



The presence of an invasive bird, the Common Starling, in an urban landscape: habitat use and relationships with other bird species

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Abstract

The Common Starling (*Sturnus vulgaris*) is an invasive bird introduced in Argentina in the 1980's that shares flocks with both native and exotic birds. Analyzing interspecific relationships and habitat use of introduced species is crucial to understand the invasion process and to alert for negative impacts on biodiversity. We conducted bird counts from April 2015 to March 2016 in a town from east-central Argentina to assess relationships between starling abundance, bird community attributes, and a group of birds as potential competitors for food. We analyzed the relationship between lawn cover and starling abundance. The starling was strongly positively associated with total bird abundance, and negatively with total bird richness and diversity, whereas the abundance and richness of the group of potential competitors showed a weak negative association with starling abundance. We found positive relationships with the abundance of native birds (Rufous-bellied Thrush *Turdus rufiventris*, Shiny Cowbird *Molothrus bonariensis*, Bay-winged Cowbird *Agelaioides badius* and Eared Dove *Zenaidura macroura*), as well as negative relationships with (Monk Parakeet (*Myiopsitta monachus*) and Picui Ground-dove *Columbina picui*) and exotic birds (Rock Dove *Columbia livia* and House Sparrow *Passer domesticus*). Moreover, starlings were positively related to lawn cover. Negative associations with local species could be the result of either competition for resources or differences in habitat use, whereas positive associations could represent advantages related to food accessibility and reduction in predation risk, or similarities in habitat use in Argentina. Our results represent a first step to understand the ecology of this invasive species, as well as to identify native species under potential ecological threat.

Keywords Bird community · Competition · Habitat use · Introduced bird · Native birds · Urban area

Zusammenfassung

Der Star als eingewandertes Vogel in einer städtischen Kulturlandschaft: Lebensraumnutzung und Beziehungen zu anderen Vogelarten. Der Star (*Sturnus vulgaris*), ein invasiver Vogel, wurde in den 1980er Jahren in Argentinien eingeschleppt und lebt dort in Schwärmen zusammen mit einheimischen und exotischen Vögeln. Eine Analyse der zwischenartlichen Beziehungen und der Lebensraumnutzung eingeführter Arten ist von entscheidender Bedeutung, um Invasionsprozesse zu verstehen und in der Lage zu sein, negative Auswirkungen auf die biologische Vielfalt feststellen zu können. Wir führten von April 2015 bis März 2016 in einer Stadt im Osten Zentralargentinien Vogelzählungen durch, um Zusammenhänge zwischen dem Vorkommen der Stare, den Eigenheiten der Vogelgemeinschaft und einer Gruppe von Vögeln als potenzielle Nahrungskonkurrenten einzuschätzen, und wir analysierten den Zusammenhang zwischen der Grasbedeckung und dem

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Vorkommen der Stare. Es gab einen starken positiven Zusammenhang zwischen den Staren und dem Vorkommen von Vögeln insgesamt und einen negativen Zusammenhang mit der Artenvielfalt, wobei das Vorkommen und die Größe der Gruppe potenzieller Konkurrenten einen schwachen negativen Zusammenhang mit dem Auftreten der Stare zeigte. Wir fanden einen positiven Zusammenhang mit der Häufigkeit einheimischer Vögel (Rotbauchdrossel *Turdus rufiventris*, Seidenkuhstärling *Molothrus bonariensis*, Graustärling *Agelaioides badius* und Ohrflecktaube *Zenaida auriculata*), sowie einen negativen Zusammenhang mit dem Mönchssittich (*Myiopsitta monachus*), dem Piciuttäubchen (*Columbina picui*) und exotischen Vögeln (Felsentaube *Columba livia*, Haussperling *Passer domesticus*). Es gab außerdem einen starken positiven Zusammenhang zwischen dem Auftreten der Stare und der Grasdecke. Ein negativer Zusammenhang mit einheimischen Arten könnte entweder das Ergebnis von Konkurrenz um Ressourcen oder von Unterschieden in der Habitatnutzung sein, während ein positiver Zusammenhang Vorteile beim Zugang zu Nahrung und bei der Verringerung des Raubtierrisikos oder auch eine ähnliche Habitatnutzung in Argentinien bedeuten könnte. Unsere Ergebnisse sind ein erster Schritt zum Verständnis der

Ökologie dieser invasiven Art und um zu erkennen, welche einheimische Art potenziell ökologisch bedroht sein könnte.

Introduction

The establishment success of introduced species is affected by the new physical environment, the availability of resources and the interspecific interactions with the species already present (Elton 1958; Stohlgren et al. 2003; Levine et al. 2004; Blackburn et al. 2009). Therefore, one major challenge introduced species face is to cope with the novel location (Blackburn et al. 2009). Urban environments are typically composed by fragmented and heterogeneous microhabitats that offer both food and nesting resources usually exploited by introduced birds (Marzluff 2001; Sol et al. 2017; Palacio et al. 2018). Other benefit these species obtain in urban areas is a low diversity and richness of native species that oppose little biotic resistance (Clergeau et al. 1998; Shea and Chesson 2002). In addition, urban areas are points of release (accidentally or deliberately) of captive species (Blackburn et al. 2009). As a result, urban avifauna is typically composed by few successful invasive species, such as the Rock Dove, the Common Starling (*Sturnus vulgaris*) and the House Sparrow, together with some native synanthropic species (Marzluff 2001; McKinney 2008; Chiari et al. 2010).

When introduced species exploit an occupied niche, they may compete for resources with native species that are at the same trophic level (Bonter et al. 2010a, b). Hence, the characteristics of the invaded community play a major role on the establishment success (Elton 1958). One possible result of the interactions between exotic and native species is the displacement of some species (Ibañez et al. 2017; Peck et al. 2014), in which populations of some species will decline (Freed and Can 2009), become extinct (Lowe et al. 2000; Bøhn et al. 2008) or shift their ecological niche to enable the coexistence with the invader (Harrington et al. 2009; Koch et al. 2012). On the other hand, some species would take advantage of the presence of the recently arrived species, such as benefits related with an antipredatory behavior

(Hernández-Brito et al. 2014). In this sense, analyzing its habitat use and interspecific relationships with previously established species would be key to understand the invasion process and to alert for potential negative impacts on biodiversity. These interactions may drive community changes through time, even though determining the real impact of introduced on native species remains a major challenge (Parker et al. 1999; Blackburn et al. 2009; Strubbe et al. 2011).

