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Effects of *Acacia melanoxylon* R. Br. removal on bird assemblages in the Tandilia Mountain System, Argentina

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Abstract: The grasslands in the Argentinian Pampas region have been largely transformed into croplands and pastures, leaving the native grasslands fragmented into isolated patches in areas unsuitable for farming. In the Tandilia Mountain System, these remnants face threats from invasive species, particularly tree species such as *Acacia melanoxylon*, which alter habitat structure, biodiversity, and ecosystem functioning. This study evaluates bird assemblages at different areas of grassland during the stages of natural restoration following *Acacia* removal within a Private Natural Reserve. Four areas were surveyed: a control site dominated by *Acacia* (AC) and three restored areas representing increasing restoration stages—a three-year restored area (R3), a recently restored (CR), and a recently restored with resprouting (PR). Vegetation composition and bird richness, abundance, and assemblages were assessed using vegetation cover sampling and bird point counts. Grassland specialist species showed significantly higher richness and abundance in restored areas compared to AC. The R3 area harbored the greatest number of species, including Bearded tachuri (*Polystictus pectoralis*), a near-threatened species. Bird assemblages differed among areas, with generalist species dominating AC and grassland specialists characterizing restored areas. Although these results are subject to limitations associated with working in a small private reserve, they nonetheless offer meaningful evidence of the positive effects of invasive tree removal on grassland bird assemblages.

Keywords: Biological invasions, biodiversity, Buenos Aires, conservation, *Racosperma melanoxylon*.

Efecto de la remoción de *Acacia melanoxylon* r. br. sobre el ensamble de aves en el sistema serrano de tandilia, argentina.

Resumen: Los pastizales de la región pampeana de Argentina han sido ampliamente transformados por el avance de los campos agrícolas-ganaderos, lo que ha dejado a los pastizales nativos fragmentados en parches aislados en zonas no aptas para la agricultura. En el Sistema Serrano de Tandilia, estos remanentes enfrentan amenazas por parte de especies invasoras, en particular árboles como *Acacia melanoxylon*, que alteran la estructura del hábitat, la biodiversidad y el funcionamiento del ecosistema. Este estudio evalúa el ensamble de aves a lo largo de distintas etapas de restauración natural de pastizales luego de la remoción de *Acacia* en una Reserva Natural Privada. Se relevaron cuatro áreas: un sitio control dominado por Acacia (AC) y tres áreas restauradas: un área restaurada hace tres años (R3), un área recientemente restaurada (CR) y un área parcialmente restaurada con rebrote (PR). Se evaluó la composición y cobertura vegetal mediante la observación de imágenes satelitales y la riqueza, abundancia y composición de las aves mediante conteos de puntos de aves. La riqueza y abundancia de aves fueron significativamente mayores para las especies especialistas de pastizal en las áreas naturalmente restauradas en comparación con AC. La zona R3 presentó la mayor riqueza de especies, incluyendo al Tachurí canela (*Polystictus pectoralis*), especie catalogada como cercana a la amenaza. El ensamble de aves difirió entre zonas, con especies generalistas dominando en AC y especialistas de pastizal caracterizando las áreas naturalmente restauradas. A pesar de las limitaciones del presente estudio asociadas al trabajo en una reserva privada pequeña, estos resultados brindan evidencia valiosa sobre los efectos positivos de la remoción de especies arbóreas invasoras en las comunidades de aves de pastizal.

Palabras clave: Invasiones biológicas, biodiversidad, Buenos Aires, conservación, *Racosperma melanoxylon*.

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INTRODUCTION

The grasslands of the Pampas region have been largely replaced by croplands and pasturelands, profoundly modifying their associated biodiversity (Azpiroz *et al.*, 2012). The last remnants of native grasslands are represented by isolated patches in areas with soils unsuitable for agriculture, such as rocky, saline, and flooded soils (León *et al.,* 1984; Herrera *et al.,* 2017). However, these patches of grasslands face the advance of invasive species, which modify their physiognomy and associated biodiversity (Echeverría *et al.,* 20.11023). Particularly, invasions of tree species on natural grasslands completely change the physiognomy, affecting biodiversity and ecosystem functioning (Zalba & Villamil, 2002; Bremer & Farley, 2010; Yansen & Biganzoli, 2022). Consequently, the possibility of preserving the last remnants of native grasslands requires management efforts aimed at their restoration (Cuevas & Zalba, 2010).

Considering the level of transformation of natural environments and the need for these spaces to be adequately preserved, it is necessary to undertake sustained programs of restoration and control of invasive species (Zalba & Ziller, 2007). These programs need to consider the successional mechanisms following the removal of invasive species to ensure the recovery of native populations and ecosystem processes. There are cases where native populations are resilient to invaders and the removal process allows them to recover, but this does not always occur (Prior *et al.*, 2018).

Birds are particularly affected by plant invasions. These invasions alter habitat structure and may consequently modify foraging behavior and the availability of nesting sites and refuge (Nelson *et al.*, 2017). Invasive plants can impact the abundance and richness of some bird species, with variations observed between different guilds (Mangachena & Geerts, 2017; Grzędzicka & Reif, 2020). Grassland birds face significant threats, one of which is the invasion of alien species in some regions of South America. Conservation efforts for these birds include the establishment of reserves and the development of action plans (Azpiroz *et al.*, 2012).

The Tandilia Mountain System in the southern Pampas region of Argentina features native grasslands and shrublands that persist on rocky soils, which pose challenges for agricultural development (Herrera & Laterra, 2011). These grassland patches represent biodiversity hotspots for endemic species in the region (Kristensen *et al.*, 2014). However, the native grasslands and shrublands of Tandilia are increasingly being altered by the spread of invasive species, specifically *Acacia melanoxylon* R. Br. (Zaninovich *et al*., 2023). These rocky environments in the Pampas region are usually private, making their restoration the responsibility of the owners but restoring environments invaded by alien plants is often overly expensive (Larson *et al*., 2011) and require more than one actor to be fully developed. Therefore, creative strategies must be devised to encourage the control of invasive species in the absence of economic incentives from the government.

