

Nest site selection by a grassland-dependent Neotropical passerine, the Tawny-bellied Seedeater *Sporophila hypoxantha*

ISMAEL FRANZ

franz@ufrgs.br

Universidade Federal do Rio Grande do Sul (UFRGS)

EDUARDO CHIARANI

VINICIUS A. G. BASTAZINI

University of Evora, Institute for Advanced Studies and Research (IIFA)

ILSI I. BOLDRINI

Universidade Federal do Rio Grande do Sul (UFRGS)

CARLA S. FONTANA

Universidade Federal do Rio Grande do Sul (UFRGS)

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Abstract

Increasing habitat loss and fragmentation along with other factors have led to the dramatic declines of multiple *Sporophila* seedeater species populations. However, the implementation of effective conservation measures is often hampered by the lack of knowledge about species' ecological requirements in their breeding grounds. Here we evaluate vegetation structure and composition of Tawny-bellied Seedeater (*Sporophila hypoxantha*) breeding sites in the upland grasslands of southern Brazil. We compared vegetation variables of sites selected by nesting Tawny-bellied Seedeaters to those that were unoccupied (n = 130 plots in each group, encompassing 26 nests) using multivariate analyses and generalized linear models. Nesting sites had gentle slope, higher shrub cover, shrub height, and lower percent of bare ground in comparison to randomly sampled (unoccupied by nests) sites in the region. Also, selected nesting sites had a higher frequency of *Andropogon lateralis*, *Saccharum angustifolium* and *Baccharis caprariifolia* while unoccupied sites a higher frequency of *Disynaphia multicrenulata*, *Escallonia megapotamica* (small tree) and *Eryngium horridum*. Because Tawny-bellied Seedeaters breed mainly on dry grasslands rich in shrubs, with high density of grasses, management measures that favor this habitat structure as low-intensity grazing and moderate burning may benefit the reproduction of this species.

Introduction

Grassland ecosystems have experienced increasing rates of habitat loss and fragmentation and are estimated to include nearly 6% of the world's threatened bird species (Collar et al. 1992). In southern Brazil, 25% of natural grasslands were lost over the past 30 years due to the expansion of agricultural activities (Overbeck et al. 2007). Similar to North America (Vickery et al. 1999, Askins et al. 2007), this habitat loss has led to the steep declines several obligate grassland breeding bird populations which are now globally or regionally threatened with extinction (Bencke et al. 2003, Bencke 2009, IUCN 2019). Prominent examples of these declines and local extinctions are the Pampas Meadowlark (*Sturnella defilippii*; Tubaro & Gabelli 1999), the Strange-tailed Tyrant (*Alectrurus risora*; Di Giacomo & Di Giacomo 2004) and most *Sporophila* seedeaters, which are endemic and some of the most characteristic elements of the South American avifauna (Silva 1999). However, effective conservation initiatives are hampered by the poor knowledge on basic aspects of their biology such as nesting habitat requirements (Cody 1985, Collar et al. 1992, Vickery et al. 1999).

Sporophila seedeaters inhabit grassy and shrubby areas, marshes and forest edges (Schauensee 1952). This genus encompasses the "capuchinos" group that is composed of obligate grassland specialists that usually breed in tall and dense grasslands, in both dry and wet habitats (Vickery et al. 1999, Bencke 2009). Specifically, the Tawny-bellied Seedeater (*Sporophila hypoxantha*) is migratory and winters in the grasslands of the *Cerrado* biome in central Brazil and in Bolivian savannahs, migrates in October/November to its breeding grounds in southern Brazil, Uruguay and northeastern Argentina, and returns in February and March to the wintering sites (Silva 1999, Areta & Repenning 2011, Areta 2012, Franz & Fontana 2013). This species has been generally described to breed in dry shrubby grasslands

and in marshes or wet grasslands (Areta & Repenning 2011), but no study so far evaluated its fine scale habitat requirements and selection of nesting sites. As the Tawny-bellied Seedeaters are declining and considered regionally 'vulnerable' (Franz et al. 2013), it is important to understand their nest site selection for the development of successful conservation initiatives.

Furthermore, differences in habitat selection within populations or closely related species may also play a role in speciation (Lack 1940), which may be the case for the capuchinos group, which experienced rapid adaptive radiation (Lijtmaer et al. 2004, Campagna et al. 2009, Campagna et al. 2011). Traits related to ecology, especially habitat preferences have been key for understanding the evolutionary relationships within the genus *Sporophila*, particularly among the capuchinos (see Areta 2008, Repenning et al. 2010, Areta & Repenning 2011, Areta et al. 2011). Although the general aspects of habitat used for most capuchinos have been described, little is known about the specific characteristics of the nesting microhabitats required by most species.