The Common Starling (hereafter starling) is a successful invasive bird currently considered one of the 100 more invasive species worldwide (Lowe et al. 2000; Craig 2020). It is native to Europe, Asia and Northern Africa and has been successfully established in New Zealand, Australia, South Africa, Canadá, United States of America, Mexico, Chile, Brazil, Argentina and some islands from the Pacific and the Caribbean (Feare 1984; Barros and Merlo 2021). In Argentina, the first record of the European starling dates from 1987 in Buenos Aires city (Pérez 1988). Since then, it has expanded its distribution in Argentina (Peris et al. 2005; Jensen 2008; Klavins and Álvarez 2012; Lucero 2013; Ortiz et al. 2013; Zanotti 2013), and recently, it has shown an accelerated westward expansion through rural and urban areas of Buenos Aires province (Zufiaurre et al. 2016). Many researchers have suggested that the starling may have a negative impact on native birds, particularly during the breeding season because of competition for cavities for nesting (Kerpez and Smith 1990; Ingold 1996; Mazgajski 2000; Koch et al. 2012). Less attention has been paid to competition for food resources with native birds, even though this type of competition has not been observed in experimental and observational studies of the feeding behavior of the starling (Williamson and Gray 1975; Beveridge and Deag 1987; Clergeau 1990). Some species in our study area have the same feeding habits as the starling and share feeding flocks, which could therefore be potential competitors for food (Palacio et al. 2016) or may take advantages from the presence of the new arrived species, such as benefits related with an antipredatory behavior (Hernández-Brito et al. 2014) or

information about the presence of feeding resources (Dolby and Grubb 1998; Mwangomo et al. 2008).

Our main predictions are that starlings should be more abundant in sites with a high lawn cover, where the species frequently forage, and that a higher starling abundance at these sites should reduce the abundance of other potential competitors, with a consequent decrease in bird diversity.

In this context, our objectives were to: (1) assess relationships between starling abundance and bird community attributes (abundance, richness and diversity), (2) examine the relationship between the starling and a group of birds as potential competitors for food with the starling, and (3) identify environmental variables associated with starling abundance in a small recently invaded town.

Materials and methods

Study area

Field sampling was performed in Llavallol town ($34^{\circ} 48' S$, $58^{\circ} 26' W$), Lomas de Zamora, north-east Buenos Aires Province, Argentina (Fig. 1). This has a surface of 11.3 km^2 and is located near the Río de La Plata shore (INDEC 2001). It is composed by (1) built-up areas including residential areas with numerous gardens and tree avenues, and an important industrial zone, and (2) exotic hardwood plantations composed by *Ligustrum lucidum*, *Pinus* spp., *Araucaria* spp., *Acacia* spp., *Platanus* spp., *Eucaliptus* spp., *Quercus* spp. and *Ceiba* spp. (Maragliano et al. 2009). The climate is humid temperate, with mean annual precipitation of 1000 mm and mean annual temperature of 16.5°C (Grassi 2011).

Bird counts and environmental variables

Bird counts were conducted following the line transect method (Bibby et al. 2000) from April 2015 to March 2016. Ten transects of $200 \text{ m} \times 50 \text{ m}$ separated by 250 m were established, in which the species and the number of the birds seen or heard were recorded. The transects had the same length, were located equidistant from one another, and were chosen to represent the different aspects of the physiognomy of the study area, covering garden areas, squares, and suburbs. The same observer (R.E. Maragliano) sampled the 10 transects every month within the 4 h after sunrise and in good weather conditions. The study area consists of low houses, with gardens in front of the houses and trees on the sidewalks.

We measured the following environmental variables from a GoogleEarth image (August 2015) of the study area using Qgis software (2011): tree cover (TC), lawn cover (LC), green cover ($\text{GC} = \text{TC} + \text{LC}$), building cover (BC), pavement cover (PC), concrete cover ($\text{CC} = \text{BC} + \text{PC}$), and bare soil (BS). Variables were tested for collinearity among variables; we discarded all (Spearman rank correlations > 0.7) but one to test for habitat associations according to biological meaning. The variable selected was “lawn cover” because starlings usually feed on insects and larvae in grassed areas during the day (Williamson and Gray 1975; Feare 1984).

Statistical analyses

Total abundance and species richness were estimated as the number of individuals and species, respectively, per transect and observation date. We computed diversity per transect

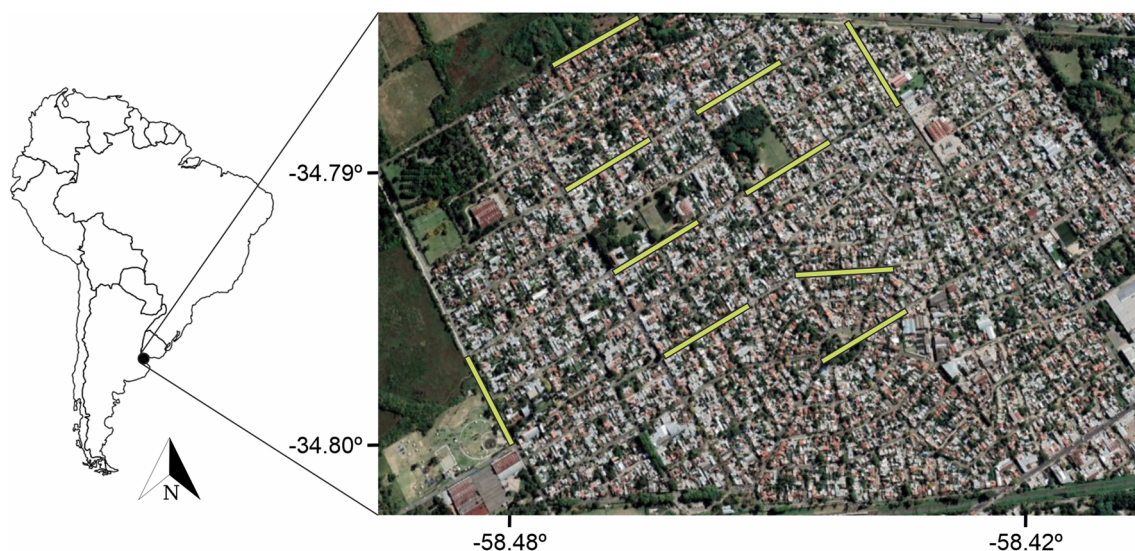


Fig. 1 Study area (Llavallol town ($34^{\circ} 48' S$, $58^{\circ} 26' W$), Lomas de Zamora, north-east Buenos Aires province, Argentina) showing transects

