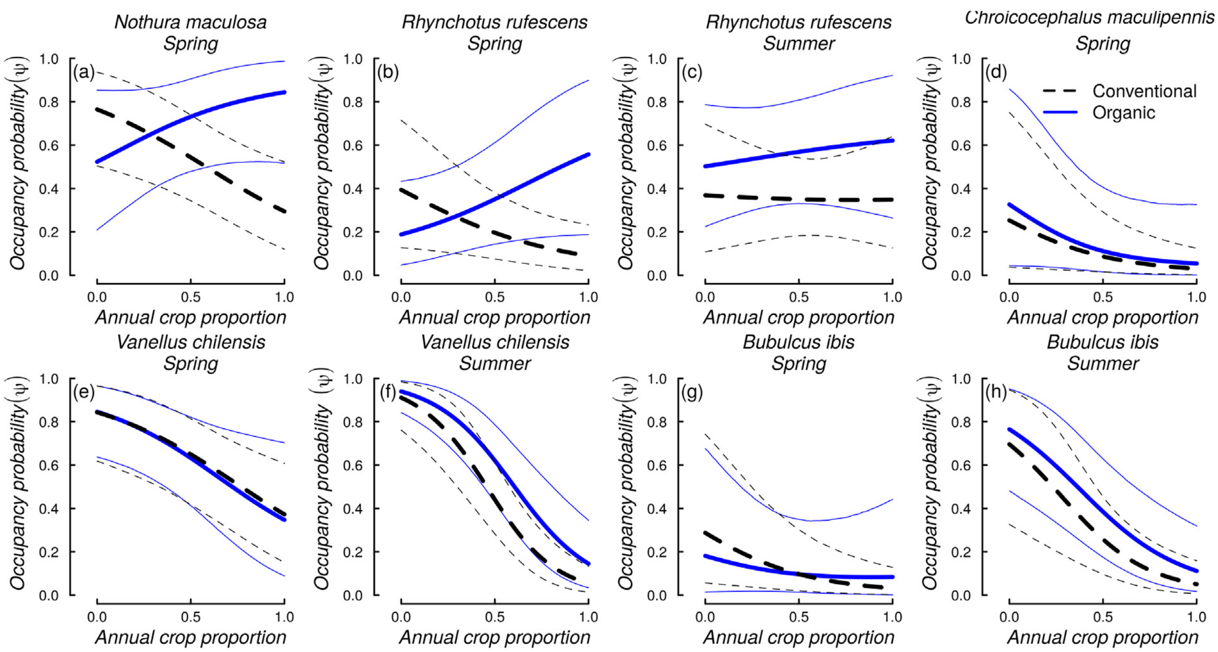

Fig. 3. Occupancy probabilities and annual crop proportion for each omnivore species and farming practice (organic farming and conventional farming). Thick lines: predicted occupancy probabilities, thin lines: 95% CRI.

fields have similar extent and sizes (i.e., large-scale) to the predominant conventional ones. To our knowledge, there are only three certified large-scale organic farms in the central region of Argentina, and we were able to survey them all. However, it is fundamental to consider that organic farms in our study area, despite being certified, are surrounded by conventional farms which could mask the positive effects of organic farming on bird occupancy because of potential cross contamination by pesticides from those farms. In the Argentine pampa, pesticides were found in the agroecological farms more than 300 m from the limit with conventional fields (Bernasconi et al., 2021). This would be particularly important for bird species with large home ranges (e.g., carnivores, some granivores, and aerial insectivores). The previously mentioned characteristics of the intensively managed agroecosystems of our study area might explain the weak positive effects of organic farming on bird occupancy that we found. Further studies based on the relationship between farming regimes, landscape complexity (compositional and configurational heterogeneity) and bird assemblage would be necessary.

