Functional role of the invasive European Starling, *Sturnus vulgaris*, in Argentina

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Abstract. The introduction of exotic species may have severe effects on native ecosystems by disrupting communities and ecosystem services. Consequently, assessing the functional role of a species newly added to a community is an important task in order to identify native species at risk. In Argentina, the ecology of the invasive European Starling (*Sturnus vulgaris*) is poorly known and studies addressing its ecological role in bird communities are still lacking. We assessed the functional role of the European Starling by sampling bird communities across four vegetation types (*Solanum* grassland, *Cynodon* grassland, flood plain and forest patches) and making comparisons of body mass, and dietary and foraging traits of European Starling with native and other introduced bird species in east-central Argentina. The European Starling was functionally most similar to two widespread, generalist native passerines – the Bay-winged Cowbird (*Agelaioides badius*) and the Chalk-browed Mockingbird (*Mimus saturninus*) – and to the invasive House Sparrow (*Passer domesticus*), which together defined a functional group of terrestrial and foliage omnivores. European Starlings were more abundant in *Solanum* grasslands than in other vegetation types and showed significant vegetation-type overlap with functionally similar species. Moreover, abundance of European Starlings was positively correlated with bird abundance and diversity. Our results identify native species that are functionally equivalent to European Starlings, and, consequently, potentially subject to ecological impacts.

Additional keywords: biodiversity, competition, foraging, invasive species.

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Introduction

The introduction of exotic species is among the major causes of biodiversity loss globally, since it may exert a range of negative impacts on ecological systems by altering mutualistic and competitive interactions among species, ecosystems functions and resource distributions (Mooney and Cleland 2001). In particular, interspecific competition is widely considered to play a major role among species (Kiesecker *et al*. 2001; Wauters *et al*. 2002; Dame *et al*. 2006) under the premise that overlap in ecological function between invasive and native species results in competition for limited resources (Blackburn *et al*. 2009). Hence, assessing the ecological role of an invasive species newly added into a bird community will be a key step in assessing potential impacts on native birds (Elton 1958), although predicting and quantifying the impact of introduced species on native populations remains a major challenge (Parker *et al*. 1999).

The European Starling (*Sturnus vulgaris*) is native to Eurasia and North Africa, and has been introduced and spread successfully in several parts of the world, including North America, South Africa, Australia, New Zealand, Argentina, Uruguay and some Pacific and Caribbean islands (Feare 1984; Peris *et al*. 2005; Mazzulla 2013). It is considered one of the 100 most invasive species worldwide (Lowe *et al*. 2000) due to its negative effects on agriculture, human health and native birds (Feare 1984; Pimentel *et al*. 2000). Studies on competition for resources with native birds have shown that its aggressive competition may negatively affect the breeding success of native species (Koenig 2003), such as the Gila Woodpecker (*Melanerpes uropygialis*) (Kerpez and Smith 1990) and the Northern Flicker (*Colaptes auratus*) (Ingold 1994, 1996) in North America, and rosellas (*Platycercus elegans* and *P. eximius*) in Australia (Pell and Tidemann 1997).

In Argentina, the European Starling was introduced at the end of the 1980s and has expanded its geographic range since then (Peris *et al*. 2005). Nevertheless, its ecology in Argentina is still poorly known. Only one study has estimated population density, assessed habitat use and quantified its interactions with native species (Ifran and Fiorini 2010), and only one study has assessed roost habitat selection (Girini *et al*. 2014). Ifran and Fiorini (2010) found some evidence of competition for food and nesting

sites with native birds, such as the Green-barred Woodpecker (*Colaptes melanochloros*), the Chalk-browed Mockingbird (*Mimus saturninus*), the Rufous Hornero (*Furnarius rufus*) and the Bay-winged Cowbird (*Agelaioides badius*). Although these studies have provided valuable knowledge about European Starling ecology, they have been restricted to urban or semiurban areas, and no study has assessed basic ecological aspects in other types of landscapes. Moreover, determining the functional role of the European Starling in native bird communities will aid better understanding of the invasion process.