and observation date using the bias-corrected Shannon entropy estimator, a nearly unbiased estimator based on species accumulation curves and outperforming other diversity measures (Chao et al. 2013). To assess relationships between the abundance of the starling and bird community attributes, we fitted a generalized linear mixed model (GLMM) with a Poisson error distribution and log-link function (Zuur et al. 2009). We included richness, diversity and total bird abundance as fixed factors (Spearman's rank correlations < 0.7). We also modeled the abundance of the starling in relation to the abundance and richness of a group of species that are potential competitors for food with the starling. Diversity of competitors showed a strong correlation with richness of competitors (Spearman's rank correlation = 0.79), so we excluded it from the model. Based on previous works, we included 11 species with similar feeding habits to the starling, considering the food items they consume, the foraging substrate and foraging method (Palacio et al. 2016). We also included species from both the literature and personal observations of the authors which have been observed sharing feeding sites with starlings (Williamson and Gray 1975; Clergeau 1990; Rebolo Ifran and Fiorini 2010; Mazzulla 2013; Di Santo et al. 2017). Species with less than 10 records were excluded. The species included in the analyses were: Rock Dove, Picazuro Pigeon (*Patagioenas picazuro*), Eared Dove, Picui Ground-dove, Rufous Hornero (*Furnarius rufus*), Rufous-bellied Thrush, Chalk-browed Mockingbird (*Mimus saturninus*), Bay-winged Cowbird, Shiny Cowbird, Monk Parakeet and House Sparrow. To assess relationships between starling abundance and local species, we performed a GLMM including the abundance of each of the 11 species as fixed effects (all Spearman's rank correlations < 0.7). To assess starling habitat use, we included lawn cover in all models. In addition, the covariate "season" (four levels: summer, autumn, winter and spring) plus the interaction between season and lawn cover were included as fixed factors to control for seasonal changes in starling abundance. We included the transect identity as a random factor (intercept-only model, constant variance for all factor levels) in all the analyses. All continuous variables were standardized to mean 0 and variance 1 for proper model convergence and comparison among predictors in all the analyses. We used model averaging based on Akaike's information criterion corrected for small sample sizes (AICc) to make model comparisons. All the possible models were ranked based on their AICc and those with substantial support were identified, i.e., the models with the smallest AICc in a range such that $\Delta AICc < 2$ (Burnham and Anderson 2002). Given the high number of predictors included in the last model (11 species and the season), model selection was based on the Bayesian information criterion (BIC), which penalizes stronger than the AIC for the same number of predictors included in the model. The relative importance of each explanatory variable

was computed as the sum of Akaike weights over all of the models in which the term appears (Burnham and Anderson 2002). A full-model averaging approach was used, in which parameters that were not included in a model were set to zero and included when averaging the coefficient estimates. Parameters with larger sum of weights (maximum = 1) are considered to have a better support (Burnham and Anderson 2002).

Given the temporal nature of the data, we assessed temporal autocorrelation in the residuals using the acf function in R (R Core Team 2016). This function estimates temporal autocorrelation for a series of lag distance values (Zuur et al. 2009). As no model showed significant autocorrelation for any lag (results not shown), an autocorrelation structure for the residuals was not needed. All the analyses and graphs were implemented with the packages entropart (Marcon and Herault 2015), lme4 (Bates et al. 2011) and MuMin (Barton 2015) available in R software v. 2.10.1 (R Core Team 2016).

Results

We recorded 36 bird species and a total bird abundance of 3,847 individuals. Mean abundance was 32.1 ± 1.0 birds per hectare. The most abundant species were the House Sparrow, the Eared Dove and the starling, with mean abundance of 6.0 ± 0.5 , 5.7 ± 0.5 and 2.5 ± 3.2 birds per hectare, respectively. At the community level, starling abundance was strongly and positively associated with bird abundance, and negatively with bird richness and diversity (Table 1).

We also found seasonal changes in starling abundance, being higher in winter and autumn and lower in spring and summer. Finally, we found a positive relationship between starling abundance and lawn cover (Tables 1, 2), with a strongest association in winter and summer, reflected by a positive interaction between season and lawn cover (Tables 1, 2, Fig. 2).

When considering the abundance and richness of the group of potential competitors, starling abundance showed a weak negative association with both attributes (Table 2). When inspecting individual species, starling abundance showed a negative relationship with the abundance of the Rock Dove and a positive relationship with the abundance of the Rufous-bellied Thrush (Table 3, Figure 3). The remaining nine potential competitors analyzed were not retained in the models with higher support, suggesting no association with starling abundance (Table 3).

Table 1 Results of generalized linear mixed modeling and model averaging analysis showing the associations between Common Starling (*Sturnus vulgaris*) abundance and bird community attributes, including lawn cover associations and seasonal changes

Variable	Estimate	Std. error	<i>z</i>	<i>p</i>	Number of containing models	Relative importance
Intercept (winter)	0.460	0.321	1.415	0.147		
Total Abundance	0.374	0.090	4.120	<0.0001	4	1
Lawn	0.626	0.301	2.055	0.048	4	1
Autumn	0.539	0.170	3.131	0.003	4	1
Spring	− 0.154	0.188	0.809	0.288	4	1
Summer	− 0.154	0.188	3.398	0.001	4	1
Lawn × autumn	− 0.435	0.131	3.287	0.002	4	1
Lawn × spring	− 0.250	0.141	1.752	0.086	4	1
Lawn × summer	0.063	0.155	0.401	0.368	4	1
Richness	− 0.076	0.097	0.782	0.294	2	0.53
Diversity	− 0.046	0.074	0.612	0.331	2	0.44

Parameter estimates and relative importance of the parameters resulting from models with $\Delta AICc \leq 2$ are shown

Table 2 Results of general linear mixed modeling and model averaging analysis showing associations between Common Starling (*Sturnus vulgaris*) abundance and the abundance and richness of potential competitors, including lawn cover associations and seasonal changes.

