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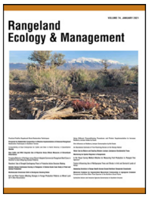

Selection for Overhead Concealment Improves Nest Survival of a Ground Nesting Bird in Argentinian Rangelands

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ABSTRACT

Grassland ecosystems have suffered intense modification worldwide, resulting in a loss of biodiversity. Birds that breed in grasslands have experienced steep population declines over recent decades. When modifications of grasslands reduce the available breeding habitat, birds may select habitat features that do not favor their breeding success. However, the relationship between selected nesting habitat and nest survival is not well established for many grassland birds. We studied the nest site selection and nest survival of a common grassland bird, the Grassland Yellow-Finch *Sicalis luteola*, in the Flooding Pampa of Argentina, a region comprised mostly of large natural rangelands. We searched for nests over three breeding seasons (2017–2020) and used linear models to analyze whether finches selected nest sites according to distance from grassland edges, type of grassland community, vegetation density, visual concealment, and grass height. We modeled daily nest survival rates (DSR) to assess whether these variables influenced breeding success. We confirmed the fate of 133 nests, of which 93 (70%) failed, predation being the principal cause (84% of failures). Our models showed that finches selected shrubby grasslands over other types available, and sites with high overhead visual concealment. Only overhead concealment was positively correlated with DSR. This may indicate that their nests are affected by avian predators that search for prey from above and that they benefit from tall and dense vegetation that provides good overhead cover. We believe that preserving areas of heterogeneous and dense shrubby grasslands within grazing plots is a good starting point that could benefit this bird species and others with similar nesting strategies.

Introduction

Understanding which habitat features are selected by animals is fundamental to assess their conservation status and to develop management strategies (Manly et al. 2002). Habitat selection is the sum of processes that results in a disproportionate use of habitat features compared to their availability (Jones 2001). Ideally, the selection of habitat features is expected to be adaptive, meaning that animals should select features that favor the survival of their populations (Devries et al. 2018; Martin 1998). However, when habitats experience changes, selection can become maladaptive, and animals may select habitats that will ultimately reduce their survival because they still perceive them to be good-quality habitats (Gilroy and Sutherland 2007). These changes are often produced by human modification, such as intensification of agriculture, fragmentation, contamination, and introduction of new species (Chalfoun and Schmidt 2012; Murray and Best 2014). A notable example occurs in North American hayfields; many birds perceive hayfields to be suitable nesting habitats, but their nests fail during the harvest (Seigel and Lockwood 2010).

Grassland ecosystems have been largely transformed due to anthropogenic activities, with around 50% of their original surface replaced by intensive agriculture and urbanization (Bardgett et al. 2021). While little of the remaining natural grassland surface is protected, the majority persists under cattle grazing regimes (Azpiroz et al. 2012; White et al. 2000). In grassland ecosystems that evolved with large native herbivores, domestic cattle grazing that emulates the natural condition can be sustainable and even beneficial, supporting a large biodiversity when managed conscientiously (Ranellucci et al. 2012). However, the growing demand for meat in recent decades has in many regions resulted in the intensification of livestock grazing beyond the natural regime, affecting the soil properties, vegetation structure and composition, and

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animal communities of the remaining natural grasslands (Evans et al. 2015). All these modifications have resulted in a general loss of biodiversity (Mace et al. 2005). This is particularly evident in birds, which are easily observed members of grassland communities and good indicators of grassland condition (Browder et al. 2002). In North and South America, birds that breed in grasslands have suffered more severe population declines than birds breeding in any other biome (Azpiroz et al. 2012; Rosenberg et al. 2019).

The breeding season of birds is a critical period during which they must select a nest site that maximizes their chances of successfully producing young (Tieleman et al. 2008). Nest site selection is a hierarchical process that operates from wider to narrower scale (Harris et al. 2020; Jones 2001). For example, a species may select breeding territories based on food abundance and specific nest sites based on concealment from predators (Chalfoun and Martin 2007). However, nest site selection patterns may not always correlate with higher breeding success, particularly in human-modified landscapes (Bertholdt et al. 2017; Renfrew et al. 2005). Therefore, understanding the relationship between nest site selection and nest survival is fundamental to determine which habitat features can be managed to preserve bird populations.

Some habitat features thought to be important for grassland birds' nest site selection and nest survival are distance to grassland edges (Fletcher and Koford 2003; Herrera et al. 2009; Perkins et al. 2013), vegetation community (Conkling et al. 2017), grass height, vegetation density, and ground cover (Fisher and Davis 2010; Fogarty et al. 2017). Generally, birds are expected to select these features in a way that reduces nest predation, which is usually the main cause of nest failure (Ludlow et al. 2014; Lyons et al. 2015). For example, nests placed near edges may be exposed to a wider variety of potential predators (Winter et al. 2000), while taller and denser grass is expected to provide better concealment (Fogarty et al. 2017). However, many studies found that some species select nest site features that do not reduce the risk of predation (Bertholdt et al. 2017; Davis 2005; Perkins et al. 2013). This shows that nest site selection and its influence on survival are highly variable among species and regions. To date, the majority of research on grassland birds has focused on Northern temperate grasslands (Pretelli et al. 2015), and these results cannot be extrapolated to other regions because different habitat features and predator communities may be involved.