Here we describe the nesting habitats selected by Tawny-bellied Seedeaters over three breeding seasons. Specifically, we describe fine scale vegetation structure and composition, slope and burning practices, and compare sites selected and unoccupied by nests. We then discuss how Tawny-bellied Seedeater nesting sites compare to other capuchinos species and propose management measures aimed to maintain habitat structure required for its nesting.

Materials and Methods

Study area

We conducted the study in hilly, dry grasslands along the Lava-Tudo River, near the cities of São Joaquim and Lages, Santa Catarina state, southern Brazil (central point: 28°18'40"S; 50°17'50"W). The study site is a contiguous area of approximately 400 ha, with elevation ranging from 800 to 1,000 m above sea level. Vegetation is mainly composed of shrubs, herbs (mostly Asteraceae), grasses (Poaceae), eryngoes (Apiaceae) and small scattered trees (see Franz & Fontana 2013). At this site, grazing occurs at low intensity due to low cattle density and prescribed burning occurs biannually.

Data collection

Data collection took place during three breeding seasons (November to March) from 2007 to 2010, and 26 active nests of Tawny-bellied Seedeaters were monitored (see Franz and Fontana 2013). Nests were mapped and, at the end of each breeding season, we assessed floristic composition and vegetation structure within five 4 m² plots (2 x 2 m). One plot was centered on the nest and four additional plots were placed 10 m distant from the center plot in each of the main cardinal directions. For each set of five plots near the nest (i.e. selected site), we established five neighbor control plots, randomly placed in the same grassland matrix and up to 100 m distant from the nearest occupied territory (i.e. unoccupied site). Thus, we sampled the same number of plots for selected and unoccupied sites (n = 130 in each group) in a paired design.

Vegetation structure, slope and burning

For each of the 260 plots, standardized measures of vegetation structure as well as data for slope and off-season burning were collected. We first distinguished two vertical strata of the vegetation: (1) lower stratum, which consisted of grasses, small herbs, climbers, and a high density of shrubs and grass tussocks, usually not more than 1 m high; and (2) higher stratum, composed of emerging tall grass stems (e.g., *Saccharum* spp.), eryngoes stems (*Eryngium horridum*) and sparse trees sometimes exceeding 2 m tall. In each plot, we used the canopy-coverage method (Daubenmire 1959) to measure the proportion (%) of bare ground, and lower stratum vegetation covering the plot. Vegetation height was determined by measuring the height of the tallest plants for each stratum using the Robel Pole technique (Robel et al. 1970). Vegetation density was estimated using a colored plate 100 cm high by 80 cm wide, set vertically in one side of the plot. We then observed the plate from the opposite side of the plot (2 m distance) controlling the viewpoint to be 80 cm from the ground and estimated the proportion of the plate that was obstructed. The slope of each plot was determined by using a clinometer facing the plot from 5 m away perpendicular to the hill. We also quantified the presence/absence of off-season burning (generally conducted between July and September in the study area) from the occurrence of burn marks on the base of shrub stems. In addition, each plot was classified according to three habitat types: (1) dry grasslands - marked by a rich diversity of herbs, shrubs and grasses with sparse small trees; (2) rocky grasslands - characterized by shallow soil with basalt outcrops and lower vegetation density; and (3) wet grasslands - consisting of patches of wet grasslands near streams, composed of plant species typical of wetlands (e.g. *Ludwigia sericea*, *Eryngium chamissonis* and several Juncaceae and Cyperaceae).

Floristic composition

The floristic composition was assessed by counting the number of individuals of each plant species present within each plot. For grasses and eryngoes we counted the number of individual clumps and stems, which are structurally distinct and define food availability (i.e. grass seeds) and perches. Plants were identified in the field, using a reference collection, or by experts (IIB).