Variable	Estimate	Std. error	<i>Z</i>	<i>p</i>	Number of containing models	Relative importance
Intercept (winter)	0.583	0.351	1.642	0.104		
Lawn	0.611	0.336	1.796	0.080	3	1
autumn	0.234	0.162	1.425	0.144	3	1
Spring	− 0.223	0.178	1.239	0.185	3	1
summer	− 0.690	0.213	3.194	0.0002	3	1
Lawn × autumn	− 0.471	0.129	3.603	<0.001	3	1
Lawn × spring	− 0.207	0.140	1.462	0.137	3	1
Lawn × summer	0.121	0.157	0.765	0.298	3	1
Richness of competitors	− 0.011	0.036	0.307	0.381	1	0.23
Abundance of competitors	− 0.013	0.042	0.313	0.380	1	0.23

Parameter estimates and relative importance of the parameters resulting from models with $\Delta AICc \leq 2$ are shown

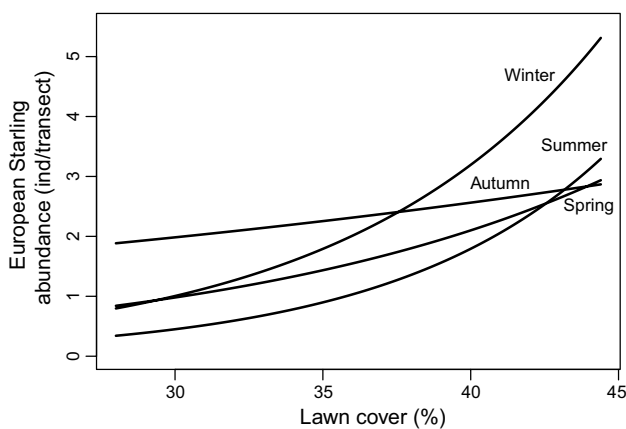


Fig. 2 Abundance of the Common Starling (*Sturnus vulgaris*) in relation to the percentage of lawn cover in each season. Each line represents the fit of a generalized linear mixed model (Poisson error structure and log-link function) conditional on the mean of lawn, abundance, richness, and diversity (see Methods)

Discussion

The abundance of the starling was strongly related to community attributes as well as to the abundance of local species. These associations could be the result of direct or indirect interspecific interactions among species, or they could be reflecting differences in habitat use. Moreover, we found positive and negative associations between the starling and some potential competitors that may reflect a positive influence of the starling on some species (facilitation) and a negative effect on others (competition). Although these results do not confirm the presence of an impact by the starling, they alert about the need of monitoring for possible changes in bird communities. Although the introduction of invasive species is considered one of the major threats to biodiversity worldwide (Lowe et al. 2000; Sakai et al. 2001; Sanders et al. 2003) several reviews have failed to find conclusive

Table 3 Results of general linear mixed modeling and model averaging analysis showing associations between Common Starling (*Sturnus vulgaris*) abundance and potential competitor species for food, including seasonal changes

Variable	Estimate	Std. error	<i>z</i>	<i>p</i>	Number of containing models	Relative importance
Intercept (winter)	0.600	0.415	1.431	0.152		
<i>Columba livia</i>	− 0.439	0.130	3.349	0.001	2	1.00
<i>Turdus rufiventris</i>	0.099	0.092	1.075	0.282	1	0.63
Autumn	0.153	0.159	0.951	0.341	2	1.00
Spring	− 0.425	0.167	2.510	0.012	2	1.00
Summer	− 0.497	0.189	2.607	0.009	2	1

Parameter estimates and relative importance of the parameters resulting from models with $\Delta\text{BICc} \leq 2$ are shown

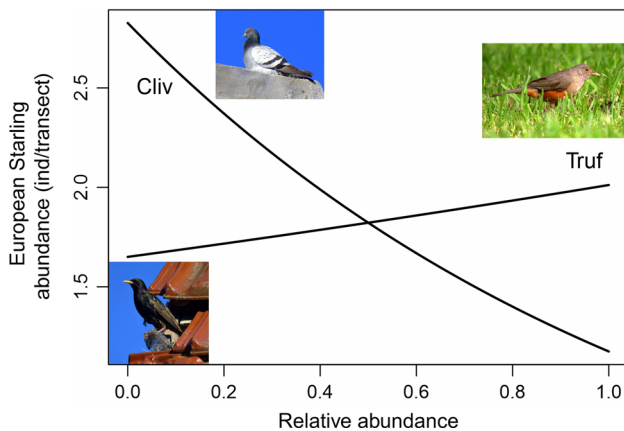


Fig. 3 Total abundance of the Common Starling (*Sturnus vulgaris*) versus the abundance of potential competitor species (**A** positively associated species, **B** and **C**: negatively associated species). Each line represents the fit of a generalized linear mixed model (Poisson error structure and log-link function) conditional on the mean of lawn and the abundance of ten local species (see Methods). Relative abundance (range=0–1) of local species is shown to aid visual comparison between species. *Truf* *Turdus rufiventris*, *Cliv* *Columba livia*

evidence of threat to native bird populations and communities linked to competition with introduced species (Blackburn et al. 2009; Bauer and Woog 2011; Baker et al. 2014; Martín-Albarracín et al. 2015). However, some studies have found negative effects on native species driven by invasive birds. For instance, Peck et al. (2014) found experimental evidence of interference competition for food between the introduced Rose-ringed Parakeet (*Psittacula krameri*) and two native urban birds in England. In another example, Le Louarn et al. (2016) showed the presence of interference competition between the Rose-ringed Parakeet and native species and found that the starling was the most affected species in France, where it is native. In North America, a study analyzing population trends of 27 native cavity-nesting species 30 years after the arrival of the starlings found a potential negative effect of the starling on only one native species (Koenig 2003). These studies suggest that the negative effect of the starling on native birds remains controversial