The Pampas Grasslands in central Argentina have historically been used for cattle grazing and crop production, although in the last three decades, the intensification of both practices has increased (Codesido et al. 2011; Modernel et al. 2016). While the region has suffered one of the most drastic modifications of South American ecosystems, less than 3% of the original grassland surface is legally protected (Azpiroz et al. 2012; Nanni et al. 2020). For this reason, many bird species depend on the remnants of natural grassland present in extensive private rangelands (Codesido et al. 2012; Codesido and Bilenca 2021). Nevertheless, these fields are under continuous pressure as new grazing strategies are adopted and more exotic pastures are planted (Agra et al. 2015). Although a few studies have analyzed birds' habitat use in these grasslands at a landscape scale (e.g., Cardoni et al. 2012; Codesido et al. 2011; Isacch et al. 2005; Isacch and Cardoni 2011), almost no research has analyzed nest site selection at smaller scales and its relationship with survival. This is an important limitation because high bird abundance per se is not an indicator of favorable breeding habitat. For example, fields that birds select due to food abundance do not necessarily contain the finer scale features that promote nest success (Chalfoun and Martin 2007; Chalfoun and Schmidt 2012).

In this study, we analyze the nest site selection of a common grassland bird in the Pampas of Argentina, the Grassland Yellow-Finch *Sicalis luteola* (Sparrman 1789), and evaluate if selected features have a positive relationship with nest survival. We searched for nests during three breeding seasons and collected data on distance from grassland edges, type of grassland community, vegetation density, visual concealment, and grass height. Our main predictions were that 1) finches would select sites far from grassland edges and with greater visual concealment, and that 2) nests with the selected features would have a greater probability of survival.

Methods

Study area

We conducted fieldwork on a private farm of ~2000 ha in Punta Piedras, Buenos Aires province, Argentina (35°20′S; 57°12′W, Fig. 1A). The farm consists mostly of natural grasslands used for moderate intensity grazing by domestic cattle. Based on differences in soil properties, slope, and water retention capabilities, the Flooding Pampas is usually divided into lowlands, half-knolls, knolls, and floodplains, each with their own grassland communities (Rodríguez and Jacobo 2012). Although only lowlands and half-knolls are present in our study site, three distinct grassland communities (hereafter "types") can be identified: short grasslands, dominated by species of the genus *Paspalidium* Stapf., which grow in lowlands and have an average height of ~13 cm; "flechillares," dominated by needlegrasses (genera *Nassella* [Trin.] É. Desv. and *Piptochaetium* J. Presl.), which grow in half-knolls and have an average height of ~55 cm; and shrubby grasslands, with similar proportions of needlegrasses and baccharises (genus *Baccharis* L.), which grow in the highest parts of half-knolls and have an average height of ~65 cm (Fig. 1). The farm is under a continuous grazing regime with a stocking rate of approximately 1 animal/ha in all plots. Cattle are moved out of some plots during vaccination events or because of poor grass growth during the winter-spring period (March–September). Forests in the area consist of continuous rows near the shore of the Río de la Plata as well as isolated patches amid the grasslands, which are dominated by native species (such as *Celtis tala* Gillies ex Planch., *Scutia buxifolia* Reissek, *Schinus longifolia* (Lindl.) Speg.) but have been invaded by exotic trees (*Morus alba* L., *Eucalyptus* L'Her. spp., *Gleditsia triacanthos* L., *Celtis australis* L., among others). Potential terrestrial nest predators in the study area include opossums (*Didelphis albiventris*), foxes (*Lycalopex gymnocercus*), lesser grisons (*Galictis cuja*), armadillos (*Chaetophractus villosus*), rodents (e.g., *Akodon* spp. and *Oligoryzomys* spp.), black-and-white tegus (*Salvator merianae*), and snakes (*Philodryas* spp.). Potential aerial nest predators include caracaras (*Daptrius chimango*, *Caracara plancus*) and Long-winged Harriers (*Circus buffoni*). Permits to conduct fieldwork were granted by the local environmental authority (OPDS #17717, Dirección de Áreas Naturales Protegidas, Buenos Aires Province, Argentina).