Statistical Analysis

Aiming to ensure the independence of the data, each set of five plots was described as the average of the sample unit, resulting in 52 sampling units (26 for each group: selected or unoccupied sites). In order to access the effect of each predictor variable (i.e. percent of bare ground, percent of shrub cover, vegetation height - lower stratum, vegetation height - higher stratum, off-season burning, vegetation density, habitat type and slope) on nest occurrence (presence/absence), we used a model selection and multimodel inference approach, within an information-theoretic framework (Anderson 2008, Burnham and Anderson 2002), fitting generalized linear models using binomial error distribution (binomial GLM). Before model selection we used Spearman's correlation to test for multicollinearity in the predictor variables, considering correlated when $r > |0.60|$, which resulted in the exclusion of 'height' and 'cover' of the medium/intermediate stratum, which are correlated with our variable 'shrub cover'. We used Akaike Information Criterion corrected for small sample sizes (AICc) to evaluate model plausibility (Anderson

2008, Burnham and Anderson 2002). We then calculated the weight of each possible model (w_i), which is the relative likelihood of the model given the data normalized across the set of candidate models to sum to one (Burnham & Anderson 2004, Johnson & Omland 2004). We performed model averaging to assess the relative importance of each predictor (Burnham & Anderson 2002). The relative importance ranges from 0 to 1, and larger values indicate larger relative importance of a predictor. As our main goal was to estimate the relative importance of the environmental variables and not temporal variations, we followed an approach used in Garcias et al. (2018) to decide whether sampling years should be included in the models. Specifically, we compared two distinct models: (i) a binomial GLM containing the environmental predictors and sampling year as a fixed factor, and (ii) a binomial GLM containing all environmental predictors, disregarding sampling period. As this last model had the highest plausibility (AICc weight = 0.79), we did not include sampling year in the final model selection and model averaging. All analyses were carried out in the R package *glmulti* (Calcagno & Mazancourt 2010).

In order to evaluate variation in floristic composition across sites we performed a Principal Coordinates Analysis (PCoA) using Euclidean Distance as the partition method using Multiv v.2.4 (Pillar 2006). The input data was the numbers of individuals of each plant species pooled within each set of five plots. For this analysis, we excluded herbaceous plant species with less than 30 individuals in total considering all plots, except for treelets and trees, which are scarce in grasslands but often play important role as perches. The data were submitted to a vectorial transformation by double adjustment (deviations from expected values via marginal totals) prior to this analysis, taking into account the expected frequency of each species given its relative abundance within the plot, when compared to the local abundance of the other co-occurring species, and its abundance between plots, along the entire gradient. We evaluated the stability of ordination axes (three axes) using bootstrap resampling (Pillar 2009), running 1,000 iterations. To test whether selected and unoccupied sites differed in floristic composition, we conducted a MANOVA using randomization test (Orlóci & Pillar 1996). Results are presented as mean $\pm$ standard deviation and the significance level to reject the null hypothesis was set a priori to $\alpha = 0.05$.

Results

We observed 26 Tawny-bellied Seedeater nests and measured habitat at 130 plots around each nest and another 130 in unoccupied plots. Of the selected plots, 63 (48%) were in dry grasslands and 67 (52%) were in rocky grasslands. Of the unoccupied plots, 91 (70%) were in rocky grasslands, 34 (26%) were in dry grasslands and five (4%) were in wet grasslands. We recorded 9,137 individuals of 91 plant species across all 260 plots observed. Of these plant species, 25 of them, including two tree species, had more than 30 individuals accounting for 5,274 (57.8%) individuals in selected sites and 3,594 (39.3%) in unoccupied sites (Table 1).

Table 1

Mean numbers of individuals of each plant species per plot in selected sites (n = 130) and sites unoccupied (n = 130) by nesting Tawny-bellied Seed eaters (*Sporophila hypoxantha*) in southern Brazilian upland grasslands. Shown are only the species with more than 30 individuals detected across sites and trees species.