Annual crop fields are the main element of many agroecosystems, and an increase in their proportion, especially in already intensively managed agroecosystems, is known to negatively affect the avian community (e.g., Donald et al., 2001). In agroecosystems of Argentina, several studies found that a high percentage of birds responded negatively to agricultural intensification, particularly to increased annual crop proportion (Codesido et al., 2008; Filloy and Bellocq, 2007; Goijman et al., 2015). In our study, we observed that the proportion of annual crops affected insectivores, omnivores, and some carnivores negatively. Nonetheless, when we looked at the effect of annual crop proportion under the different farming regimes, we found two ways in which annual crops supported higher occupancy probabilities of some bird species in organic farms than conventional ones. First, occupancy of an insectivorous aerial forager (*T. savana*) decreased as annual

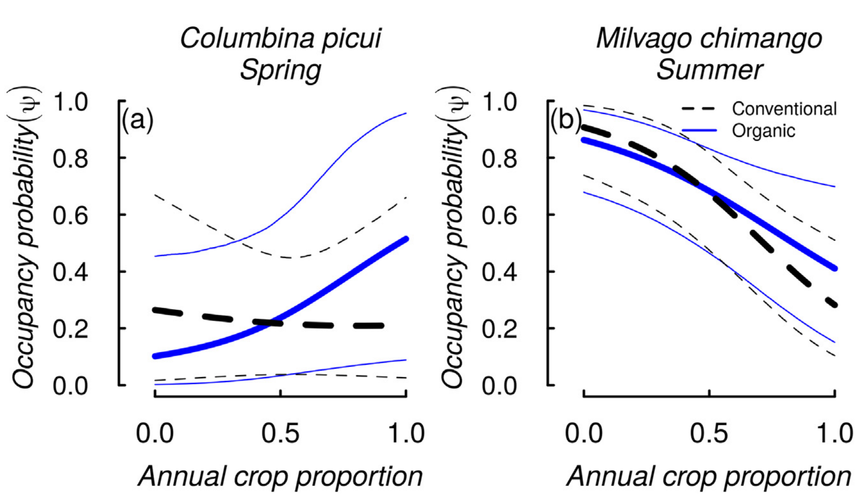

Fig. 4. Occupancy probabilities and annual crop proportion for a granivore species (*Columbina picui*) and a carnivore species (*Milvago chimango*) and farming practice (organic farming and conventional farming). Thick lines: predicted occupancy probabilities, thin lines: 95% CRI.

crop proportion increased in both types of farming regimes, although this effect seemed mitigated by organic farming. Second, occupancy probabilities of some insectivorous foliage gleaners (*Sporophila caerulescens*, *Synallaxis albescens, Pseudocolopterix* sp., *Sicalis luteola* and *Molothrus bonaeriensis*) and two omnivores (*Rhynchotus rufescens* and *Nothura maculosa*) decreased with annual crop proportion in conventional farms but increased in organic ones. These effects may be related to the application of herbicides in conventional farming regime, which would reduce the diversity of plant species in fields by the killing of weeds, resulting in a uniform growth of the crop and a lower vegetation structural diversity (i.e., homogeneous fields). This would also affect arthropods populations, and the feeding and nesting requirements of birds (Newton, 2017; Wilson et al., 2005). Considering the aforementioned, fields under organic farming are structurally more heterogeneous than conventional ones which benefits some insectivorous and omnivorous birds. On the other hand, in this study area, tillage is implemented as mechanical weed control in organic fields, which may increase food available on the ground surface favoring omnivorous species. Domínguez et al. (2014) found in this same area that organic farming supports higher abundance of soil macrofauna than conventional farming. Finally, higher occupancy probabilities of some insectivorous birds, mainly foliage gleaners, recorded in summer may be due to the higher prey availability compared to spring. Goijman et al. (2020) found that, in conventional farmlands in Argentina, arthropod abundance available as prey for insectivorous birds was higher in summer than in spring, despite insecticide applications.