On a private ranch, which includes a Private Reserve in the Tandilia System, a control scheme removing the invasive *Acacia* has been implemented by using its wood for firewood and boards, and allowing land to recover as a natural grassland for livestock grazing (Zaninovich *et al.*, 2023). In addition, previous studies in this place observed that the areas invaded by *Acacia* in the hills maintain a seed bank of native grassland, and shrub species that resemble areas with native vegetation (Vignolio *et al.*, 2021). However, no studies in the region have evaluated the effect of these invasive plants on avifauna, nor have they assessed the effects of different management efforts. In this context, we developed a sampling design to evaluate the bird response to *Acacia* invasion and to different stages of *Acacia* control management. We aim to assess habitat use by birds related to different *Acacia* removal times. Our main focus is on the response of grassland specialist birds, which are the target species in these conservation reserves and potentially the most vulnerable species to the *Acacia* invasion.

MATERIALS AND METHODS

Study area

The study area is located in the Tandilia Mountain Range System in the southern Pampas region of Argentina. These ancient mountains from the Paleozoic form an arc of discontinuous elevation of approximately 1,400,000 ha (Herrera *et al.*, 2017). The maximum height of the mountains is estimated to be between 400 and 500 meters above sea level (Martínez, 2011). Vegetation is characterized by two types of grasslands, some dominated by genera such as *Nassella* E. Desv., *Piptochaetium* J. Presl, *Aristida* L.; and others consisting of tall grasses mostly of the species *Paspalum quadrifarium* Lam. There are also important shrubland areas of species like *Baccharis dracunculifolia* DC. and *Colletia paradoxa* (Spreng.) Escal. (Arana *et al.*, 2021). While the mountains are considered a non-cultivable environment, the surrounding matrix is dominated by agricultural fields cultivated with annual crops such as soybeans, sunflowers, wheat, and corn (Herrera *et al.*, 2017). Specifically, the study was carried out in the Paititi Private Natural Reserve (37°54' S, 57°49' W), which is considered a Valuable Grassland Area (Bilenca & Miñarro, 2004), being part of the "Alianza del pastizal" and registered in the Argentine Network of Private Natural Reserves (RARNAP, 2016). The reserve is divided into two principal areas named "Sierra Chica" and "Sierra Grande" (Fig. 1).

Different invasive species in the Paititi Private Natural Reserve have been recognized, being *A. melanoxylon* one of the most worrying conservation problems in the area (Echeverría *et al.*, 2023). For this species, there is a management plan consisting of initial stages to identify impacts and carry out biodiversity surveys, while the final stages focus on removing the trees, using the wood for sale, and monitoring the efficacy of these control methods (see Zaninovich *et al.*, 2023).

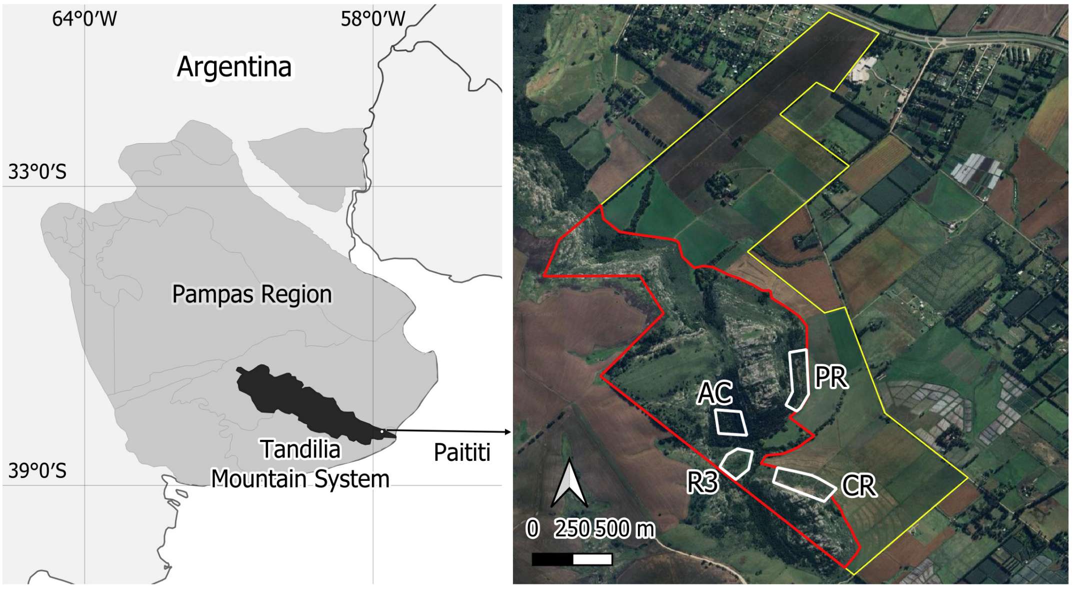

Fig. 1. Map of the study area and treatment sites within the Paititi Private Natural Reserve (red polygon), located in the Tandilia Mountain System, Pampas region, Argentina. The yellow polygon indicates the extent of the Paititi Ranch.

Acacia management and sampling design

The estimated area invaded by *Acacia* in 2020 was 20% of the reserve (Zaninovich *et al.*, 2023). In consequence, a control program has been in place to halt the dispersal of this invasive species, which consists mainly of felling small trees and then brushing the stump with the product Tocon® Extra, with native grassland restoration occurring through natural regeneration after the removal of *Acacia melanoxylon*. In this way, as different areas of the reserve were managed at different times, four treatments were chosen for comparison in the present study: 1) "AC" – unmanaged area dominated by *A. melanoxylon*; 2) "PR" – partial removal in Sierra Grande, where incomplete removal of *A. melanoxylon* had been carried out five months before the first sampling date, leading to subsequent regrowth of these trees; 3) "CR" – complete removal in Sierra Chica, where *A. melanoxylon* had been entirely removed five months before the first sampling date; and 4) "R3" – area with complete removal performed three years before the first sampling date (see Fig. 1). Unfortunately, we do not have control sites with well-preserved natural grasslands. However, the existence of a gradient in grassland regeneration time after *Acacia* removal, together with access to previous census data from natural mountain grasslands, allows us to make a relatively accurate assessment of the effects of *Acacia* and its management on grassland birds. Our study was developed in a relatively small, protected area (220 ha) with a patchy distributed habitat surrounded by an agriculture dominated landscape matrix. We are aware that our results may present biases associated with the edge effect and landscape contexts, but these are limitations common to many reserves, considering that one of the problems of protected areas at a global level is that they are mostly small (Schauman *et al.*, 2023).