and therefore deserves further research (Bauer and Woog 2011). In Argentina, two studies have analyzed the association between the abundance of the starling and bird communities. Ifrán and Fiorini (2010) found no relationship between the presence and the abundance of the starling and bird richness in Buenos Aires city. However, this study was performed in urban parks, so some key elements of the urban landscape that commonly affect bird assemblages, such as the presence of buildings, were not considered. On the other hand, Palacio et al. (2016) found a positive correlation between starling abundance, total bird abundance and diversity in a non-urban area composed of grasslands, a flood plain and patches of native woods, located 25 km from our study area. In Llavallol, starling abundance was also positively related with total bird abundance but negatively related to diversity. Communities with a high diversity are expected to be more resistant to invasions under a scenario of resource limitation, because fewer resources are vacant (Elton 1958; Tilman 2004; Stachowicz and Byrnes 2006). By contrast, when resources are not limited, the relationship between native and introduced species changes with the availability of resources and with species composition (Stachowicz and Byrnes 2006). In addition, exotic birds usually exploit novel ecological niches found in human-altered environments, whereas most native species are unable to tolerate high environmental alterations (Marzluff 2001; MacKinney 2008; Evans et al 2011; Sol et al. 2017). In this context, the negative relationship with diversity and richness observed here may be reflecting spatial changes in the availability of resources, differences in the composition of the bird communities among sites or the use of different ecological niches between the starling and the species previously present.

When considering the group of potential competitors, we found negative trends between the abundance of the starling and both richness and abundance of birds. This result may be reflecting competition between the starling and species using the same food resources. Nevertheless, environmental confounding factors, such as the availability of resources or human and predator presence may be altering the dynamics among species (Bonter et al. 2010a, b; Dures and Cuming

2010; Peck et al. 2014). In urban parks of Buenos Aires city, Ifrán and Fiorini (2010) found that starlings fed in mixed flocks with some native species, such as the Rufous Hornero, the Eared Dove, the Shiny Cowbird, the Bay-winged Cowbird, the Chalk-browed Mockingbird, the Rufous-bellied Thrush, the Creamy-bellied Thrush (*Turdus amaurochalinus*), the Goldenbreasted Woodpecker (*Colaptes melanochloros*), the Picazuro Pigeon and the Monk Parakeet, and with the exotic Rock Dove. Among these species, two exotic urban exploiters, the Rock Dove and the House Sparrow, were negatively associated with starling presence. Both species are commonly found in high numbers in cities around the world and are known to share heterospecific flocks with starlings (Williamson and Gray 1975; Beveridge and Deag 1987; Clergeau 1990; MacGregor-Fors et al. 2010).

Blackburn et al. (2009) proposed that previously established exotic species may have an important role in the establishment success of species introduced in a later stage if competition among these species is strong, especially if the species involved are ecologically similar. Nevertheless, although we found negative associations between the starling and these species, we should not discard possible differences in habitat selection as the cause of these associations (Bonter et al. 2010a, b). If both species share flocks without aggressive interaction, negative associations in their abundances would be related to competition by exploitation of the same resources or by a passive interference, if one of the species creates barriers that indirectly impedes the access to some resources by the other species (Cresswell 1997). Although the associations with the whole group of potential competitors and in particular are negative, some species showed a positive association with the starling. Sharing mixed groups would provide some benefits exceeding the costs of sharing resources (Julien and Clobert 2000). For instance, it would facilitate the finding of food by the species that exploit the same niche (Latta and Wunderle 1996; Dolby and Grubb 1998; Mwangomo et al. 2008). Some researchers have observed that the starling commonly fed in mixed flocks with other bird species and suggested that the starling take advantages from this behavior related to food accessibility (Williamson and Gray 1975; Feare 1984). Clergeau (1990) experimentally analyzed the feeding behavior of the starling and obtained results supporting this hypothesis. Moreover, the starling has been observed to mimic the foraging behavior of other species when feeding in mixed flocks (Williamson and Gray 1975). This behavior would be an advantage for the starling, especially in the areas where it was introduced (Williamson and Gray 1975), and would encourage its joining to mixed flocks. Other advantage of sharing flocks would be the reduction of predation risk (Slotow and Paxinos 1997; Thiollay 1999). For instance, some native species take advantage from the effective antipredatory

behavior of an invasive species, the Rose-ringed Parakeet, in Spain (Hernández-Brito et al. 2014). The Rufous-bellied Thrush belongs to a genus with species that commonly share mixed flocks with the starling in Europe, such as the Redwing (*Turdus iliacus*), the Eurasian Blackbird (*T. merula*), the Song Thrush (*T. philomenos*), the Fieldfare (*T. pilaris*) and the Mistle thrush (*T. viscivorous*) (Clergeau 1990), and in North America, such as the American Robin (*T. migratorius*) (Williamson and Gray 1975; Feare 1984). These results show that in the absence of the same species, the starling share mix flocks with species both phylogenetically and ecologically related to those found in its native area or in other areas previously introduced.

Despite the fact that our study was carried out for a single year and the area studied was relatively small (relatively short transects), we can affirm that the starling was more abundant in areas with a higher lawn proportion, represented mainly by parks and gardens in the study area. The starling usually feeds on lawns extracting insects, larvae and earthworms from the upper layers of the soil (Williamson and Gray 1975; Tinbergen 1981; Caccamise 1991; Mennechez and Clergeau 2001; Devereux et al. 2004). In northern Europe, it has been hypothesized that the reduction of pastures in modern landscapes is one of the causes of the population decline of the starling (Solonen et al. 1991; Smith and Bruun 2002). In contrast, an opposite trend has been observed in south-western Europe, with an increase in urban starling population, possibly related with the increment in lawn plantings (Mennechez and Clergeau 2001). Lawn cover seems therefore to be a major landscape element determining starling presence and abundance, as it provides suitable foraging sites. We thus suggest that areas with intermediate levels of urbanization, such as Llavallol, would be more susceptible to starling invasion, and warn to the problem of endangerment of native biodiversity caused by invaders.