We studied the ecological role of the European Starling in bird communities from north-east Buenos Aires province, Argentina. Specifically, we assessed (1) functional similarities between the European Starling and native species, (2) the effect of vegetation type on European Starling abundance, and (3) the overlap in use of vegetation types between the European Starling and functionally similar species.

Methods

Study area

The study was carried out within a 100-ha rectangular plot located in San Vicente (35°01′S, 58°25′W), north-east Buenos Aires province, Argentina. The study site is grazed by horses and includes four identifiable vegetation types: (1) a flood plain dominated by *Scirpus* sp., *Typha* sp. and *Zizaniopsis* sp., (2) a grassland dominated by *Cynodon* sp. and isolated *Celtis ehrenbergiana* trees, (3) a grassland dominated by *Solanum* sp. and small patches of *Parkinsonia* sp. trees, and (4) remnant forest patches (~0.6 ha) of *Celtis ehrenbergiana* trees. The climate is wet and warm-temperate with average temperatures ranging from 9°C (July) to 23°C (January). Annual precipitation is 900 mm, with the wettest months being January and February but without a well defined dry season (Cueto and López de Casenave 2000).

Bird sampling

We conducted 108 bird counts in 12 sampling periods from December 2009 to December 2010 by the standardised area search method (Slater 1994), in which rectangular plots of 150 m 40 m were walked at a steady pace along parallel transects lengthways through each plot (~15 min per plot). Three plots were located in the flood plain, two in the *Cynodon* grassland, two in the *Solanum* grassland and two in the forest patches, separated by 200 m each. In each plot, the species and number of all birds seen or heard were recorded. The same observer (REM) surveyed the nine plots every month (except for February 2010 due to inclement weather), within 4 h of sunrise during good weather conditions. Each plot took a total time of ~180 min to complete. We considered that the bird community of the study area was adequately represented, given the 100–150 min required to obtain a complete species list (Slater 1994) and that the richness accumulation curve of bird species approached an asymptote (results not shown).

Data analysis

Both abundance and species richness were estimated as the number of individuals and number of species, respectively, per plot and observation date. Alpha diversity was estimated as the reciprocal form of the Simpson index (Hill 1973), expressed as:

$$D = 1/\sum p_i{}^2,$$

where p_i represents the proportion of individuals in the *i*th species. To assess similarities in functional terms between European Starling and native species, we used non-metric multidimensional scaling (NMDS) (Kruskal and Wish 1978) on a species by traits matrix based on the following traits (modified from Hidasi-Neto *et al.* 2012): body mass, food item (vertebrates, invertebrates, leaves and buds, fleshy fruits and arillate seeds, dry fruits, nectar), foraging method (pursuit, gleaning, reaching, pecking, screening, scavenging, probing) and foraging substrate (water, mud, ground, vegetation, air). Body mass and ecological data were taken from Dunning (2008) and del Hoyo *et al.* (1992, 1994, 1996, 1997, 1999, 2002, 2003, 2004, 2005, 2006, 2009, 2010, 2011), respectively, and from our own unpublished data. The species by traits matrix was converted to a Gower distance matrix, appropriate for both continuous and categorical data (Gower 1971). Nearby points in trait space (i.e. similar values in multidimensional trait space) would reflect similar roles or redundancy in an ecosystem functioning (Walker 1992; Petchey *et al.* 2007; Dehling *et al.* 2016). We did not include reproductive traits (e.g. nest type, nest location, clutch size) since our data spanned both breeding and non-breeding seasons. Common and scientific names follow Remsen *et al.* (2016).

To assess habitat use by European Starlings we fitted a generalised linear mixed model (GLMM) (Bolker *et al.* 2009), including plot and vegetation type as random and fixed effects, respectively. Abundance data were zero-inflated relative to Poisson distribution, so we modelled habitat use with a zero-inflated Poisson GLMM and log-link function (Zuur *et al.* 2009). We also fitted GLMMs to examine relationships between community attributes (total bird abundance, species richness and diversity) and European Starling abundance, including time and plot as fixed and random effects, respectively. For abundance and species richness as response variables we used Poisson error structure and log-link functions; for diversity as a response variable we used Gaussian error structure and identity link function. Neither model nor residual plots showed overdispersion or clear patterns.