Vegetation and bird surveys

In order to understand the different management effects on biodiversity we performed vegetation and bird surveys between March 2022 and December 2022. To characterize the vegetation of the four different areas surveyed in this study, we took four random points within each area and first recognized the dominant vegetation on the ground, which corresponded to grasses (native grasslands dominated by *Paspalum quadrifarium*) and shrubs (native shrublands dominated by *Baccharis dracunculifolia*). It is important to highlight that due to the small size of the reserve, and consequently also the areas, we were unable to choose more survey points. Subsequently, we used Google™ Earth at each point within the different areas, we delineated circles with a 30 m radius and visually estimated the coverage percentage of the dominant vegetation types (grassland, shrubs, *Celtis tala* Gillies ex Planch. trees, and *A. melanoxylon* trees) as well as bare soil, which is mostly a result of the removal of the *A. melanoxylon* trees (see Table 1). *C. tala* is a native tree, which is advancing on the grassland as a result of anthropogenic disturbances, such as fire and grazing.

Bird censuses (point counts; following Bibby *et al.*, 1998) of five minutes each in a 30 m radius were conducted during the morning. Surveys were carried out at the same four random points within each of the areas previously mentioned, maintaining a minimum distance of 100 m between points. At each point, bird species and their abundance were recorded. We conducted three censuses at each point on different days during each season (autumn, winter, spring, and summer) to better characterize the birds using each area. However, to strengthen the statistical analyses, and because our focus was not on seasonal differences, we pooled all data across seasons for the analyses. This approach also allowed us to increase sample size, since we only had one year of sampling and thus no seasonal replication. Also, we classified bird species according to habitat preference as habitat generalist or grassland specialist based on: Codesido *et al*. (2011), Comparatore *et al*. (1996), Isacch & Cardoni (2011), Pretelli *et al*. (2018), Román *et al*. (2025).

Statistical analysis

To compare bird assemblages (response variable) between areas (explicative variable), multivariate analyses using a PERMANOVA analysis based on Bray-Curtis distances and 9999 permutations were conducted. All variables included in the analysis met the assumption of homogeneity of variances. Subsequently, to visualize the composition of bird assemblages, a non-metric multidimensional scaling (nMDS) on three axes, based on Bray-Curtis distances and a minimum of 20 and a maximum of 100 random starts (Palacio *et al.*, 2020) was performed. To identify which bird species were indicators of each area, the indicator value method (IndVal) (Dufrene & Legendre, 1997) was used, calculated with the R package *indicspecies* (De Cáceres & Legendre, 2009). This method assesses species association with a given site based on specificity (the proportion of occurrences restricted to that site) and fidelity (the frequency of occurrence in that site). A high indicator value (specificity × fidelity) suggests that a species is characteristic of a particular site (Dufrene & Legendre, 1997). The significance of this indicator value was assessed through a permutation test (De Cáceres & Legendre, 2009).

Using the collected data, we calculated bird abundance and richness as the mean across the three count points within each area over the entire study period, without distinguishing between seasons, resulting in a total of 12 replicates per area. Using this information, Generalized Linear Mixed-effects Models (GLMM) with negative binomial structure and log link function to compare the abundance and richness of birds between areas were calculated using the R package *lme4* (Bates *et al.*, 2015). The identity of the count point and the sampling date were included as random effects in the model. We employed a backward selection procedure removing non-significant terms from the model, one by one, in decreasing levels of interactions and decreasing order of p-values within the same level (Burnham & Anderson, 2002). Graphical visualizations using *ggplot2* package (Wickham, 2016) were done. Data management and statistical analyses were carried out using R software, version 4.3.3 (R Core Team, 2024).

RESULTS

Vegetation

The greatest grassland cover was found in R3. Both CR and PR also showed extensive grassland cover, along with a considerable amount of bare soil resulting from *Acacia* clearing. It is important to note that in CR we found small, resprouting *Acacia* trees, whereas this did not occur in PR. Finally, AC was characterized by the dominance of *A. melanoxylon* (Table 1).

Table 1. Coverage percentage (mean ± standard deviation) of the dominant vegetation types (grassland, shrubs, *Tala* and *Acacia* trees) and bare soil for each surveyed area in the Paititi Private Natural Reserve, Buenos Aires province, Argentina.

Area	Grassland	Shrubland	Acacia trees	Tala trees	Bare soil
R3	65.00 ± 13.54	28.75 ± 13.15	2.50 ± 5.00	3.75 ± 2.50	0.00 ± 0.00
CR	32.50 ± 11.90	46.25 ± 7.50	0.00 ± 0.00	0.00 ± 0.00	21.25 ± 4.79
PR	33.75 ± 17.50	32.50 ± 19.36	6.25 ± 2.50	8.75 ± 2.50	18.75 ± 8.54
AC	15.00 ± 16.83	0.00 ± 0.00	83.75 ± 16.01	0.00 ± 0.00	0.00 ± 0.00

Bird richness and abundance

The greatest number of specialist grassland species (82%) was recorded in the area with complete removal of *Acacia* (CR). A large number of species was recorded in the area with complete removal performed three years before the first sampling date (R3) with high numbers of generalist and specialist species (Table 2). The only species with a global conservation concern (Bearded Tachuri *Polystictus pectoralis*, NT) was recorded in R3.

There were no significant differences in habitat generalist bird species in their abundance (Table 3; AC = 8.93 ± 4.77, R3 = 11.79 ± 6.65, CR = 7.43 ± 2.83, PR = 7.52 ± 5.26, Fig. 2A), but there were differences in grassland specialist bird species among areas (Table 3), since we found the higher values for R3, CR, and PR compared to AC (GLMM: $\beta = 2.62 \pm 0.80$, $z = 3.29$, $p = 0.005$; $\beta = 2.31 \pm 0.81$, $z = 2.87$, $p = 0.020$; $\beta = 2.52 \pm 0.80$, $z = 3.14$, $p = 0.008$ respectively; AC = 0.16 ± 0.53, R3 = 2.52 ± 2.59, CR = 1.92 ± 1.75, PR = 2.38 ± 1.91, Fig. 2A). There were no significant differences in the species richness of habitat generalist bird species among areas (Table 3, AC = 9.45 ± 3.36, R3 = 11.67 ± 2.61, CR = 10.00 ± 3.16, PR = 8.00 ± 2.56, Fig. 2B), although there were differences in grassland specialist bird species richness (Table 3) with higher values in R3, CR and PR, in comparison with AC (GLMM: $\beta = 3.05 \pm 0.94$, $z = 3.23$, $p = 0.006$; $\beta = 3.28 \pm 0.94$, $z = 3.49$, $p = 0.002$; $\beta = 3.09 \pm 0.94$, $z= 3.29$, $p = 0.005$ respectively; AC = 0.90 ± 0.30, R3 = 1.92 ± 1.08, CR = 2.42 ± 1.24, PR = 2.00 ± 0.95, Fig. 2B).