Conclusions

Overall, our approach showed association between the Common Starling and a recently invaded bird community. These associations alert on a potential future threat altering bird communities in our country, especially if the starling experiences a population growth. Under this scenario, some species might be benefited, while others are expected to suffer detrimental effects. Our findings would help management efforts to focus on priority areas and target species. Although further experimental research is needed to elucidate whether these associations are related to biotic interactions among species or to differences in habitat use of the species

involved, our results represent a first step to understand the ecology of an invasive species, as well as to identify native species under potential ecological threat.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10336-023-02047-x>.

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Data Availability The data in this publication is available to anyone who needs it.

Declarations

Conflict of 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.

References

- Baker J, Harvey KJ, French K (2014) Threats from introduced birds to native birds. *Emu* 114:1–12. <https://doi.org/10.1071/MU12122>
- Barros R, Merlo F (2021) Primeros registros de Estornino pinto en Chile ¿Un nuevo capítulo de su invasión en el Cono Sur? *La Chiricoca* 27:26–31. <https://doi.org/10.6084/m9.figshare.16692034>
- Barton K (2015) MuMIn: multi-model inference. R package version 1.13.4. <http://CRAN.R-project.org/package=MuMIn>
- Bates D, Maechler M, Bolker B (2011) lme4: linear mixed-effects models using Eigen and Eigen. R package version 0.999375-42. <http://CRAN.R-project.org/package=lme4>
- Bauer HG, Woog F (2011) On the ‘invasiveness’ of non-native bird species. *Ibis* 153:204–206. <https://doi.org/10.1111/j.1474-919X.2010.01085.x>
- Beveridge F, Deag J (1987) The effects of sex, temperature and companions on looking-up and feeding in single and mixed species flocks of house sparrows (*Passer domesticus*), chaffinches (*Fringilla coelebs*), and starlings (*Sturnus vulgaris*). *Behaviour* 100:303–319. <https://doi.org/10.1163/156853987X00170>
- Bibby CJ, Burgess ND, Hill DA, Mustoe S (2000) *Bird census techniques*. Academic Press, London
- Blackburn TM, Lockwood JL, Cassey P (2009) *Avian invasions: the ecology and evolution of exotic birds*. Oxford University Press, Oxford
- Bøhn T, Amundsen PA, Sparrow A (2008) Competitive exclusion after invasion? *Biol Invasions* 10:359–368. <https://doi.org/10.1007/s10530-007-9135-8>
- Bonter DN, Zuckerberg B, Dickinson JL (2010a) Invasive birds in a novel landscape: habitat associations and effects on established species. *Ecography* 33:494–502. <https://doi.org/10.1111/j.1600-0587.2009.06017.x>
- Bonter DN, Zuckerberg B, Dickinson JL (2010b) Invasive birds in a novel landscape: habitat associations and effects on established species. *Ecography* 33:494–502. <https://doi.org/10.1111/j.1600-0587.2009.06017.x>
- Burnham KP, Anderson DR (2002) *Model selection and multimodel inference: a practical information theoretic approach*. Springer-Verlag, New York
- Caccamise DF (1991) European starling fidelity to diurnal activity centers: role of foraging substrate quality. *Wilson Bull* 103:13–24
- Chao A, Wang YT, Jost L (2013) Entropy and the species accumulation curve: a novel entropy estimator via discovery rates of new species. *Methods Ecol Evol* 4:1091–1100. <https://doi.org/10.1111/2041-210X.12108>
- Chiari C, Dinetti M, Licciardello C, Licitra G, Pautasso M (2010) Urbanization and the more-individuals hypothesis. *J Anim Ecol* 79:366–371. <https://doi.org/10.1111/j.1365-2656.2009.01631.x>
- Clergeau P (1990) Mixed flocks feeding with starlings: an experimental field study in Western Europe. *Bird Behav* 8:95–100. <https://doi.org/10.3727/015613890791784308>
- Clergeau P, Savard JPL, Mennechez G, Falardeau G (1998) Bird abundance and diversity along an urban-rural gradient: a comparative study between two cities on different continents. *Condor* 100:413–425. <https://doi.org/10.2307/1369707>
- Craig AJFK (2020) The common starling *Sturnus vulgaris*. In: Downs CT, Hart LA (eds) *Invasive birds: global trends and impacts*. CABI, Wallingford, pp 9–24
- Cresswell W (1997) Interference competition at low competitor densities in blackbirds *Turdus merula*. *J Anim Ecol* 66:461–471. <https://doi.org/10.2307/5941>
- Devereux CL, McKeever CU, Benton TG, Whittingham MJ (2004) The effect of sward height and drainage on Common Starlings *Sturnus vulgaris* and Northern Lapwings *Vanellus vanellus* foraging in grassland habitats. *Ibis* 146:115–122
- Di Santo M, Battisti C, Bologna MA (2017) Interspecific interactions in nesting and feeding urban sites among introduced Monk Parakeet (*Myiopsitta monachus*) and syntopic bird species. *Ethol Ecol Evol* 29:138–148. <https://doi.org/10.1080/03949370.2015.1119761>
- Dolby AS, Grubb TC (1998) Benefits to satellite members in mixed-species foraging groups: an experimental analysis. *Anim Behav* 56:501–509. <https://doi.org/10.1006/anbe.1998.0808>
- Dures SG, Cumming GS (2010) The confounding influence of homogenising invasive species in a globally endangered and largely urban biome: does habitat quality dominate avian biodiversity? *Biol Conserv* 143:768–777. <https://doi.org/10.1016/j.biocon.2009.12.019>
- Elton CS (1958) *The ecology of invasions by animals and plants*. Methuen, London
- Evans KL, Chamberlain DE, Hatchwell BJ, Gregory RD, Gaston KJ (2011) What makes an urban bird? *Glob Change Biol* 17:32–44. <https://doi.org/10.1111/j.1365-2486.2010.02247.x>
- Feare CJ (1984) *The starling*. Oxford University Press, Oxford
- Freed LA, Cann RL (2009) Negative effects of an introduced bird species on growth and survival in a native bird community. *Curr Biol* 19:1736–1740. <https://doi.org/10.1016/j.cub.2009.08.044>
- Grassi AH (2011) *Lomas de Zamora: estancia, aldea, municipio, ciudad: antología histórica lugareña*. Banco de la Provincia de Buenos Aires, Buenos Aires
- Harrington LA, Harrington AL, Yamaguchi N, Thom MD, Ferreras P, Windham TR et al (2009) The impact of native competitors on an alien invasive: temporal niche shifts to avoid interspecific aggression? *Ecology* 90:1207–1216. <https://doi.org/10.1890/08-0302.1>
- Hernández-Brito D, Carrete M, Popa-Lisseanu AG, Ibáñez C, Tella JL (2014) Crowding in the city: losing and winning competitors of an invasive bird. *PLoS ONE* 9:e100593. <https://doi.org/10.1371/journal.pone.0100593>
- Ibáñez LM, Girini JM, Palacio FX, Fiorini VD, Montalti D (2017) Interacciones entre el estornino pinto (*Sturnus vulgaris*) y aves nativas de Argentina por el uso de cavidades. *Revista Mexicana De Biodiversidad* 88(2):477–479. <https://doi.org/10.1016/j.rmb.2017.03.022>