Overlap of vegetation-type usage between European Starlings and functionally similar native species was assessed using the Morisita niche overlap index (Morisita 1959):

$$M_{ab} = \frac{2\sum p_{ai}p_{bi}}{\sum p_{ai}\left(\frac{n_{ai}-1}{\sum n_{ai}-1}\right) + \sum p_{bi}\left(\frac{n_{bi}-1}{\sum n_{bi}-1}\right)},$$

where p_{ai} is the proportion of individuals of species *a* in habitat type *i*, p_{bi} is the proportion of individuals of species *b* in habitat type *i*, n_{ai} is the number of individuals of species *a* in habitat type *i*, and n_{bi} is the number of individuals of species *b* in habitat type *i*. The Morisita overlap index varies from 0 (no overlap) to 1 (total overlap). To test for significance in niche overlap values, we computed 95% confidence intervals with 999 bootstrap samples for each species pair (De Cáceres *et al.* 2011).

All analyses and graphs were run in R 3.2.1 (R Development Core Team 2015) using the packages vegan (Oksanen *et al.*

2015), glmmADMB (Skaug *et al.* 2014), lme4 (Bates *et al.* 2015) and spaa (Zhang 2013).

Results

In total, 84 species from 35 families were recorded (Table S1 in the online supplementary material). For these species, the most frequent food item was invertebrates (82.14%), followed by dry fruits (40.48%); ground and vegetation were the most common foraging substrates (71.43% and 30.95%, respectively), and the most common foraging methods were gleaning and probing (64.29% and 20.24%, respectively). According to the NMDS, European Starling (SVU) was functionally most similar to the native Chalk-browed Mockingbird (MSA) and Bay-winged Cowbird (ABA), and to the exotic House Sparrow (PDO) (Fig. 1). On the basis of the species by trait matrix (Table S1), these four species defined a functional group of terrestrial and foliage omnivores.

Habitat use analysis showed that European Starling abundance differed significantly between vegetation types (Table 1). European Starlings were more abundant in the *Solanum* grassland (1.458 ± 3.911 individuals ha^{-1}, $n = 24$) than in all other vegetation types. In addition, there were no differences in abundances between the *Cynodon* grassland (0.069 ± 0.340 individuals ha^{-1}, $n = 24$), flood plain (0.046 ± 0.278 individuals ha^{-1}, $n = 36$) and forest patches (0.069 ± 0.340 individuals ha^{-1}, $n = 24$) (Table 1). The mean relative density in the study area was 0.222 ± 1.155 individuals ha^{-1} ($n = 108$), whereas the
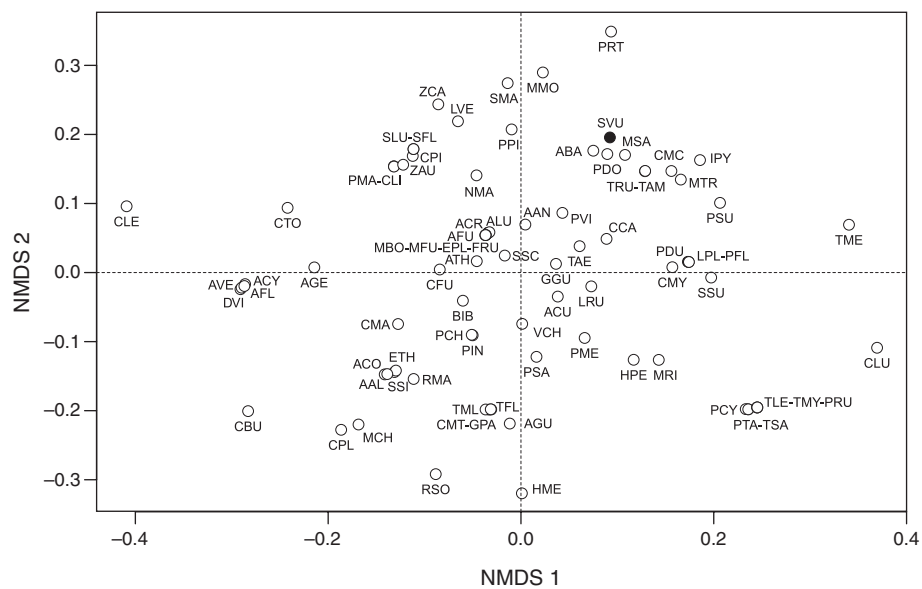