Bird assemblage

Bird assemblage differed among areas (PERMANOVA: df = 3, $F = 5.95$, $p < 0.001$). All areas were different from AC ($p < 0.01$; Fig. 3A and 3B). Also, we found differences between both CR and PR with R3 ($p < 0.05$; Fig. 3B), whereas there were no differences between CR and PR ($p = 0.31$; Fig. 3A and 3B).

The indicator species for AC were Picazuro Pigeon (*Patagioenas picazuro*), Rufous-bellied Thrush (*Turdus rufiventris*), Tropical Parula (*Setophaga pitiayumi*), White-throated Hummingbird (*Leucochloris albicollis*), Small-billed Elaenia (*Elaenia parvirostris*) and Creamy-bellied Thrush (*Turdus amaurochalinus*). For R3 we found Hooded Siskin (*Spinus magellanicus*) and Black-and-rufous Warbling Finch (*Poospiza nigrorufa*) as indicators. The indicator species for the group AC + R3 was Harris's Hawk (*Parabuteo unicinctus*). For the group R3+CR the indicator species were Freckle-breasted Thornbird (*Phacellodomus striaticollis*) and Chalk-browed Mockingbird (*Mimus saturninus*), and for the group R3+CR+PR indicators were Great Pampa-Finch (*Embernagra platensis*), Rufous-collared Sparrow (*Zonotrichia capensis*) and Shiny Cowbird (*Molothrus bonariensis*). There were no indicator species for CR and PR (Table 4).

Table 2. Abundance (Ab), relative frequency occurrence percentage (RF), habitat and threatened status (TS) for each species recorded in the surveyed areas (AC, R3, CR, PR) in Paititi Private Natural Reserve, Buenos Aires province, Argentina. Scientific names follow the South American Classification Committee of the American Ornithological Society. The classification of birds as habitat generalists or grassland specialists is based on Codesido et al. (2011), Comparatore *et al*. (1996), Isacch & Cardoni (2011), Pretelli *et al*. (2018), Román *et al*. (2025).

Habitat	Species	Ab	RF (%)	TS	AC	R3	CR	PR
Grassland specialist	*Anthus* sp.	2	2.13	-			x	
	Circus buffoni	1	2.13	LC			x	
	Donacospiza albifrons	14	6.38	LC		x	x	x
	Embernagra platensis	146	70.21	-		x	x	x
	Hymenops perspicillatus	2	4.26	LC		x	x	
	Leistes loyca	7	6.38	LC			x	
	Nothura maculosa	3	4.26	LC			x	
	Polystictus pectoralis	1	2.13	NT		x		
	Rhynchotus rufescens	6	10.64	LC		x	x	x
	Sicalis luteola	102	23.40	LC		x	x	x
	Sporophila caerulescens	191	31.91	LC	x	x	x	x
Habitat generalist	*Agelaioides badius*	46	19.15	LC	x	x	x	x
	Anumbius annumbi	3	4.26	LC			x	
	Carduelis carduelis	4	2.13	-		x		
	Chlorostilbon lucidus	17	6.38	LC		x	x	x
	Colaptes campestris	3	4.26	-			x	x
	Colaptes melanochloros	11	12.77	-	x		x	x
	Columbina picui	8	2.13	LC				x
	Elaenia parvirostris	19	8.51	LC	x	x		
	Falco sparverius	1	2.13	LC			x	
	Furnarius rufus	125	63.83	LC	x	x	x	x
	Hirundo rustica	2	2.13	LC		x		
	Icterus pyrrhopterus	2	4.26	LC		x	x	
	Leptotila verreauxi	8	4.26	LC	x			
	Leucochloris albicollis	8	8.51	LC	x			
	Milvago chimango	4	6.38	LC	x	x		x
	Mimus saturninus	31	17.02	LC		x	x	
	Molothrus bonariensis	64	31.91	LC		x	x	x
	Molothrus rufoaxillaris	10	2.13	LC			x	
	Myiophobus fasciatus	3	4.26	LC		x	x	
	Parabuteo unicinctus	8	17.02	LC	x	x		
	Passer domesticus	1	2.13	LC		x		

	Patagioenas maculosa	7	6.38	-	x		x	
	Patagioenas picazuro	129	40.43	LC	x	x	x	x
	Phacellodomus striaticollis	74	46.81	LC		x	x	x
	Pitangus sulphuratus	55	42.55	LC	x	x	x	x
	Polioptila dumicola	1	2.13	LC	x			
	Poospiza nigrorufa	28	21.28	LC		x	x	x
	Rauenia bonariensis	2	4.26	-		x		
	Rupornis magnirostris	4	2.13	LC				x
	Serpophaga subcristata	80	46.81	-	x	x	x	x
	Setophaga pitiayumi	13	10.64	-	x			
	Sicalis flaveola	33	27.66	LC	x	x		x
	Spinus magellanicus	175	25.53	LC	x	x		x
	Troglodytes musculus	240	93.62	-	x	x	x	x
	Turdus amaurochalinus	6	8.51	LC	x	x		
	Turdus rufiventris	97	44.68	LC	x	x	x	x
	Tyrannus melancholicus	21	17.02	LC	x	x	x	x
	Tyrannus savana	2	2.13	LC		x		
	Zenaida auriculata	94	57.45	LC	x	x	x	x
	Zonotrichia capensis	491	89.36	LC	x	x	x	x