Plant species	Selected sites		Unoccupied sites	
	Mean $\pm$ SD	Total	Mean $\pm$ SD	Mean $\pm$ SD
Shrubs				
<i>Symphyopappus compressus</i>	2.5 $\pm$ 3.7	334	1.6 $\pm$ 2.2	218
<i>Disynaphia multicrenulata</i>	0.7 $\pm$ 2.7	99	2.0 $\pm$ 4.1	265
<i>Grazielia serrata</i>	0.1 $\pm$ 0.8	22	0.2 $\pm$ 0.9	34
<i>Chromolaena laevigata</i>	0	0	0.4 $\pm$ 1.4	56
<i>Vernonanthura chamaedrys</i>	2.7 $\pm$ 2.7	387	2.2 $\pm$ 3.3	287
<i>Baccharis caprariifolia</i>	2.8 $\pm$ 3.4	373	1.0 $\pm$ 2.6	130
<i>Baccharis cognata</i>	1.0 $\pm$ 2.6	135	0.4 $\pm$ 1.4	61
<i>Baccharis dracunculifolia</i>	0	1	0.3 $\pm$ 1.7	45
<i>Baccharis coridifolia</i>	0.6 $\pm$ 2.0	85	0.3 $\pm$ 2.0	46
<i>Baccharis rufescens</i>	1.4 $\pm$ 2.4	198	1.3 $\pm$ 2.4	170
<i>Baccharis stenocephala</i>	0.5 $\pm$ 1.5	68	0.5 $\pm$ 1.6	64
<i>Baccharis crispa</i>	0.4 $\pm$ 2.1	61	0.6 $\pm$ 1.8	88
<i>Baccharis ochracea</i>	0.4 $\pm$ 1.4	52	0.3 $\pm$ 1.5	43
Grasses				
<i>Andropogon lateralis</i>	9.2 $\pm$ 10.3	1,223	3.6 $\pm$ 5.6	473
<i>Andropogon virgatus</i>	5.7 $\pm$ 8.4	745	3.5 $\pm$ 6.0	455
<i>Saccharum angustifolium</i> (clump)	3.3 $\pm$ 4.7	431	1.3 $\pm$ 2.5	175
<i>Saccharum angustifolium</i> (stem)	1.9 $\pm$ 3.0	248	1.2 $\pm$ 2.5	159
<i>Schizachyrium</i> sp.	1.3 $\pm$ 6.8	170	1.1 $\pm$ 9.7	150
<i>Eriochrysis cayennensis</i>	0.4 $\pm$ 1.5	63	0.5 $\pm$ 2.1	63
Eryngoes				
<i>Eryngium horridum</i>	1.8 $\pm$ 2.9	263	3.1 $\pm$ 3.8	411
<i>Eryngium elegans</i>	1.5 $\pm$ 4.8	199	0	0

Plant species	Selected sites		Unoccupied sites	
	Mean $\pm$ SD	Total	Mean $\pm$ SD	Mean $\pm$ SD
<i>Eryngium pristis</i>	0.5 $\pm$ 3.2	75	0	0
Small trees				
<i>Schinus terebinthifolius</i>	0	4	0.1 $\pm$ 0.6	17
<i>Lithraea brasiliensis</i>	0	0	0	5
<i>Escallonia megapotamica</i>	0	11	0.8 $\pm$ 1.9	108
Herbs				
<i>Cunila incana</i>	0	2	0.2 $\pm$ 1.1	31
<i>Pterocaulon polystachyum</i>	0.1 $\pm$ 0.7	25	0.3 $\pm$ 0.9	40

The first axis of the PCoA explained 21.7% of the variation in the data, while the second axis explained 12.8% (Fig. 1). The randomization test indicated significant difference ($P = 0.006$) in the floristic composition between selected and unoccupied sites. The lower stratum of selected sites was dominated by the grasses *Andropogon lateralis* ($n = 1,223$ individuals), *A. virgatus* ($n = 745$), and *Saccharum angustifolium* ($n = 431$) but also had high amounts of the eryngo *Eryngium elegans* ($n = 199$), shrubs such as *B. caprariifolia* ($n = 373$), *Vernonanthura chamaedrys* ($n = 387$) and *Symphypappus compressus* ($n = 334$). Unoccupied sites also had *A. lateralis* and *A. virgatus* but in much lower abundances (473 individuals and 455 individuals, respectively). On the other hand, the unoccupied sites had a prominent presence of small trees, especially *Escallonia megapotamica* ($n = 108$), and of the eryngo *Eryngium horridum* ($n = 411$).

The three best models ($\Delta AICc < 2$) indicate that selected sites were influenced by five predictors measured (Table 2). Bare ground ($\bar{X} = 6.1 \pm 12.9\%$ in selected plots, $\bar{X} = 7.2 \pm 13.3\%$ in unoccupied plots), shrub cover ($\bar{X} = 78.4 \pm 21.2\%$ in selected plots, $\bar{X} = 50.2 \pm 31.5\%$ in unoccupied plots) and height of the lower stratum ($\bar{X} = 95.0 \pm 18.1$ cm in selected plots, $\bar{X} = 84.6 \pm 14.8$ cm in unoccupied plots) were the most influential predictors of nest occupancy (i.e. highest weights; Fig. 2), and the strongest effect observed was shrub cover (Table 3).

Table 2

Top models ($\Delta AICc < 2$) testing the influence of vegetation variable, burning (not selected), and slope on occupation of sites by nests of the Tawny-bellied Seedeater (*Sporophila hypoxantha*) in southern Brazilian upland grasslands. Bare ground and shrub cover are percentages.