Fig. 1. Non-metric multidimensional scaling (NMDS) based on a species by traits matrix of 84 bird species in a bird community from north-east Buenos Aires province, Argentina. The black circle represents the position of European Starling (*Sturnus vulgaris*) (SVU) in ordination space. Species separated by hyphens had identical or almost identical values in ordination space. Species abbreviations: NM: *Nothura maculosa*, SSI: *Syrigma sibilatrix*, ETH: *Egretta thula*, ACO: *Ardea cocoi*, AAL: *Ardea alba*, BIB: *Bubulcus ibis*, PIN: *Phimosus infuscatus*, PCH: *Plegadis chihi*, CMA: *Ciconia maguari*, CTO: *Chauna torquata*, DVI: *Dendrocygna viduata*, CLE: *Callonetta leucophrys*, ACY: *Anas cyanoptera*, AVE: *Anas versicolor*, AFL: *Anas flavirostris*, AGE: *Anas georgica*, RSO: *Rostrhamus sociabilis*, CBU: *Circus buffoni*, RMA: *Rupornis magnirostris*, CPL: *Caracara plancus*, MCH: *Milvago chimango*, PSA: *Pardirallus sanguinolentus*, AGU: *Aramus guarauna*, HME: *Himantopus mexicanus*, VCH: *Vanellus chilensis*, GPA: *Gallinago paraguaiae*, TML: *Tringa melanoleuca*, TFL: *Tringa flavipes*, CMT: *Calidris melanotos*, CLI: *Columba livia*, PPI: *Patagioenas picazuro*, PMA: *Patagioenas maculosa*, ZAU: *Zenaida auriculata*, CPI: *Columbina picui*, LVE: *Leptotila verreauxi*, MMO: *Myiopsitta monachus*, GGU: *Guira guira*, CMY: *Coccyzus melacoryphus*, ACU: *Athene cunicularia*, CLU: *Chlorostilbon lucidus*, CMC: *Colaptes melanochloros*, CCA: *Colaptes campestris*, CFU: *Cinclodes fuscus*, FRU: *Furnarius rufus*, LPL: *Leptasthenura platensis*, PME: *Phleocryptes melanops*, AAN: *Anumbius annumbi*, SSU: *Serpophaga subcristata*, PFL: *Pseudocolopteryx flaviventris*, PRU: *Pyrocephalus rubinus*, LRU: *Lessonia rufa*, HPE: *Hymenops perspicillatus*, MRI: *Machetornis rixosa*, TME: *Tyrannus melancholicus*, TSA: *Tyrannus savana*, PSU: *Pitangus sulphuratus*, PRT: *Phytotoma rutila*, PCY: *Progne chalybea*, PTA: *Progne tapera*, TLE: *Tachycineta leucorrhoa*, TMY: *Tachycineta meyeni*, TAE: *Troglodytes aedon*, PDU: *Polioptila dumicola*, TRU: *Turdus rufiventris*, TAM: *Turdus amaurochalinus*, MSA: *Mimus saturninus*, MTR: *Mimus triurus*, AFU: *Anthus furcatus*, ACR: *Anthus correndera*, ALU: *Anthus lutescens*, SFL: *Sicalis flaveola*, SLU: *Sicalis luteola*, EPL: *Embernagra platensis*, ZCA: *Zonotrichia capensis*, IPY: *Icterus pyrrhopterus*, ATH: *Agelasticus thilius*, PVI: *Pseudoleistes virescens*, ABA: *Agelaioides badius*, MBO: *Molothrus bonariensis*, MFU: *Molothrus rufoaxillaris*, SSC: *Sturnella superciliaris*, SMA: *Spinus magellanicus*, PDO: *Passer domesticus*.