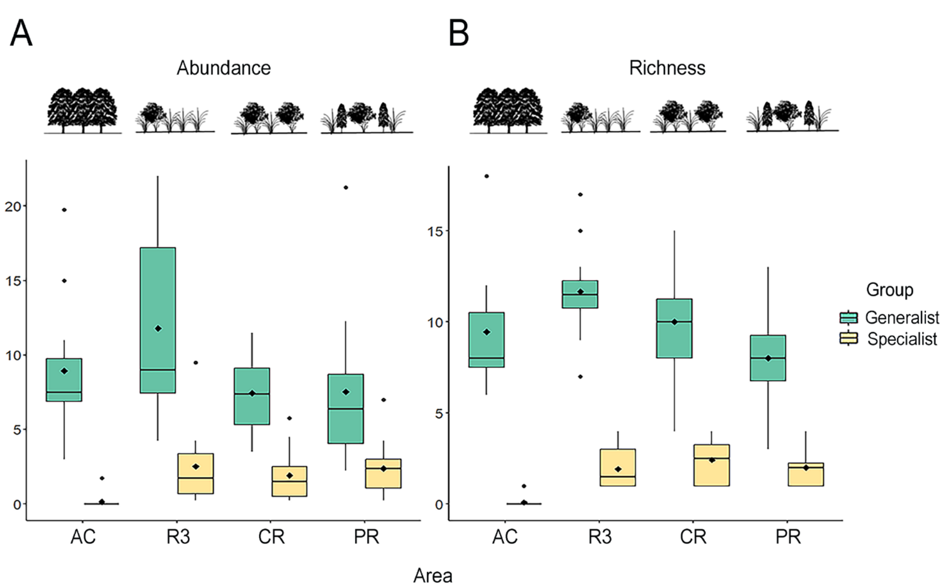

Fig. 2. Box plot showing the abundance **A** and richness **B** of habitat generalist birds (green) and specialist birds (yellow) across different areas (AC: unmanaged area dominated by *A. melanoxylon*, R3: three years removal area, CR: five months complete removal area, PR: five months partial removal area). Black diamonds indicate the mean.

Table 3. Bird species richness and abundance (response variable) as a function of different *Acacia* invasion stages (explicative variable) in the Paititi Private Natural Reserve in the Pampas region, Buenos Aires province, Argentina.

Response variable	Explicative variable	Final model		Statistics at elimination	
		X^2	p	X^2	p
Habitat generalists richness	Area			6.80	0.08
Grassland specialists richness	Area	15.50	0.001		
Habitat generalists abundance	Area			6.15	0.10
Grassland specialists abundance	Area	11.44	0.009		

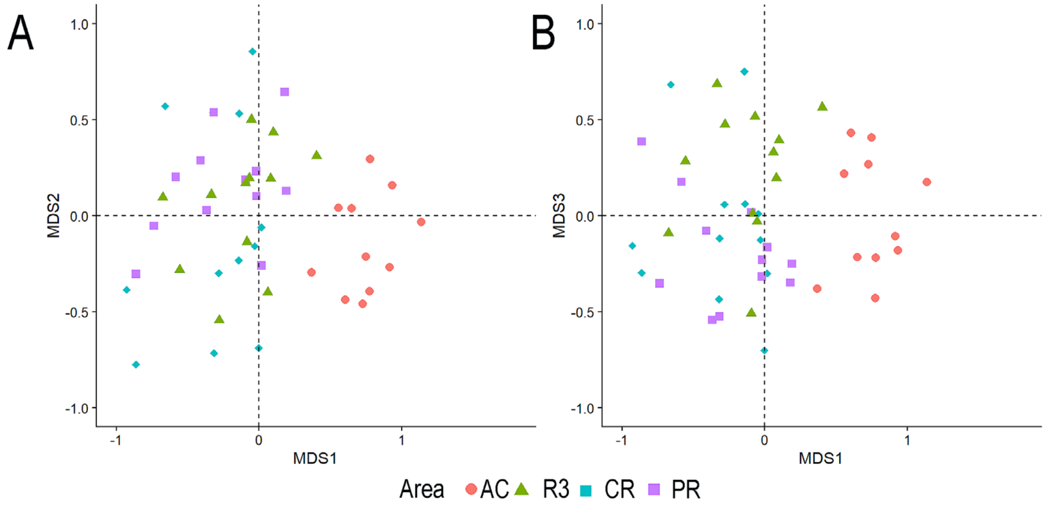

Fig. 3. Non-metric multidimensional scaling (nMDS; stress = 0.17) representing the composition of bird assemblages across the different areas. The nMDS ordination illustrates the similarity or dissimilarity of assemblages based on species composition, where closer points indicate more similar assemblages. Here, we present MDS1 vs. MDS2 (**A**) and MDS1 vs. MDS3 (**B**).

DISCUSSION

The Tandilia Mountain System represents a significant refuge for native biodiversity in the Pampas region (Echeverría *et al.*, 2017; Vera *et al.*, 2021; Aranguren *et al.*, 2023; O'Connor *et al.*, 2024; Sottile *et al.*, 2024; Wraage *et al.*, 2025) considering the high level of transformation in much of the region (Herrera *et al.*, 2017). Although bird diversity in the Pampas region has been relatively well studied, bird diversity in the Tandilia Mountains System has been poorly studied (Isacch *et al.*, 2016).

Invasive species are one of the most important threats for grassland ecosystems (Bardgett *et al.*, 2021). In particular, the Tandilia Mountain System presents a great invasion of *A. melanoxylon* that is threatening the native grassland remnants patches in the region. Previous studies have shown the recovery of native vegetation after the removal of this invasive tree through different chemical treatments (Rojas *et al.*, 2025). In the present study we evaluated the bird response in a control area dominated by *A. melanoxylon* compared to three recovered areas at different stages of restoration. However, it is important to note some limitations of our design, such as the absence of a native grassland control and the relatively small number and close proximity of bird survey points, which may influence the interpretation of our results. Despite these constraints, this work provides valuable insights into natural restoration dynamics and bird responses in small private reserves, a

Table 4. Specificity, fidelity, and indicator value (i.e., specificity*fidelity) of species recorded in the surveyed areas in Paititi Private Natural Reserve, Buenos Aires province, Argentina.