Study species

The Grassland Yellow-Finch (hereafter "finch") is a common granivorous bird that inhabits open areas in most of South America (Rising et al. 2020). The southern subspecies *S. luteola luteiventris* is present from southern Brazil to northern and central Argentina, with some populations in Peru, Bolivia, and central Brazil (Rising et al. 2020). Its breeding season in Argentina spans from October to January (Salvador and Salvador 1986). It builds open cup nests made of grass and cattle hair, which are attached to vegetation up to 40 cm from the ground (Freitas and Francisco 2012; Salvador and Salvador 1986). Clutch size is usually four to five eggs, which are incubated by the female for 11 d (Freitas and Francisco 2012; Salvador and Salvador 1986). Although it is a fairly common bird in some areas, data on its nest success are based on a limited number

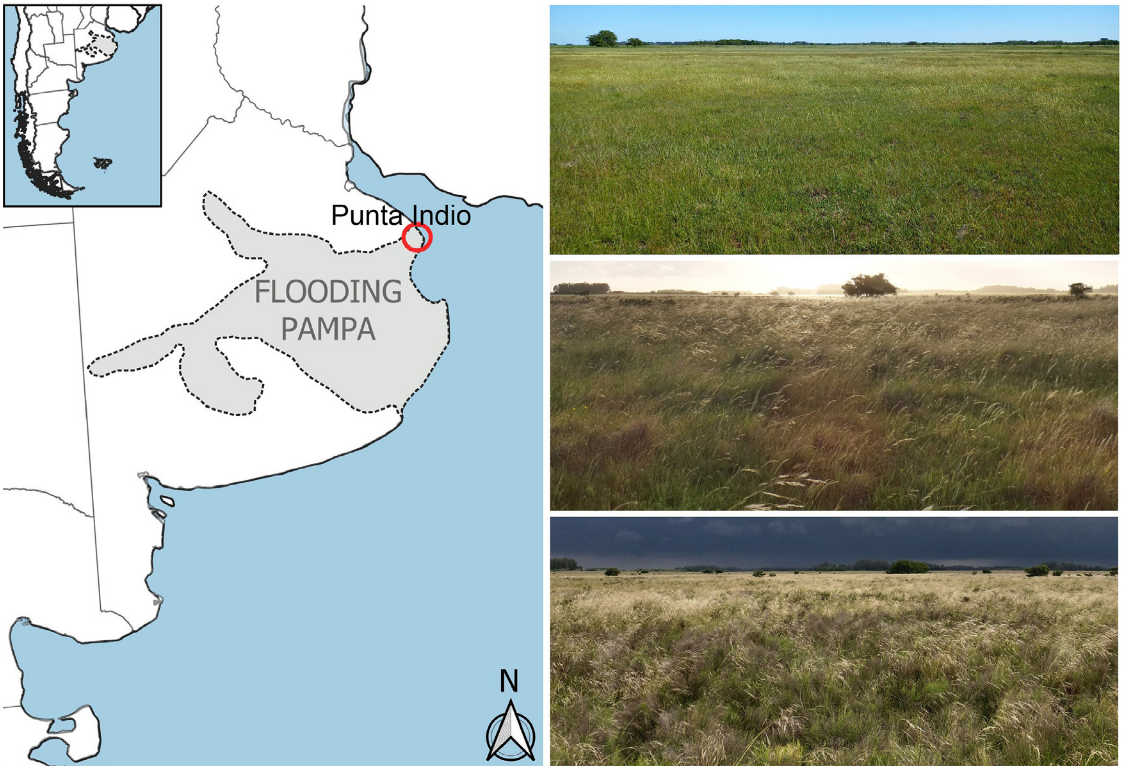

Figure 1. Location of study site (small circle) in Punta Indio, Buenos Aires province, Argentina **(left)** and different grassland types found in the farm **(right)**. Top: short grasslands dominated by *Paspalidium* spp., middle: “flechillares” dominated by *Nassella* spp. and *Piptochaetium* spp., bottom: shrubby grasslands dominated by *Nassella* spp. and *Baccharis* spp.

of nests (Freitas and Francisco 2012; Salvador and Salvador 1986), and no studies have analyzed nest site selection.

Field procedure

We searched for finch nests from October to February during three breeding seasons in 2017–2020. We found nests by dragging a 20-m-long rope between two people and by systematic walking with sweeping sticks to flush incubating females (Winter et al. 2003), covering an area of 250 ha. In addition, we looked for adults carrying nest material or food to locate nests under construction or during the nestling stage, respectively. Once found, we marked each nest location using a handheld GPS unit and placed a small flag (a 5-cm red tape attached to a 50-cm-long wire) 5 m from the nest to relocate it in subsequent visits. This flag was inconspicuous and unlikely to be learned by predators at our study site (Jacobson et al. 2011).

We monitored nests every 2–3 d until they were successful (at least one young fledged) or failed (the nest was depredated or abandoned before fledging). We confirmed nest success by observing fledglings or adults delivering food in the area after the nest was empty and nestlings were old enough to fledge (9–10 d, MAC *unpublished data*). We considered a nest depredated when the eggs disappeared between consecutive visits or when nestlings disappeared before the minimum expected fledging age, usually supported by the lack of parental activity in the surrounding area. We considered a nest trampled if the nest was turned over or destroyed with signs of cattle activity in the surrounding grass. We considered a nest abandoned if we found that the eggs were cold after the beginning of incubation or if we found dead nestlings with no signs of predation (Colombo and Segura 2023). We tried to determine the cause of abandonment when possible (e.g., wet eggs or water in the nest bottom indicated flooding).