Agroecosystems vary seasonally due to continuous changes in crop field operations (ploughing, harvesting, and mowing) and crop phenology (Rodríguez-Pastor et al., 2016). These changes modify the availability of food not only for insectivorous and omnivorous species, but also for granivorous birds. In our study, this group is mainly composed of pigeons, and only one of them, *Columbina picui,* responded positively to increases in annual crop proportion under organic farming, in spring. Some pigeons are considered a disservice for agriculture because they consume seeds, sprouting plants of sunflower and soybean during their germination periods (Bruggers et al., 1998), and seeds of wheat stubble (Zufiaurre et al., 2017). A higher availability of these resources in spring in organic farms may be beneficial to those species. In contrast, in our study region most pigeons responded negatively to organic farming in summer. Finally, *Milvago chimango* responded negatively to annual crop proportion as opposed to findings in previous studies on the tolerance of this species to agricultural intensification (Filloy and Bellocq, 2007; Gavier-Pizarro et al., 2012; Goijman et al., 2015). This discrepancy could be a consequence of the scale of analyses in our study, which might be small for species of the carnivore group where a regional level scale would be necessary. Additionally, we did not measure landscape features that increase the availability of perching sites for carnivores, like power lines, isolated trees or field margins.

Except for *Polystictus pectoralis* and *Bartramia longicauda,* listed as vulnerable at national level, in our study area we did not record species with any degree of threat at national or global level (IUCN, 2019; MayDS and AA, 2017). Although *R. rufescens* is globally listed as of least concern, its populations might be experiencing a decline (Goijman et al., 2015; IUCN, 2019). Results in our study suggest that organic farming may be a good conservation tool to mitigate population declines of this species, although more research focused on this species may be necessary. The few species that positively responded to organic farming regime are known as "common species" (i.e. species less sensitive to anthropogenic disturbances) (Baker et al., 2018; Gaston, 2010). The maintenance of high occupancy probabilities of these species could ensure a greater provision of ecosystem services, such as pest removal (Kirk et al., 1996; Şekercioğlu et al., 2004; Swift et al., 2004; Wilby et al., 2005). Nonetheless, results obtained at single-species level must be interpreted with caution since hierarchical models use less frequent species to estimate the means of the hyper-parameters of the entire group or community, limiting the conclusions. Inferences for those species will always be restricted by small sample sizes (Burton et al., 2012), and for this reason it is important to model detection probabilities and include more sampling units in future studies.

5. Conclusions

Our results showed that, in large-scale homogeneous cropping systems, the positive effect of organic farming regime on occupancy of birds is limited and varies by species and groups. In addition, the proportion of annual crops increase occupancy probabilities of some species, mainly insectivorous foliage gleaners and omnivores in farms under organic farming, but not in conventional farms.

In our agroecosystems both organic and conventional farms are intensively managed, differing almost exclusively in the application or not of pesticides. This, together with the low number of organic farms, would be the reasons for the weak positive effect of organic farming on occupancy probabilities of birds. Despite this, we were able to survey the entire area under certified large-scale organic regime in southeastern Córdoba province, therefore our work provides relevant information on the effect of organic farming on the bird community in the Pampas region of Argentina. Our study helps to alleviate biases in the literature toward North American and European farming regions and toward small heterogeneous farming systems, which is important from a global avian conservation and research perspective. However, future studies that consider landscape configuration and composition at multiple spatial scales, as well as evaluate the resource availability for birds in each farming regime, would be necessary to improve the understanding of organic farming as a biodiversity conservation policy in large-scale homogeneous cropping systems.

CRedit autorship contribution statement

Facundo Contreras: Conceptualization, Methodology, Investigation, Software, Formal analysis, Writing - Original Draft, Visualization. **Andrea P. Goijman:** Conceptualization, Methodology, Investigation, Software, Formal analysis, Writing - Review & Editing, Project administration. **José A. Coda:** Investigation, Review & Editing. **Vanesa N. Serafini:** Software, Review & Editing. **José W. Priotto:** Conceptualization, Methodology, Investigation, Writing - Review & Editing, Project administration.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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