Area	Species	Specificity	Fidelity	Indicator value
AC	*Patagioenas picazuro*	0.87	1	0.93
	Turdus rufiventris	0.90	0.91	0.85
	Setophaga pitiayumi	1	0.45	0.67
	Leucochloris albicollis	1	0.36	0.60
	Elaenia parvirostris	0.88	0.27	0.49
	Turdus amaurochalinus	0.77	0.27	0.46
R3	*Spinus magellanicus*	0.84	0.67	0.75
	Poospiza nigrorufa	0.86	0.58	0.71
CR	-	-	-	-
PR	-	-	-	-
AC+R3	*Parabuteo unicinctus*	1	0.35	0.59
AC+CR	-	-	-	-
AC+PR	-	-	-	-
R3+CR	*Phacellodomus striaticollis*	0.87	0.75	0.81
	Mimus saturninus	1	0.33	0.58
R3+PR	-	-	-	-
CR+PR	-	-	-	-
R3+CR+PR	*Embernagra platensis*	1	0.92	0.96
	Molothrus bonariensis	1	0.42	0.65
	Zonotrichia capensis	0.93	1	0.97

type of protected area increasingly relevant yet understudied in the region, which, given the scarcity of large natural protected areas, often represents the most effective strategy for bird conservation, as has been shown in North America (Pavlacky *et al.*, 2021).

More than the 50% bird species recorded were not observed in the control sites (AC). Although we did not find differences in richness and abundance of habitat generalist bird species among areas, higher levels of richness and abundance of grassland specialist bird species were noted in all areas compared to the control site. Grassland bird species are highly sensitive to habitat loss (Correll *et al.*, 2019), and in this sense, previous studies in the Northern Hemisphere have also shown that grassland bird populations are negatively affected by the degradation of native grasslands caused by introduced plant species (Greer *et al.*, 2016). Also, supporting our results, other studies have shown how the recovery of native grasslands benefit the abundance and richness of birds, including some species of conservation importance (Roberts *et al.*, 2022; Lengyel *et al.*, 2023). Also, despite the absence of native grassland control sites in the present study, it is noteworthy that we recorded in the restored areas almost all of the specialist species previously reported for the reserve's native grasslands (Román *et al.*, 2025), with the exception of White-browed Meadowlark (*Leistes superciliaris*), Brown-and-yellow marshbird (*Pseudoleistes virescens*), and Grass Wren (*Cistothorus platensis*).

The management strategies carried out by the Paititi Natural Reserve owner present a unique opportunity to evaluate how bird assemblages vary across different stages of habitat restoration. In this study we found differences between the control site (AC) and the other areas (R3, CR, and PR). At AC, we identified as indicators generalist species such as Picazuro Pigeon and Rufous-bellied Thrush, which are common across a wide variety of habitats, including urban and suburban areas near the study site (Leveau & Leveau, 2004), and also other habitat generalists like Tropical Parula, White-throated Hummingbird and Small-billed Elaenia. In this regard, previous studies mention how landscape transformation due to the spread of invasive trees may benefit the expansion of generalist species populations, such as White-throated Hummingbird (Zalba, 2000). Meanwhile in R3+CR+PR a grassland specialist species, such as Great Pampa-Finch, was found as an indicator species. This species is one of the most abundant birds associated with *Paspalum quadrifarium* grasslands in the region (Isacch & Martinez, 2001), suggesting that it may be among the first grassland specialist to appear in the recovery areas and could serve as an indicator of successful habitat restoration. We also observed differences between R3 and CR+PR, highlighting the importance of maintaining control measures over time. Notably, Bearded Tachuri which is recognized as a species of national conservation priority in many countries within its distribution range (Fitzpatrick *et al.*, 2020), was recorded in R3. Additionally, Trofino Falasco *et al.* (2022) found that the breeding biology of this species is closely tied to tall native grasslands, making it vulnerable to changes in grassland vegetation structure. Finally, there were no significant differences between CR and PR indicating that probably the initial sprout of *A. melanoxylon* in PR, is not a problem in the early stages of management strategies as long as the percentage of grassland cover is not affected. However, these differences could evolve into a problem in the future if it is not properly managed.

This is the first study that assesses bird assemblages among different stages after removal of an invasive tree in the Tandilia System of Buenos Aires province, Argentina. The results of this study underscore the importance of preserving and recovering native grassland patches in the Tandilia Mountain System for the native avifauna. The significant presence of grassland specialist species in natural recovered areas highlights the effectiveness of restoration efforts through the removal of invasive *A. melanoxylon*. However, our findings also stress the need for continued monitoring and maintenance of control measures, as early-stage regeneration of invasive species could pose long-term threats if not managed properly. Thus, active and sustained management is essential for the successful natural restoration of grassland ecosystems and the conservation of sensitive bird species in the region.

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REFERENCES

Arana, M. D., Natale, E. S., Ferretti, N. E., Romano, G. M., Oggero, A. J., Martínez, G., Posadas, P. E., & Morrone, J. J. (2021). Esquema biogeográfico de la República Argentina. Fundación Miguel Lillo.

Aranguren, M. F., Velasco, M. A., Trofino-Falasco, C., Pizzarello, M. G., Vera, D.G., & Berkunsky, I. (2023). Mammals of the Tandilia Mountain system, current species inhabiting Pampean highland grasslands. *Neotropical Biology and Conservation*, *18*(1), 13-29. https://doi.org/10.3897/neotropical.18.e98374

Azpiroz, A. B., Isacch, J. P., Dias, R. A., Di Giacomo, A. S., Fontana, C. S., & Palarea, C. M. (2012). Ecology and conservation of grassland birds in southeastern South America: a review. *Journal of Field Ornithology*, *83*(3), 217-246. https://doi.org/10.1111/j.1557-9263.2012.00372.x

Bardgett, R. D., Bullock, J. M., Lavorel, S., Manning, P., Schaffner, U., Ostle, N., Chomel, M., Durigan, G., Ellen, L. F., Johnson, D., Lavallee, J. M., Le Provost, G., Luo, S., Png, K., Sankaran, M., Hou, X., Ma, L., Ren, W., Li, X., Ding, Y., Li, Y., & Shi, H. (2021). Combatting global grassland degradation. *Nature Reviews Earth & Environment*, *2*(10), 720-735. https://doi.org/10.1038/s43017-021-00207-2

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Bibby, C. J., Jones, M., & Marsden, S. (1998). Bird surveys. Expedition Advisory Centre.

Bilenca, D., & Miñarro, F. (2004). Identificación de Áreas Valiosas de Pastizal (AVPs) en las Pampas y Campos de Argentina, Uruguay y sur de Brasil. Fundación Vida Silvestre Argentina.