Habitat features

Immediately after each nesting attempt ended, we measured the following nest site vegetation features (nest site scale): height of the nest opening from the ground (nest height), height of the supporting grass or shrub (clump height), horizontal visual obstruction index (hVOI), upper visual obstruction index (uVOI), and distance to the nearest perch (tree or pole >1 m). We measured hVOI by placing a pole divided in 10 cm sections at the center of the nest and recording the first visible section from a height of 1 m at a distance of 4 m in the four cardinal directions (Colombo and Segura 2023). This provided scores from 1 (lowest obstruction) to 10 (highest obstruction), which we averaged to obtain the final hVOI score for each nest. We measured uVOI by placing an 8-cm diameter disk divided in eight sections on top of the nest and recording the number of visible sections from directly overhead. The final uVOI score was 8 minus the number of visible sections (Colombo et al. 2021). We recorded the distance to the nearest perch using a GPS unit.

We then obtained a random location located within 5–50 m from each nest, using a random number generator to obtain a distance and a bearing from the original nest location. We repeated the same vegetation measurements at the random location except for nest height. Clump height and visual obstruction measurements were measured at the tallest clump in a 20 cm radius around the exact location determined by random numbers.

At a wider scale (study site scale), we recorded the grassland type where the nest was located (short grassland, flechillar, or shrubby grassland) and the distance to the nearest grassland edge (forest or road). We measured distances by analyzing a SPOT 6 satellite image (1.5-m spatial resolution) in software QGIS (QGIS Development Team 2020). We then created an equal number of random points distributed across the entire nest search area using the “Random Points” tool in QGIS and measured the distance of each random point from the edges. We recorded the grassland type at each random point in a later visit to the site.

Statistical analysis

Nest site selection

To analyze selection at the nest site scale we used a case–control design (Keating and Cherry 2004), pairing each nest (case) with its respective random location (control). We built generalized linear mixed models to analyze the selection of each variable (clump height, hVOI, uVOI, and distance to perch), including the identity of each case–control pair as a random factor. Prior to fitting models, we checked for correlation among vegetation variables using Spearman's r (Dormann et al. 2013). We included a quadratic term for hVOI to allow the possibility of selecting intermediate or extreme values. We considered all possible combinations of explanatory variables unless two variables were correlated. We used Akaike's Information Criterion corrected for small sample sizes (AICc) to compare models and choose the most supported (lowest AICc value) (Burnham and Anderson 2002). We considered models within two AICc units from the best model to be equally competitive (Burnham and Anderson 2002), although we did not consider a model to be relevant if it was a more complex version (i.e., with extra parameters) of a better supported one (Arnold 2010), or if it had higher AICc value (less support) than the null model (model with no covariates).

To analyze selection at the study site scale, we used generalized linear models to evaluate the probability of finches selecting a nest site in relation to grassland type and distance to edges, including forests, roads, and both combined (i.e., distance to nearest edge regardless of type). We followed the same procedure for model selection based on AICc values. We conducted all nest site selection analyses using software R (version 4.3.3, R Core Team 2024), packages MASS (version 7.3, Venables and Ripley 2002), and lme4 (version 1.3, Bates et al. 2015).

Nest survival

We assigned a clutch-initiation date to each nest corresponding to the date of laying of the first egg. We determined the date directly for nests found during construction or egg-laying. For nests found during incubation, we backdated from the hatching date using the known incubation period. For nests found during the nestling stage, we estimated the hatching date from nestling age, using visual cues (opening of eyes, overall feather development, and wing chord length). For nests found during incubation that failed before hatching ($n = 30$ nests), we assumed that the observed period represented the middle portion of the incubation period (e.g., if a nest was found during incubation and depredated after 6 d of observation, we considered the 3rd d of the observed period to be the middle point of incubation) (Colombo and Segura 2023).

We estimated the daily nest survival rate (DSR) using generalized linear models with a logistic-exposure link function (Shaffer 2004). These models include the duration of each visit interval as exposure time (in days) and the fate of the nest as the response variable (coded as 0 = failed during the interval and 1 = survived the interval). We created a null model of constant DSR to estimate the cumulative nest survival probability for the species by raising the DSR to a power equal to the length (in days) of a complete breeding cycle of an average finch nest of 24.9 d, including 3.4 d of egg laying, 11.5 of incubation, and 10 of nestling rearing (M.A. Colombo, *unpublished results*).