Model	AICc	$\Delta AICc$	Weight
bare ground + shrub cover + height lower stratum	37.38	0.00	0.21
bare ground + shrub cover + height lower stratum + vegetation density	38.77	1.40	0.10
bare ground + shrub cover + height lower stratum + slope	39.27	1.90	0.08

Table 3

Model averaged parameter estimates of the vegetation structure and slope on the occupancy of nests of Tawny-bellied Seedeaters (*Sporophila hypoxantha*) in southern Brazilian upland grasslands.

Predictors	Parameter Estimate	Unconditional Variance
Bare ground (%)	-2.5141479	0.97267026
Height (lower stratum)	2.6439648	1.50727636
Shrub cover (%)	3.1259345	1.17207595
Slope	-0.1040663	0.06101852
Vegetation density	-0.1560510	0.09524995

Discussion

We show that Tawny-bellied Seedeaters nest in dry or rocky grasslands with more shrub cover, less bare ground, and higher densities of vegetation less than 1 m. On the other hand, the species avoid nesting in grassland areas characterized by a greater density of the emerging stratum (i.e. vegetation above 1 m in height). In fact, clumps of *Andropogon* spp. and *Saccharum* spp. and shrubs such as *Vernonanthura chamaedrys*, *Baccharis caprariifolia* and *Symphyopappus compressus* are abundant in the study area (Table 1) and such plant species are the most often used species as support for nests (Franz and Fontana 2013, 2021). While dry shrubby grasslands with remarkable presence of such plants seems to be preferentially used by Tawny-bellied Seedeaters, dry grasslands with patches of *Escallonia megapotamica* and *Eryngium horridum* are avoided (Table 1).

Unoccupied sites included also mainly rocky grasslands characterized by steeper slope and lower floristic diversity, where species such as *Disynaphia multicrenulata* are dominant. In such sites, however, shrubs in which Tawny-bellied Seedeaters commonly build nests (Franz & Fontana 2013) rarely occur, so this type of grassland may provide lower quality nest sites than dry grasslands. The increased diversity and presence of important plant species for Tawny-bellied Seedeater nesting in dry compared to rocky grasslands may be explained by the deeper soils in these areas. Furthermore, steep areas with dry soil,

rocky grasslands and high densities of *Escallonia megapotamica* are commonly used as nesting sites for Tropeiro Seedeaters (*Sporophila beltoni*) (Repenning 2012, Repenning & Fontana 2019), possibly suggesting spatial segregation between these sympatric congeneric species. In fact, instances of spatial segregation based on vegetation structure are common among sympatric grassland birds (Cody 1985). This reinforces the hypothesis that habitat segregation may be one of the most important barriers fostering speciation in *Sporophila* seedeaters (Sick 1967).

Despite previous reports of Tawny-bellied Seedeaters nesting in both dry and wet grasslands, they have been more commonly associated with wet sites (Ridgely & Tudor 1989, Belton 1994, Sick 1997, Azpiroz 2001, Bencke et al. 2003). The preferred breeding habitat varies geographically with the five known “regiolects” (regional song dialects; Areta & Repenning 2011), and this differentiation may have been favored by the patchiness of dry shrubby grasslands. In this study, we confirmed the dependence of the “southeastern Brazil regiolect” on dry grasslands rich in shrubs (high shrub cover). In Argentina (Reserva El Bagual), despite nesting also in lowlands dominated by *Paspalum intermedium* and *Sorghastrum pellitum*, 90% of the nests of Tawny-bellied Seedeaters were found in tall and dry grasslands dominated by *Imperata brasiliensis* and *Elionurus muticus* or *Andropogon lateralis* (Di Giacomo 2005), which may indicate a preference for dense dry grasslands.

Notwithstanding Tawny-bellied Seedeater occurring sympatrically with other capuchinos, there is low overlap and high specialization for nesting sites. Although, another capuchino, the Black-bellied Seedeater (*Sporophila melanogaster*) which also occurs in the study area and breeds only in southern Brazil, showed a similar trend than Tawny-bellied Seedeater, selecting nest areas with a dense mid-stratum in both dry grasslands and wetlands (Rovedder & Fontana 2012), but apparently favoring the latter (Repenning et al. 2010). Marsh Seedeaters (*S. palustris*) breed exclusively in wet grassland habitats (Vizentin-Bugoni et al. 2013), while Chestnut Seedeaters (*S. cinnamomea*) nests preferably on dry ridges or valleys of grasslands with gentle slopes and - less frequently - in marshes or wet and dry grasslands dominated by *Eryngium horridum* and *Cardus* spp. (i.e. *Caraguatal-Cardal* grasslands) (Areta 2008). The latter is also the preferred habitat of the Dark-throated Seedeater (*S. ruficollis*), which also breeds in Pampas grasslands, “undulating” grasslands, and annual crops (Areta et al. 2011). The recently described Iberá Seedeater (*S. iberaensis*) apparently nests in marshes and wet grasslands dominated by tall grasses such as *Paspalum durifolium* (Poaceae) and *A. lateralis* (Turbek et al. 2019).