- Ingold DJ (1996) Delayed nesting decreases reproductive success in Northern Flickers: implications for competition with European starlings. *J Field Ornithol* 67:321–326
- Jensen RF (2008) Nuevos registros de estornino pinto (*Sturnus vulgaris*) para el sureste de la provincia de Entre Ríos Argentina. *Nuestras Aves* 53:22
- Jullien M, Clobert J (2000) The survival value of flocking in Neotropical birds: reality or fiction? *Ecology* 81:3416–3430. [https://doi.org/10.1890/0012-9658\(2000\)081\[3416:TSVOFI\]2.0.CO;2](https://doi.org/10.1890/0012-9658(2000)081[3416:TSVOFI]2.0.CO;2)
- Kerpez TA, Smith NS (1990) Competition between European Starlings and native woodpeckers for nest cavities in saguaros. *Auk* 107:367–375. <https://doi.org/10.2307/4087621>
- Klavins J, Álvarez D (2012) El estornino pinto (*Sturnus vulgaris*) en la provincia de Córdoba, Argentina. *Nuestras Aves* 57:27–29
- Koch AJ, Martin K, Aitken KE (2012) The relationship between introduced European Starlings and the reproductive activities of Mountain Bluebirds and Tree Swallows in British Columbia, Canada. *Ibis* 154:590–600. <https://doi.org/10.1111/j.1474-919X.2012.01242.x>
- Koenig WD (2003) European Starlings and their effect on native cavity-nesting birds. *Conserv Biol* 17:1134–1140. <https://doi.org/10.1046/j.1523-1739.2003.02262.x>
- Latta SC, Wunderle JM (1996) The composition and foraging ecology of mixed-species flocks in pine forests of Hispaniola. *Condor* 98:595–607. <https://doi.org/10.2307/1369572>
- Le Louarn M, Couillens B, Deschamps-Cottin M, Clergeau P (2016) Interference competition between an invasive parakeet and native bird species at feeding sites. *J Ethol* 34:291–298. <https://doi.org/10.1007/s10164-016-0474-8>
- Levine JM, Adler PB, Yelenik SG (2004) A meta-analysis of biotic resistance to exotic plant invasions. *Ecol Lett* 7:975–989. <https://doi.org/10.1111/j.1461-0248.2004.00657.x>
- Lowe S, Browne M, Boudjelas S, De Poorter M (2000) 100 of the world's worst invasive alien species: a selection from the global invasive species database Species Survival Commission. World Conservation Union (IUCN), New Zealand. Invasive Species Specialist Group, Auckland.
- Lucero F (2013) Nuevas aves, primeras evidencias y localidades para las provincias de San Juan y Catamarca Argentina. *Ecoregistros* 3:14
- MacGregor-Fors I, Morales-Pérez L, Quesada J, Schondube JE (2010) Relationship between the presence of House Sparrows (*Passer domesticus*) and Neotropical bird community structure and diversity. *Biol Invasions* 12:87–96. <https://doi.org/10.1007/s10530-009-9432-5>
- Maragliano RE, Marti LJ, Ibañez LM, Montalti D (2009) Comunidades de aves urbanas de Lavallol, Buenos Aires, Argentina (Urban bird communities from Lavallol, Buenos Aires, Argentina). *Acta Zoológica Lilloana* 53:108–114
- Marcon E, Hérault B (2015) Entropart: an R package to measure and partition diversity. *J Stat Softw* 67:1–26. <https://doi.org/10.18637/jss.v067.i08>
- Martin-Albarracín VL, Amico GC, Simberloff D, Nuñez MA (2015) Impact of non-native birds on native ecosystems: a global analysis. *PLoS ONE* 10:e0143070. <https://doi.org/10.1371/journal.pone.0143070>
- Marzluff JM (2001) Worldwide urbanization and its effects on birds. In: Marzluff JM, Bowman R, Donnelly R (eds) *Avian ecology and conservation in an urbanizing world*. Springer, New York, pp 19–47
- Mazgajski TD (2000) Competition for nest sites between the starling and other cavity nesters. *Acta Ornithologica* 35:103–107
- Mazzulla J (2013) Primeros registros de estornino pinto *Sturnus vulgaris* (Linnaeus 1758) (Aves, Passeriformes, Sturnidae) en Uruguay. *Novedades Ornitológicas* 3:13–17
- McKinney ML (2008) Effects of urbanization on species richness: a review of plants and animals. *Urban Ecosyst* 11:161–176
- Mennechez G, Clergeau P (2001) Settlement of breeding European starlings in urban areas: importance of lawns vs. anthropogenic wastes. In: Marzluff JM, Bowman R, Donnelly R (eds) *Avian ecology and conservation in an urbanizing world*. Springer, New York, pp 275–287
- Mwangomo EA, Hardesty LH, Sinclair ARE, Mduma SA, Metzger KL (2008) Habitat selection, diet and interspecific associations of the rufous-tailed weaver and Fischer's lovebird. *Afr J Ecol* 46:267–275. <https://doi.org/10.1111/j.1365-2028.2007.00903.x>
- Ortiz D, Capllonch P, Aveldaño S, Mamani J, Quiroga O, Ten Moreno T (2013) Los passeriformes de Tucumán, Argentina: lista, distribución y migración. *Biológica* 16:39–71
- Palacio FX, Maragliano RE, Montalti D (2016) Functional role of the invasive European Starling, *Sturnus vulgaris*, in Argentina. *Emu* 116:387–393. <https://doi.org/10.1071/MU16021>
- Palacio FX, Ibañez LM, Maragliano RE, Montalti D (2018) Urbanization as a driver of taxonomic, functional, and phylogenetic diversity losses in bird communities. *Can J Zool* 96:1114–1121. <https://doi.org/10.1139/cjz-2018-0008>
- Parker IM, Simberloff D, Lonsdale WM, Goodell K, Wonham M, Kareiva PM et al (1999) Impact: toward a framework for understanding the ecological effects of invaders. *Biol Invasions* 1:3–19. <https://doi.org/10.1023/A:1010034312781>
- Peck HL, Pringle HE, Marshall HH, Owens IP, Lord AM (2014) Experimental evidence of impacts of an invasive parakeet on foraging behavior of native birds. *Behav Ecol* 25:582–590. <https://doi.org/10.1093/beheco/aru025>
- Pérez J (1988) Estornino pinto en la Capital Federal. *Nuestras Aves* 17:14
- Peris Álvarez S, Soave GE, Camperi AR, Darrieu CA, Aramburu RM (2005) Range expansion of the European Starling *Sturnus vulgaris* in Argentina. *Ardeola* 52:359–364
- R development Core Team (2016) R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. <http://www.R-project.org>.
- Rebolo Ifran N, Fiorini VD (2010) European Starling (*Sturnus vulgaris*): population density and interactions with native species in Buenos Aires urban parks. *Ornitología Neotropical* 21:507–518
- Sakai AK, Allendorf FW, Holt JS, Lodge DM, Molesky J, With KA et al (2001) The population biology of invasive species. *Ann Rev Ecol Evol Syst* 32:305–332. <https://doi.org/10.1146/annurev.ecolsys.32.081501.114037>
- Sanders NJ, Gotelli NJ, Heller NE, Gordon DM (2003) Community disassembly by an invasive species. *Proc Natl Acad Sci* 100:2474–2477. <https://doi.org/10.1073/pnas.0437913100>
- Shea K, Chesson P (2002) Community ecology theory as a framework for biological invasions. *Trends Ecol Evol* 17:170–176. [https://doi.org/10.1016/S0169-5347\(02\)02495-3](https://doi.org/10.1016/S0169-5347(02)02495-3)
- Slotow R, Paxinos E (1997) Intraspecific competition influences food return-predation risk trade-off by White-crowned Sparrows. *Condor* 99:642–650. <https://doi.org/10.2307/1370476>
- Smith HG, Bruun M (2002) The effect of pasture on starling (*Sturnus vulgaris*) breeding success and population density in a heterogeneous agricultural landscape in southern Sweden. *Agric Ecosyst Environ* 92:107–114. [https://doi.org/10.1016/S0167-8809\(01\)00266-3](https://doi.org/10.1016/S0167-8809(01)00266-3)
- Sol D, González-Lagos C, Lapiedra O, Díaz M (2017) Why are exotic birds so successful in urbanized environments? In: Murgui E, Hedblom M (eds) *Ecology and conservation of birds in urban environments*. Springer, Cham, pp 75–89