To build the candidate model set we used a stepwise procedure to reduce the number of superfluous models to evaluate (Arnold 2010). First, we evaluated the influence of temporal variables that could a priori influence nest survival, including year, time of breeding within season, and nest age with a linear and quadratic term (Colombo and Segura 2021; Grant et al. 2006). These models were ranked according to their AICc values, and the variables present in the best model were kept for the following stage. Next, we created a model set containing all the habitat variables present in the best nest site selection models (including all the possible combinations among them) to evaluate if the selected features favored DSR. In a third step, we created a model set containing all the nonselected habitat variables (and nest height) to control for other habitat features that could influence nest DSR. We built a final model set including the variables present in the best models of each step and all the possible combinations among them. We evaluated the final model set based on AICc values following the same criteria as for nest site selection (see above). We also examined the parameters' 95% confidence intervals to determine whether their effects were significant. We conducted nest survival analyses using software R (R Core Team 2024), package MASS (Venables and Ripley 2002).

Results

We found 137 nests over the three breeding seasons (44 in 2017–2018, 54 in 2018–2019, and 39 in 2019–2020). Seven nests were located in short grasslands, 48 in flechillares, and 82 in shrubby grasslands. We confirmed the fate of 133 nests, of which 40 were successful (30%) and 93 failed (70%). Among failed nests, 78 were depredated (84%) and 15 were abandoned (16%). Other four nests remained active at the end of the field season. Nine nests were abandoned after flooding, one was abandoned after being parasitized by Shiny Cowbird *Molothrus bonariensis* (which was the only parasitism event we recorded), one was trampled by cattle, and four were abandoned for unknown causes.

Nest site selection

A subset of 114 nests with paired random locations had complete data to be used in the nest site scale selection analysis. At this scale, the best model included hVOI with a quadratic term, uVOI, and clump height (Table 1). Although a second competitive model also included the distance to the nearest perch, this resulted in a higher AICc value and the 95% confidence intervals for this parameter included zero (−0.01 to 0.03), thus we considered the simpler model to be more parsimonious. Finches selected sites with intermediate hVOI scores, and with higher uVOI and clump height than their paired random sites (Table 2, Fig. 2). Habitat features recorded are summarized in supplementary material (Table S1). At the study-site scale ($n = 137$ nests and random

Table 1
Generalized linear mixed models explaining nest site selection of the Grassland Yellow Finch (*Sicalis luteola*) in Punta Indio, Argentina, at the nest site scale.

Model	df	AICc	ΔAICc	*wi*
$S\sim\text{uVOI}+\text{hVOI}+\text{hVOI}^2+\text{Clump}$	6	135.07	0.00	0.55
$S\sim\text{uVOI}+\text{hVOI}+\text{hVOI}^2+\text{Clump}+\text{Perch}$	7	135.96	0.89	0.35
$S\sim\text{uVOI}+\text{hVOI}+\text{Clump}$	5	139.60	4.53	0.06
$S\sim\text{uVOI}+\text{hVOI}+\text{Clump}+\text{Perch}$	6	140.31	5.24	0.04
$S\sim\text{uVOI}+\text{Clump}$	4	143.83	8.76	0.01
$S\sim\text{uVOI}+\text{Clump}+\text{Perch}$	5	145.36	10.29	0.00
$S\sim\text{uVOI}+\text{hVOI}+\text{hVOI}^2+\text{Perch}$	6	152.25	17.18	0.00
$S\sim\text{uVOI}+\text{hVOI}+\text{hVOI}^2$	5	152.69	17.62	0.00
S(.)[1]	2	320.13	185.06	0.00

S(.), null model; hVOI, horizontal visual obstruction index; uVOI, upper visual obstruction index; Clump, clump height (height of the supporting grass or shrub); Perch, distance to nearest perch (tree or pole >1 m); df, degrees of freedom; AICc, Akaike's Information Criterion corrected for small sample sizes (lower values indicate higher support); ΔAICc, difference in AICc from the best-supported model; *wi*, relative weight of model. Models are ranked from higher to lower support.

[1] Omitted 14 models with lower support.

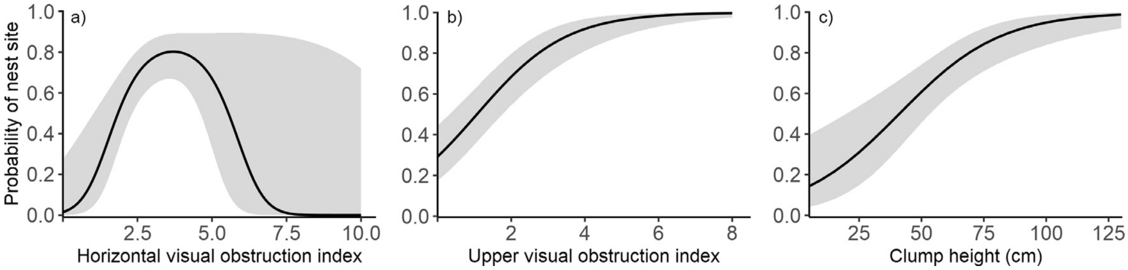

Figure 2. Nest site selection by the Grassland Yellow-Finch (*Sicalis luteola*) as predicted by the best-supported generalized linear mixed model at the nest site scale. Plots represent the probabilities of a location being chosen based according to **(A)** horizontal visual obstruction index, **(B)** upper visual obstruction index, and **(C)** supporting clump height while keeping all the other variables at their mean value. Shaded areas represent the 95% confidence intervals.