In southern Brazil, cattle ranching is one of the most important economic activities conducted in areas of natural grasslands (Nabinger et al. 2000). The intensity of grazing and associated management practices, such as burning, directly influences vegetation structure and composition and, therefore, affects directly the reproduction of grassland birds. Agriculture intensification and overgrazing are known to affect Tawny-bellied Seedeater populations. This species, as well as the Dark-throated Seedeater, were unable to persist in areas where agriculture was increased from 20 to 60% (Filloy & Bellocq 2006). Under low grazing intensity, upland grassland environments tend to be dominated by tall grasses (e.g., *Andropogon* spp. and *Schizachyrium* spp.) and shrubs such as *Vernonanthura* spp. and *Baccharis* spp. (Asteraceae) (Behling & Pillar 2007). As we show here, these plants are important for

Tawny-bellied Seedeater nesting, suggesting that low-intensity grazing can be beneficial to the species. As for other capuchinos, overgrazing negatively affects nesting habitats, but at low or moderate intensity, grazing may maintain vegetation structure and composition required by this species. Thus, adopting the best management practices, cattle ranching is an economic activity compatible with Tawny-bellied Seedeater conservation and is certainly a less harmful alternative land use than agriculture or forestry (Areta 2008, Franz et al. 2013).

Fire is often used to inhibit encroachment and induce growth of fresh pasture for cattle grazing. Thus, burning may produce high quality habitat by reducing woody encroachment (Duquette et al. 2019) allowing *Baccharis* spp. and other shrub species to thrive (Müller et al. 2007). Additionally, burning tends to increase the proportion of bare ground, which we found to be negatively associated with Tawny-bellied Seedeater nesting. Some plant species that were abundant in unoccupied sites, such as *Eryngium horridum*, become more abundant after burning (Fidelis et al. 2008), which may decrease the habitat quality for Tawny-bellied Seedeater nesting. Furthermore, Franz & Fontana (2021) found that burning, along with cattle trampling, was responsible for 9% of unsuccessful Tawny-bellied Seedeater nesting attempts at the same study site. Therefore, burning may have an overall positive effect on Tawny-bellied Seedeater site selection and nesting when it occurs before the breeding period (until early August) and with moderate intensity (if possible, skipping 2–3 years without burning), allowing maintenance of the shrubby stratum. Thus, two extreme management practices could potentially harm grassland structure and consequently its use by seedeaters and other grassland specialists: (1) fire exclusion; and a (2) high intensity regime of fire combined with overgrazing (Buisson et al. 2018).

In sum, this study presents the first in-depth assessment of the Tawny-bellied Seedeater nesting habitat requirements. Our findings deepen the knowledge about its breeding biology (Di Giacomo 2005, Facchinetti et al. 2008, Franz & Fontana 2013, 2021) and supports the conclusion that the Tawny-bellied Seedeater depends on dry grasslands with high density of grasses and tall Asteraceae shrubs. Although this species is associated with several open habitats during its life cycle, our more-detailed analysis reveals that it selects certain types of grasslands within a complex mosaic of distinct grassland types. Initiatives aimed at the conservation of this species within existing or newly protected areas should, therefore, include management techniques, such as low-intensity grazing, take place that promote the shrub grassland habitat required for its nesting.

Declarations

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Author Contributions

IF: Conceptualization, data collection, investigation, analysis, writing, review; EC: writing, review; VAGB: writing, analysis; IIB: review, methodology; CSF: conceptualization, resources, supervision, writing, review.