Bay-winged Cowbird and the Chalk-browed Mockingbird were relatively more abundant (0.380 ± 1.458 and 0.370 ± 0.804 individuals ha^{-1}, respectively). The House Sparrow, in contrast, was the least abundant (0.019 ± 0.135 individuals ha^{-1}). In addition, European Starling abundance was positively related to bird diversity and total bird abundance, but not to species richness (Table 2).

Vegetation-type overlap between the European Starling and functionally similar species was significantly different from zero for all species pairs (Table S2). Overlap was higher for House Sparrow and Chalk-browed Mockingbird, and lower for Bay-winged Cowbird. Several other species had higher vegetation-type overlap values, although these were functionally different from the European Starling, and thus would play different ecological roles in the community.

Discussion

Our study provides a first look at identifying native species functionally equivalent to European Starlings in Argentina, and, consequently, potentially subject to competition effects (Gitay *et al.* 1996). Similarities in ecological function and habitat use between the European Starling and native species indicate that these species may be considered functionally equivalent (Walker 1992; Gitay *et al.* 1996; Loiselle *et al.* 2007). The European Starling was functionally similar to two common generalist native species found in bird communities of Buenos Aires province (Montalti and Kopij 2001; Horlent *et al.* 2003; Maragliano *et al.* 2009; Palacio and Montalti 2013), and which, more importantly, are widely distributed in South America (Ridgely and Tudor 2009). To a lesser extent, we also found functional similarities with the non-native House Sparrow, a successful and widespread invasive bird in North, Central and South America (Sibley 2001). Both species share relevant ecological traits that promote invasion, such as aggressive competition with local species (Gowaty

1984; Koenig 2003), dietary generalisation (Feare 1984; Gavett and Wakeley 1986) and behavioural flexibility to expand its distribution range throughout human-altered landscapes (Clergeau and Quenot 2007; Kark *et al.* 2007).

Despite the potential for competition for resources, we failed to find evidence of negative impacts of European Starlings on the local avifauna, supporting previous studies (e.g. Ifran and Fiorini 2010; Ibañez 2015). Indeed, there are few examples of dominance over food sources by non-native species resulting in displacement of native species. In the only experimental study on food competition involving an exotic bird species, Peck *et al.* (2014) found that exposure to the invasive Rose-ringed Parakeet (*Psittacula krameri*) in the United Kingdom affected the foraging behaviour of native species by decreasing food consumption of local species. In a recent review, Martín-Albarracín *et al.* (2015) found that competition for resources between native and non-native birds is a widespread phenomenon, even though it may not seriously threaten local bird communities (but see Freed *et al.* 2008; Freed and Cann 2009). However, the changes in foraging behaviour in response to an invasive species may represent an overlooked mechanism for displacement (Peck *et al.* 2014) and therefore needs further research.

European Starlings were more abundant in the *Solanum* grassland compared with other vegetation types (i.e. flood plain, *Cynodon* grassland and forest patches). European Starlings are essentially grassland feeders and prefer open areas that provide good all-round visibility (Feare 1984). Starling abundance in the *Cynodon* grassland was lower, possibly because of differences in soil moisture. The *Solanum* grassland had a wet soil compared with that of the *Cynodon* grassland, which would facilitate gaping and probing behaviour to find soil invertebrates (Devereux *et al.* 2004). Moreover, invertebrate density tends to be higher in damp (but not flooded) habitats (Milsom *et al.* 2002). In the only study that has quantified population density of European Starlings in Argentina, Ifran and Fiorini (2010) estimated that relative density was 2.21 individuals ha^{-1} in urban parks of Buenos Aires city, a value much higher than our estimated maximum value of 1.46 individuals ha^{-1} in the *Solanum* grassland. It is known that urban bird communities tend to include fewer species and greater abundances than those from natural habitats (Gavareski 1976; Beissinger and Osborne 1982; Ortega-Álvarez and MacGregor-Fors 2009). Combined with the fact that Buenos Aires represents the main focus of invasion (Peris *et al.* 2005) and had more time to increase its population levels, it is expected that European Starling densities will be higher than in non-urban areas.