Table 2
Parameter estimates of the best-supported model explaining selection at the nest site scale.

Variable	Estimate	SE	95% CI
(Intercept)	−9.109	1.816	(−12.667; −5.55)
hVOI	3.023	1.074	(0.918; 5.127)
hVOI^2	−0.408	0.169	(−0.739; −0.078)
Clump	0.050	0.013	(0.024; 0.074)
uVOI	0.828	0.150	(0.534; 1.121)

SE, standard error; CI, confidence intervals; hVOI, horizontal visual obstruction index; uVOI, upper visual obstruction index; Clump, clump height (height of the supporting grass or shrub).

Table 3
Generalized linear models explaining nest site selection of the Grassland Yellow Finch (*Sicalis luteola*) in Punta Indio, Argentina, at the study-site scale ($n = 137$ nests).

Model	df	AICc	ΔAICc	*wi*
S∼Grassland	3	371.70	0.00	0.73
S∼Grassland + Edge	4	373.71	2.01	0.27
S(.)	1	381.86	10.16	0.00
S∼Edge	2	382.61	10.91	0.00

S(.), null model; Grassland, grassland type (short, flechillar, or shrubby); Edge, distance to the nearest edge (forest or road); df, degrees of freedom; AICc, Akaike's Information Criterion corrected for small sample sizes (lower values indicate higher support); ΔAICc, difference in AICc from the best-supported model; *wi*, relative weight of model. Models are ranked from higher to lower support.

locations), the best-supported linear model included only grassland type (Table 3), which showed that finches selected shrubby grasslands over flechillares and short grasslands (parameter estimates for shrubby grasslands = 1.498 ± 0.47; flechillares = 0.859 ± 0.48; intercept = −1.099 ± 0.44).

Nest survival

DSR estimated by the null model was 0.9311 ± 0.002 (SE) ($n = 137$ nests), which produced an estimated cumulative survival probability of 16.9% for an average nesting cycle. The temporal variables that best explained DSR were nest age with a quadratic term and time of breeding. The only habitat variable that received support was uVOI (Table 4). The top model of the final set indicated that DSR followed a quadratic trend with nest age (decreasing toward hatching and then increasing toward fledging), and that it was higher in nests with higher uVOI (Table 5, Fig. 3). Although time of breeding was included in the best model, showing a negative association with DSR, its inclusion in the model only marginally increased its support (see Table 4), and its 95% confidence intervals included zero (Table 5), meaning that the effect was nonsignificant.

Table 4
Models explaining daily nest survival rates of the Grassland Yellow Finch *Sicalis luteola* in Punta Indio, Argentina ($n = 137$ nests).

Model	*k*	AICc	ΔAICc	*wi*
Temporal variables[1]				
S∼Age + Age^2 + Time	4	474.97	0.00	0.48
S∼Age + Age^2	3	475.84	0.87	0.31
S∼Age + Age^2 + Time + Year	6	477.75	2.78	0.12
S∼Age + Age^2 + Year	5	479.22	4.25	0.06
Selected habitat variables[2]				
S∼uVOI	2	481.90	0.00	0.29
S∼uVOI + Clump	3	483.40	1.56	0.13
S∼uVOI + hVOI	3	483.90	2.02	0.11
S(.)	1	484.50	2.62	0.08
Other variables[3]				
S(.)	1	484.50	0.00	0.38
S∼Perch	2	486.30	1.81	0.15
S∼Edge	2	486.40	1.90	0.15
S∼Height	2	486.50	2.01	0.14
S∼Perch + Edge	3	488.30	3.82	0.06
S∼Perch + Height	3	488.30	3.83	0.06
S∼Edge + Height	3	488.40	3.92	0.05
Final set[4]				
S∼Age + Age^2 + uVOI + Time	5	473.00	0.00	0.38
S∼Age + Age^2 + uVOI	4	473.10	0.03	0.37
S∼Age + Age^2 + Time	4	475.00	1.93	0.14
S∼Age + Age^2	3	475.80	2.80	0.09

S(.), null model; Age, nest age since start of egg laying; Time, time of clutch initiation within season; Year, field season of each nest (2017–2018, 2018–2019, 2019–2020); hVOI, horizontal visual obstruction index; uVOI, upper visual obstruction index; Clump, clump height (height of the supporting grass or shrub); Perch, distance to nearest perch (tree or pole >1 m); Grassland, grassland type (short, flechillar, or shrubby); Edge, distance to the nearest edge (forest or road); Height, nest height from the ground; df, degrees of freedom; AICc, Akaike's Information Criterion corrected for small sample sizes (lower values indicate more support); ΔAICc, difference in AICc from the best-supported model; *wi*, relative weight of model within each set. The variables in the best models of each subset were used to build the final model set. Models are ranked from higher to lower support.