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Figures

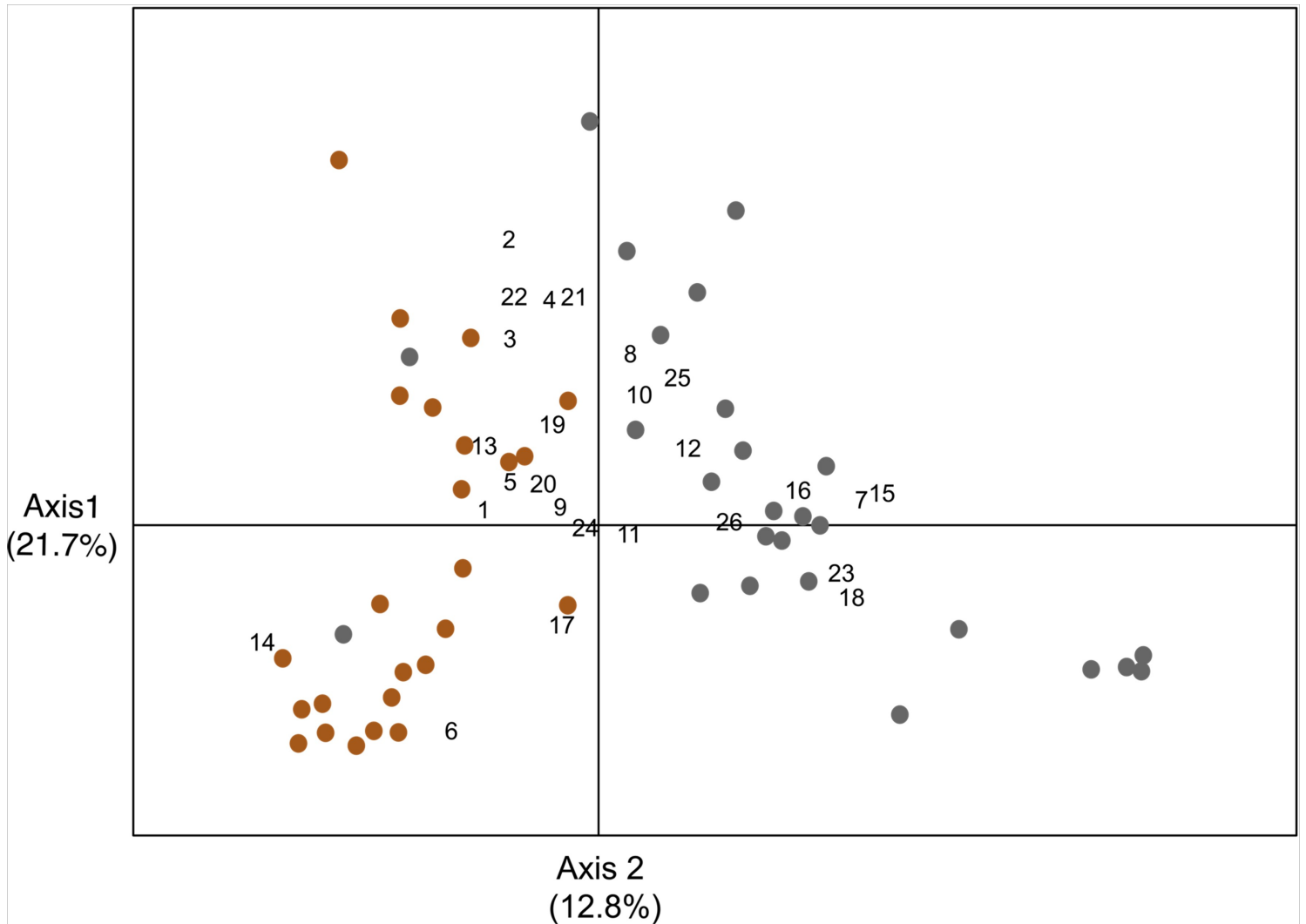


Figure 1

Ordination of selected sites (orange dots) and sites unoccupied (gray dots) by nests of Tawny-bellied Seedeaters (*Sporophila hypoxantha*) in southern Brazilian upland grasslands. The scatter diagram is defined by ordination axis 1 and 2 generated by Principal Coordinates Analysis (PCoA) using the Euclidean Distance calculated with the abundance data of 27 plant species observed at each site. The percentage of total variation represented by the Axis is indicated in the parentheses. The position of the numbers, 1 to 27, represent the loadings of the most common plant species present in each site. Plant species: 1 *Symphypappus compressus*, 2 *Disynaphia multicrenulata*, 3 *Grazielia serrata*, 4 *Chromolaena laevigata*, 5 *Vernonanthura chamaedrys*, 6 *Baccharis caprariifolia*, 7 *B. cognata*, 8 *B. dracunculifolia*, 9 *B. coridifolia*, 10 *B. rufescens*, 11 *B. stenocephala*, 12 *B. crispa*, 13 *B. ochracea*, 14 *Andropogon lateralis*, 15 *A. virgatus*, 16 *Saccharum angustifolium* (clump), 17 *S. angustifolium* (stem), 18 *Schizachyrium* sp., 19 *Schinus terebinthifolius*, 20 *Lithraea brasiliensis*, 21 *Escallonia megapotamica*, 22 *Eryngium horridum*, 23 *E. elegans*, 24 *E. pristis*, 25 *Cunila incana*, 26 *Pterocaulon polystachyum*, 27 *Eriochrysis cayennensis*.