Bremer, L., & Farley, K. (2010). Does plantation forestry restore biodiversity or create green deserts? A synthesis of the effects of land-use transitions on plant species richness. *Biodiversity and Conservation*, *19*, 3893–3915. https://doi.org/10.1007/s10531-010-9936-4

Burnham K. P., & Anderson, D. R. (2002). Model selection and multimodel inference: a practical information-theoretic approach. Springer, New York.

Correll, M. D., Strasser, E. H., Green, A. W., & Panjabi, A. O. (2019). Quantifying specialist avifaunal decline in grassland birds of the Northern Great Plains. *Ecosphere*, *10*(1), e02523. https://doi.org/10.1002/ecs2.2523

Cuevas, Y. A., & Zalba, S. M. (2010). Recovery of native grasslands after removing invasive pines. *Restoration Ecology*, *18*(5), 711-719. https://doi.org/10.1111/j.1526-100X.2008.00506.x

De Cáceres M., & Legendre, P. (2009). Associations between species and groups of sites: indices and statistical inference. *Ecology*, *90*, 3566-3574. https://doi.org/10.1890/081823.1

Dufrene M., Legendre, P. (1997). Species assemblages and indicator species: The need for a flexible asymmetrical approach. *Ecological Monographs, 67*, 345-366. https://doi.org/10.2307/2963459

Echeverría, M. L., Alonso, S. I., & Comparatore, V. M. (2017). Survey of the vascular plants of Sierra Chica, the untouched area of the Paititi Natural Reserve (southeastern Tandilia mountain range, Buenos Aires province, Argentina). *Check List*, *13*(6), 1003-1036. https://doi.org/10.15560/13.6.1003

Echeverría, M. L., Alonso, S. I., & Comparatore, V. M. (2023). Vegetation of a hill grassland of the Paititi Natural Reserve (Pampa biome) and early detection of non-native species acting as invasive. *Boletín de la Sociedad Argentina de Botánica*, *58*(1), 71-90. https://doi.org/10.31055/1851.2372.v58.n1.38512

Greer, M. J., Bakker, K. K., & Dieter, C. D. (2016). Grassland bird response to recent loss and degradation of native prairie in central and western South Dakota. *The Wilson Journal of Ornithology*, *128*(2), 278-289. https://doi.org/10.1676/wils-128-02-278-289.1

Grz□dzicka, E., & Reif, J. (2020). Impacts of an invasive plant on bird communities differ along a habitat gradient. *Global Ecology and Conservation*, *23*, e01150. https://doi.org/10.1016/j.gecco.2020.e01150

Herrera, L., & Laterra, P. (2011). Relative influence of disturbance histories and landscape patterns on floristic structure and diversity of fragmented grasslands. *Applied Vegetation Science*, *14*, 181-188.

Herrera, L. P., Sabatino, M. C., Jaimes, F. R., & Saura, S. (2017). Landscape connectivity and the role of small habitat patches as stepping stones: an assessment of the grassland biome in South America. *Biodiversity and Conservation*, *26*, 3465-3479. https://doi.org/10.1007/s10531-017-1416-7

Isacch, J. P., Bó, M. S., Vega, L. E., Favero, M., Baladrón, A. V., Pretelli, M. G., Stellatelli, O. A., Cardoni, D. A., Copello, S., Block, C., Cavalli, M., Comparatore, V. M., Mariano-Jelicich, R., Biondi, L. M., García, G. O., & Seco Pon, J. P. (2016). Diversidad de Tetrápodos en un mosaico de ambientes del sudeste de la ecorregión Pampeana como herramienta para planificar en conservación. *Revista del Museo Argentino de Ciencias Naturales*, *18*(2), 211-233. https://doi.org/10.22179/REVMACN.18.463

Isacch, J. P., & Martínez, M. M. (2001). Estacionalidad y relaciones con la estructura del hábitat de la comunidad de aves de pastizales de paja colorada (*Paspalum quadrifarium*) manejados con fuego en la provincia de Buenos Aires, Argentina. *Ornitología Neotropical*, *12*(4), 345-354.

Kristensen, M. J., Lavornia, J., Leber, V. A., Pose, M. P., Dellapé, P., Salle, A., Braccalente, L., Giarratano, M., & Higuera, M. (2014). Estudios para la conservación de la Pampa austral. I. Diagnóstico de la biodiversidad local. *Revista Estudios Ambientales*, *2*(1), 105-118.

Larson, D. L., Phillips-Mao, L., Quiram, G., Sharpe, L., Stark, R., Sugita, S., & Weiler., A. (2011). A framework for sustainable invasive species management: Environmental, social, and economic objectives. *Journal of environmental management*, *92*(1), 14-22. https://doi.org/10.1016/j.jenvman.2010.08.025

Leveau, L. M., & Leveau, C. M. (2004). Comunidades de aves en un gradiente urbano de la ciudad de Mar del Plata, Argentina. *El Hornero*, *19*(1), 13-21.

Lengyel, S., Nagy, G., Tóth, M., Mészáros, G., Nagy, C. P., Mizsei, E., Szabolcs, M., Mester, B., & Mér□, T. O. (2023). Grassland restoration benefits declining farmland birds: A landscape-scale before-after-control-impact experiment. *Biological Conservation*, *277*, 109846.

León, R. J. C., Rusch, G. M., & Oesterheld, M. (1984). Pastizales pampeanos-impacto agropecuario. *Phytocoenologia*, *12*(2/3), 201-218.

Mangachena, J. R., & Geerts, S. (2017). Invasive alien trees reduce bird species richness and abundance of mutualistic frugivores and nectarivores; a bird's eye view on a conflict of interest species in riparian habitats. *Ecological Research*, *32*, 667-676. https://doi.org/10.1007/s11284-017-1481-0

Martínez, G. (2011). Geomorfología del paisaje serrano e inter serrano de tandilia oriental. In H. Massone (Ed.), Laguna de Los Padres y La Brava: un recurso natural y social para cuidar y compartir. Universidad Nacional de Mar del Plata.