[1,2,3,4] Omitted 11, 27, 1, and 14 models with weights ≤0.01.

Table 5
Parameter estimates of the best model explaining nest survival of the Grassland Yellow Finch.

Variable	Estimate	SE	95% CI
(Intercept)	4.651	0.817	(3.050; 6.252)
Age	−0.341	0.111	(−0.559; −0.123)
Age^2	0.012	0.004	(0.004; 0.019)
uVOI	0.089	0.045	(0.001; 0.178)
Time	−0.008	0.005	(−0.018; 0.003)

SE, standard error; CI, confidence intervals; Age, nest age since start of egg laying; uVOI, upper visual obstruction index; Time, time of clutch initiation within season.

Discussion

Our results showed that finches selected nesting sites according to grassland type, clump height, and visual obstruction. They selected shrubby grasslands more than available, and their nest sites

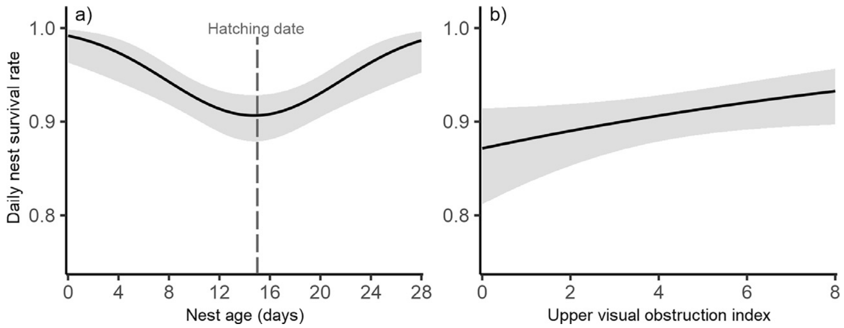

Figure 3. Daily nest survival rate of the Grassland Yellow-Finch (*Sicalis luteola*) as predicted by the best-supported generalized linear model. **(A)** Effects of nest age, with upper visual obstruction index held at the mean value; **(B)** effect of upper visual obstruction at the midpoint of nest age (14 d). Shaded areas represent the 95% confidence intervals.

had higher vegetation clumps, intermediate horizontal visual obstruction, and higher upper visual obstruction compared to paired random locations. Among all the features selected, only higher upper visual obstruction improved the nest survival rate.

Compared to other grassland types at the study site, shrubby grasslands are taller and more heterogeneous. The selection in favor of shrubby grasslands suggests that this vegetation community provides a more suitable vegetation structure for nest placement than the shorter and more homogeneous grasslands. In addition, birds may choose nest sites close to food sources to ensure provisioning during the nestling period (Barea 2012). Shrubby grasslands may provide a better food supply for breeding birds than more homogeneous types (Brüggeshemke et al. 2022), although further research on the nestling provisioning of finches would be needed to confirm this relationship. Although grassland type did not have a direct effect on nest survival, knowing the overall characteristics of grasslands selected by nesting birds is important because it is possible to manage cattle to preserve them (Aldabe et al. 2024; Derner et al. 2009).

Finches did not avoid nesting near grassland edges, unlike what is expected of many grassland passerines (Ellison et al. 2013; Keyel et al. 2013; Renfrew et al. 2005). The avoidance of grassland edges is often considered an evolutionary response to higher rates of nest predation or brood parasitism near forests or other types of habitats (Benson et al. 2013; Winter et al. 2000). However, avoiding edges can have little to no benefit for nest survival under many scenarios. For example, although some nest predators are more active in grassland edges (such as some small and medium-sized mammals), there is also a specific community of nest predators that thrive in open grasslands (Colombo and Segura 2021; Renfrew et al. 2005). These include snakes, small rodents, and Long-winged Harriers at our study site. Furthermore, brood parasitism was extremely rare, suggesting that, unlike other species, finches would not gain a substantial benefit from avoiding edges for this reason (Benson et al. 2013). Consistent with this explanation, we found no effect of distance to edges on the DSR of the finch. This generalist species could have an advantage compared to species that avoid edges because it is able to use the whole grassland surface at no cost to nest success.

At the nest site scale, finches selected sites with intermediate horizontal visual obstruction. This is not surprising given that nest site selection usually involves a trade-off between nest concealment (to avoid detection of the brood by predators) and visibility of the surroundings (to allow adults to detect predators and survive themselves) (Lima 2009; Magaña et al. 2010). Moreover, sites with denser vegetation could favor some potential nest predators (e.g., small mammals or snakes) that find protection from raptors and other larger predators (Dion et al. 2000). The fact that the same variable did not affect DSR suggests that nest predation is unlikely to be significantly affected by the observed variation of horizontal concealment and that the species has reached an optimal value or “adaptive peak” (Latif et al. 2012).