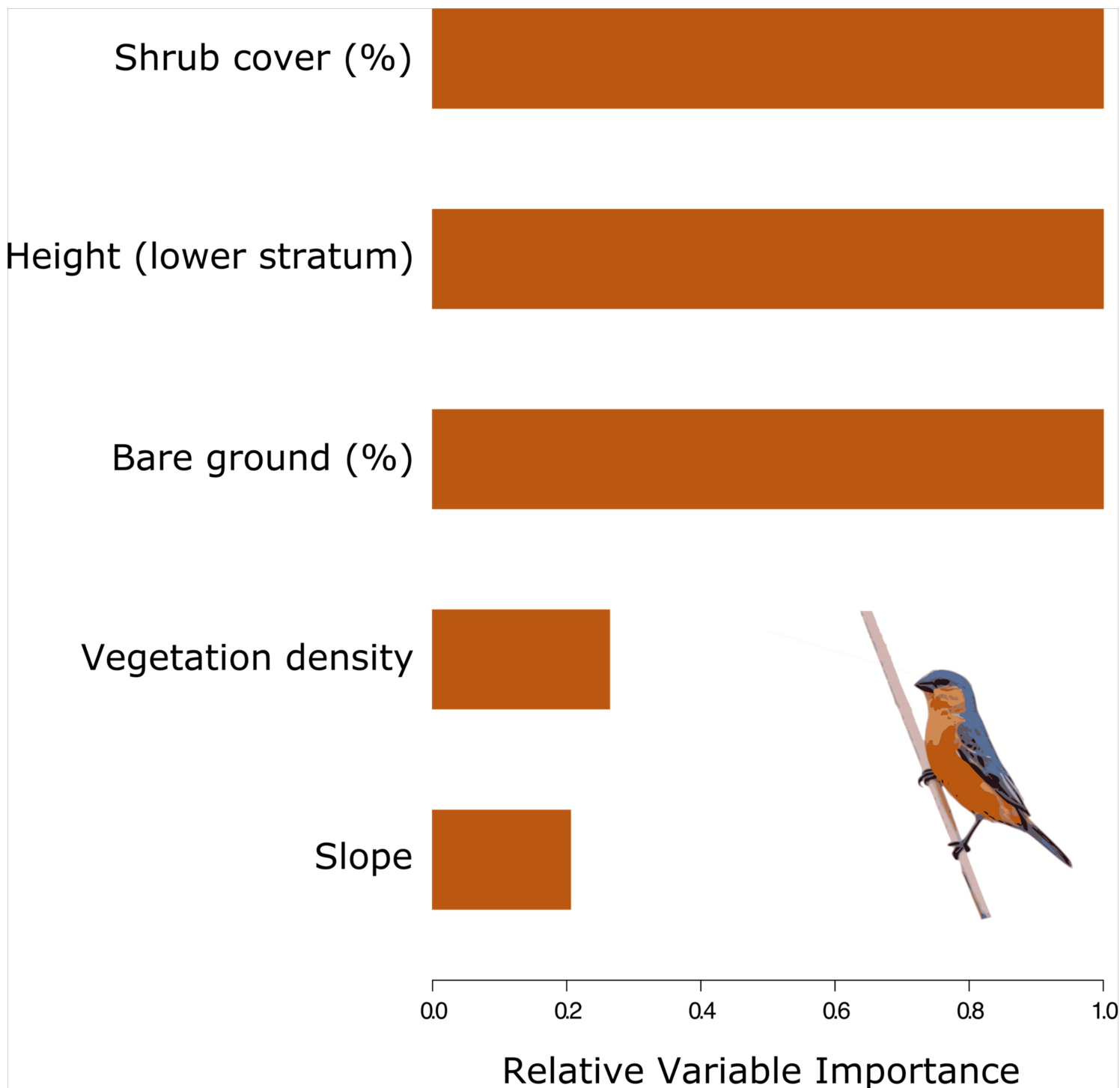


Figure 2

Model-averaged importance of the vegetation structure variables and slope on the occupancy of sites by nests of Tawny-bellied Seedeaters (*Sporophila hypoxantha*) in southern Brazilian upland grasslands.