Nelson, S. B., Coon, J. J., Duchardt, C. J., Fischer, J. D., Halsey, S. J., Kranz, A. J., Parker, C. M., Schneider, S. C., Swartz, T. M., & Miller, J. R. (2017). Patterns and mechanisms of invasive plant impacts on North American birds: a systematic review. *Biological Invasions*, *19*, 1547-1563. https://doi.org/10.1007/s10530-017-1377-5

O'Connor, T., Paz, J. A., Castano, M. V., Román, S. B., Hernandez, M. M., & Zumpano, F. (2024). Diversidad de aves y caracterización de la vegetación en Sierra los Difuntos, Buenos Aires, Argentina: implicancia de la estacionalidad y la topografía. *El Hornero*, *39*(1), 91-103. https://doi.org/10.56178/eh.v39i1.1483

Palacio, F. X., Apodaca, M. J., & Crisci, J. V. (2020). Análisis multivariado para datos biológicos: teoría y su aplicación utilizando el lenguaje R. Fundación de Historia Natural Félix de Azara.

Pavlacky, D. C., Hagen, C. A., Bartuszevige, A. M., Iovanna, R., George, T. L., & Naugle, D. E. (2021). Scaling up private land conservation to meet recovery goals for grassland birds. *Conservation biology*, *35*(5), 1564-1574.

Prior, K. M., Adams, D. C., Klepzig, K. D., & Hulcr, J. (2018). When does invasive species removal lead to ecological recovery? Implications for management success. *Biological Invasions*, *20*, 267-283. https://doi.org/10.1007/s10530-017-1542-x

R Core Team. (2024). R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. https://www.r-project.org/

RARNAP [Red Argentina de Reservas Naturales Privadas]. (2016). Reservas Naturales Privadas. http://reservasprivadas.org.ar/reservas-naturales-privadas. (Accessed on: 2024-11-05).

Roberts, C. P., Scholtz, R., Fogarty, D. T., Twidwell, D., & Walker Jr, T. L. (2022). Large‐scale fire management restores grassland bird richness for a private lands ecoregion. *Ecological Solutions and Evidence*, *3*(1), e12119.

Rojas, S., Echeverría, M. L., O'Connor, T., & Comparatore, V. M. (2025). Chemical control of the invasive exotic *Acacia melanoxylon* R. Br. and plant succession in the Pampa Biome (Argentina). *Journal for Nature Conservation*, *86*, 126931. https://doi.org/10.1016/j.jnc.2025.126931

Román, S. B., Martin Sirito, S., O'Connor, T., Alberti, J., Cardoni, A., González Zugasti, E., & Isacch, J. P. (2025). Managing small grassland reserves: bird response to regenerative grazing in a Private Reserve in Argentina. *PARKS (International Journal of Protected Areas and Conservation)*, *31*(2), 111-121. https://doi.org/10.2305/TRTY4762

Schauman, S. A., Peñuelas, J., Jobbágy, E. G., & Baldi, G. (2023). The geometry of global protected lands. *Nature Sustainability*, *7*, 82–89. https://doi.org/10.1038/s41893-023-01243-0

Sottile, G. D., O'Connor, T., Herrera, G. B., Wraage, C. P., & Suárez, P. A. (2024). Helechos y licofitas del sudeste del Sistema de Tandilia. *Boletín de la Sociedad Argentina de Botánica*, *59*(3), 345-374. https://doi.org/10.31055/1851.2372.v59.n3.44744

Trofino Falasco, C., Di Giacomo, A. S., Aranguren, M. F., Martínez Aguirre, T., Grilli, P., Paz, E. L., Pizzarello, M. G., Vera, D. G., & Berkunsky, I. (2022). Nesting biology of the Hudson´ s Canastero (*Asthenes hudsoni*) and the Bearded Tachuri (*Polystictus pectoralis*), two threatened and poorly known birds of the Pampas grasslands. *Studies on Neotropical Fauna and Environment*, *59*(1), 74-83. https://doi.org/10.1080/01650521.2022.205268

Vera, D. G., Di Pietro, D. O., Tettamanti, G., Eirin, M., Trofino Falasco, C., Aranguren, M. F., Williams, J. D., Kacoliris, F. P., & Berkunsky, I. (2021). An annotated list of the reptiles of the highland grassland of Tandilia Mountains, Argentina. *Neotropical Biology and Conservation*, *16*(1), 185–204. https://doi.org/10.3897/neotropical.16.

Vignolio, O. R., Garavano, M. E., Diez de Ulzurrun, P., Angelini, H. P., & Ispizúa, V. N. (2021). Soil seed bank study in a grassland of a natural reserve of the Tandilia System (Buenos Aires, Argentina) invaded by *Racosperma melanoxylon*. *Ecología Austral*, *31*, 390-399. https://doi.org/10.25260/EA.21.31.3.0.1247

Wickham, H. 2016. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag.

Wraage, C. P., Sottile, G. D., Fernández Honaine, M., Meretta, P. E., & Vásquez Pérez, C. (2025). Contribución al estudio de la vegetación y su relación con la geodiversidad en ambientes serranos de Sierra de los Padres y Sierra La Brava, en el extremo sudeste del Sistema de Tandilia (Buenos Aires, Argentina). *Boletín de la Sociedad Argentina de Botánica*, *60*(1), 49-72. https://doi.org/10.31055/1851.2372.v60.n1.46339

Yansen, M. V., & Biganzoli, F. (2022). Exotic tree species in Argentina: characterization and identification of current and potentially problematic species. Darwiniana, 10, 80-97. https://doi.org/10.14522/darwiniana

Zalba, S. M. (2000). Efectos de la forestación con especies exóticas sobre comunidades de aves del pastizal pampeano (PhD Thesis). Universidad Nacional del Sur, Bahía Blanca, Argentina.

Zalba, S. M., & Ziller, S. R. (2007). Adaptive management of alien invasive species: putting the theory into practice. Natureza & Conservação, 5, 86–92.

Zalba, S. M., & Villamil, C. B. (2002). Woody plant invasion in relictual grassland. Biological Invasions, 4, 55–72.

Zaninovich, S. C., Herrera, L., Carro, N. G., Zugasti, E. A. G., & Montti, L. (2023). Bases para el manejo adaptativo de la leñosa invasora Acacia melanoxylon (Fabaceae) en la Reserva Natural Privada Paititi, sierras del Sistema de Tandilia, Argentina. Boletín de la Sociedad Argentina de Botánica, 58(1), 21-30. https://doi.org/10.3897/10.31055/1851.2372.v58.n1.38462