While the selected horizontal concealment did not affect nest survival, finches selected sites with higher upper visual obstruction, and higher values improved their DSR. Considering that the vast majority of nest failures were due to predation (84%), the selection for higher upper visual obstruction and its positive influence on DSR may indicate that finch nests are affected by avian predators (such as harriers and caracaras), and being better concealed from above is more advantageous than the ability to see in that direction. Finch nests are open cups built in the center of vegetation clumps and lack a consistent overhead cover like nests built at the base of bent clumps (Colombo and Segura 2023) or with dome shape (Fogarty et al. 2017); therefore, finches rely on dense vegetation to provide sufficient overhead concealment more than other species. Additionally, finches may select sites with greater overhead cover because it provides better protection against adverse weather, such as excessive rainfall or heat (Fogarty et al. 2017), which is a secondary cause of nest failure. Increasing the extension of areas with higher upper visual obstruction, which can be easily measured in the field, would provide more nesting habitat for finches and improve their nesting success. This could also benefit species of higher conservation concern that build nests in a similar way at similar heights, such as the Bearded Tachuri *Polystictys pectoralis* (Trofino Falasco et al. 2022) in our study site.

We also found that DSR varied with nest age, decreasing during incubation, and then increasing toward fledging. This is a similar trend to that found for the Hellmayr’s Pipit *Anthus hellmayri* in the same study area (Colombo and Segura 2023), which suggests that they are exposed to a similar set of risks across the different stages of their nesting cycles (including ground-dwelling predators, cattle disturbance, and extreme weather events). The Spotted Nothura *Nothura maculosa* also showed a decrease in DSR along the incubation period (Colombo and Segura 2021), lending further support to this explanation. DSR could decrease during incubation due to the accumulation of smells that may attract predators (Clark and Wobeser 1997) and increase during chick-rearing as adults defend their nests more actively (Kozma and Kroll 2010). Further studies on the behavior of this species and on predator identities are needed to confirm these patterns.

In summary, our results show that Grassland Yellow-Finches benefit from structurally complex and relatively tall grasslands, which provide their preferred nesting sites, and from dense vegetation which provides them overhead concealment and improves their nest survival. In addition, nest success was rather low, although higher than that of other grassland birds in the area (Colombo and Segura 2021; 2023; Colombo et al. 2021). The generally low nest success of grassland birds in the area raises concern about the sustainability of their populations under the current management practices in the Flooding Pampas.

The information from this common species could provide a baseline to understand which habitat characteristics to prioritize when implementing management strategies to preserve the breeding habitat of grassland birds in the region. The most traditional and widespread form of management is low-intensity continuous grazing, which has resulted in the replacement of the native plant community and an increased proportion of short grasslands (Codesido and Bilenca 2021). Improved management practices, such as adjusting stocking rates based on grass height and restricting the mating period to a single season, can promote heterogeneous fields and benefit birds while also increasing cattle productivity (Aldabe et al. 2024). We believe that managing stocking rates carefully with rotational regimes to increase grassland heterogeneity is a good starting point that can benefit the whole bird community, including more specialized species (Codesido and Bilenca 2021; Hovick et al. 2015; Vaccaro et al. 2020). Given the low coverage of protected areas in the Pampas Grasslands and the increasing pressure from intensive agriculture and urbanization (Agra et al. 2015; Nanni et al. 2020), we encourage authorities and landowners to adopt management practices that promote birds' nesting habitat and nest survival and to develop programs to monitor bird populations. Simultaneously, we call for further research on nest site selection and survival of less studied species in these grasslands, which is crucial to assess the impacts of agricultural practices on biodiversity.

Implications

Most of the research analyzing the impacts of cattle grazing on birds in the Flooding Pampas has focused either on nest survival or habitat use, comparing grazed and ungrazed grasslands. Our results provide an additional tool by incorporating a variety of nest site selection measures and their possible impacts on the reproductive outcome of birds in grazed fields.

Our study species did not avoid nesting near edges; however, within the same fields, it selected some grassland types more than others, and nest survival was positively affected by grass cover above the nest. This implies that total grassland area alone is not a sufficient proxy for habitat quality in this system. The traditional practice of continuous grazing tends to homogenize the grasslands and reduce the overall grass height and upper cover that birds select for nesting. Land managers should make an effort to preserve flechillares and shrubby grasslands in their fields while considering the adoption of grazing strategies that promote grass height and density, and which could also increase cattle productivity. When managing cattle during birds' breeding seasons, periodic measurements of upper visual obstruction could be helpful to make decisions about exclosures and stocking densities.

Declaration of competing interest

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

CRediT authorship contribution statement

Martín Alejandro Colombo: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Katelyn Marie Depot:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Conceptualization. **Luciano Noel Segura:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.rama.2024.05.004.

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