European Starling abundance was also positively related to both total bird abundance and diversity. This suggests that

Table 1.   Habitat use in European Starling

Results of the zero-inflated Poisson generalised linear mixed model between European Starling (*Sturnus vulgaris*) abundance and vegetation type in a bird community from north-east Buenos Aires province, Argentina. Plot was included as a random effect. b, parameter estimate; s.e., standard error

Parameter	b	s.e.	P
Intercept (*Solanum* grassland)	1.732	0.339	<0.0001
Cynodon grassland	−3.236	1.245	0.009
Flood plain	−3.672	1.214	0.002
Forest patch	−3.275	1.242	0.008

Table 2.   Relationships between European Starling abundance and community attributes

Results of the generalised linear mixed models between community attributes (abundance, species richness and diversity) and European Starling (*Sturnus vulgaris*) abundance in a bird community from north-east Buenos Aires province, Argentina. Plot was included as a random effect. ESA, European Starling abundance; b, parameter estimate, s.e., standard error

Parameter	Total bird abundance			Species richness			Simpson inverse index		
	b	s.e.	P	b	s.e.	P	b	s.e.	P
Intercept	3.150	0.103	<0.0001	2.063	0.103	<0.0001	5.279	0.509	<0.0001
Time	0.001	0.0002	<0.0001	0.0005	0.0003	0.085	0.0004	0.002	0.790
ESA	0.048	0.013	<0.001	0.046	0.024	0.056	0.384	0.169	0.023

community abundance and diversity patterns may be partially influenced (positively or negatively) by European Starling abundance. If European Starling abundance does not influence abundance and diversity patterns, it could potentially influence community attributes in the future. One possible explanation for the patterns observed is that areas with favourable conditions for high productivity (abundance and diversity) can also support more invasive species (Stachowicz and Byrnes 2006). In addition, increasing abundance and diversity might increase the probability of including species that facilitate the colonisation and establishment of new species (Stachowicz and Byrnes 2006). European Starlings frequently forage in association with several common native species, including the Rufous Hornero (*Furnarius rufus*), the Eared Dove (*Zenaida auriculata*), the Shiny Cowbird (*Molothrus bonariensis*), the Bay-winged Cowbird and the Chalk-browed Mockingbird (Vega 2004; Ifran and Fiorini 2010; Ibañez 2015). This behaviour of foraging in mixed-species flocks has frequently been documented in other invaded communities (Williamson and Gray 1975; Feare 1984; Fischl and Caccamise 1985; Beveridge and Deag 1987; Mazzulla 2013), and it may be viewed as facilitating rather than competition foraging by providing safety to forage more openly (Feare 1984).

Our results contrast with those of Ifran and Fiorini (2010), who found no relationship between European Starling abundance and bird diversity in urban parks of Buenos Aires city. Compared with little-disturbed or non-disturbed landscapes, urban areas lead to biotic homogenisation (i.e. decrease in diversity in a community) (Olden and Rooney 2006; Devictor *et al.* 2008), so the relationship between diversity and European Starling abundance in urban landscapes may be absent or of low intensity. This evidence may indicate that different ecological processes may be occurring in different bird communities where the European Starling is present, a hypothesis that deserves further research.

Overall, our study identifies native species functionally similar to the European Starling. In this sense, the analysis of ecological traits of both invasive and native species could provide insight into how (in ecological terms) an exotic species can be added to a novel community. Finally, this approach can be an important tool to identify further equivalent species, allowing conservation efforts to be focussed on native species that may be impacted ecologically.

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