- Solonen T, Tiainen J, Korpimäki E, Saurola P (1991) Dynamics of Finnish starling *Sturnus vulgaris* populations in recent decades. *Ornis Fennica* 68:158–169
- Stachowicz JJ, Byrnes JE (2006) Species diversity, invasion success, and ecosystem functioning: disentangling the influence of resource competition, facilitation, and extrinsic factors. *Mar Ecol Progress Ser* 311:251–262. <https://doi.org/10.3354/meps311251>
- Stohlgren TJ, Barnett DT, Kartesz JT (2003) The rich get richer: patterns of plant invasions in the United States. *Front Ecol Environ* 1:11–14. [https://doi.org/10.1890/1540-9295\(2003\)001\[0011:TRGRPO\]2.0.CO;2](https://doi.org/10.1890/1540-9295(2003)001[0011:TRGRPO]2.0.CO;2)
- Strubbe D, Shwartz A, Chiron F (2011) Concerns regarding the scientific evidence informing impact risk assessment and management recommendations for invasive birds. *Biol Conserv* 144:2112–2118. <https://doi.org/10.1016/j.biocon.2011.05.001>
- Thiollay JM (1999) Frequency of mixed species flocking in tropical forest birds and correlates of predation risk: an intertropical comparison. *J Avian Biol* 30:282–294. <https://doi.org/10.2307/3677354>
- Tilman D (2004) Niche tradeoffs, neutrality, and community structure: a stochastic theory of resource competition, invasion, and community assembly. *Proc Natl Acad Sci* 101:10854–10861. <https://doi.org/10.1073/pnas.0403458101>
- Tinbergen JM (1981) Foraging decisions in starling *Sturnus vulgaris*. *Ardea* 69:1–67. <https://doi.org/10.5253/arde.v69.p1>
- Williamson P, Gray L (1975) Foraging behavior of the starling (*Sturnus vulgaris*) in Maryland. *Condor* 77:84–89. <https://doi.org/10.2307/1366761>
- Zanotti M (2013) Presencia del estornino pinto (*Sturnus vulgaris*) en la provincia de Mendoza, Argentina. *Nuestras Aves* 58:5–7
- Zufiaurre E, Abba A, Bilenca D, Codesido M (2016) Role of landscape elements on recent distributional expansion of European Starlings (*Sturnus vulgaris*) in agroecosystems of the Pampas, Argentina. *Wilson J Ornithol* 128:306–313. <https://doi.org/10.1676/wils-128-02-306-313.1>
- Zuur A, Ieno EN, Walker NJ, Saveliev AA, Smith GM (2009) *Mixed effects models and extensions in ecology with R*. Springer, New York

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