

MACRO AND MICRO-HABITAT SELECTION BY *VANELLUS CHILENSIS* (AVES: CHARADRIIFORMES) IN SOUTHERN BRAZIL

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ABSTRACT.- The Southern Lapwing (*Vanellus chilensis*) is a typical bird from southern Brazil, but it is widely distributed across South America. It is well-recognized by its characteristic colors, imposing vocalization and aggressive behavior. The species inhabits grasslands, which can vary locally and regionally. The aim of this study is to evaluate how Southern Lapwings select their macro- and micro-habitats, which is necessary to better understand the species' ecology, its relationship with the environment and the complex interaction between behavior and territory. This research intends to verify if there is any kind of selection for a specific environment and which factors influence the choice of feeding and breeding territories. Fieldwork was carried out at 40 ha in the state of Rio Grande do Sul, with 60 sampling points divided across six different vegetal formations. For macro-habitats, we analyzed data on availability and use of the area through the selection index, while for micro-habitat selection we constructed Generalized Linear Models (GLM) with the measures of environmental variables for each point. The selection index indicates that there is a strong preference for impacted grasslands, while lapwings seem to avoid forests and shrubland during both breeding and non-breeding seasons. The micro-habitat analysis indicates that the birds generally select areas with low vegetation height, and a certain degree of local human impact, but that the presence of farm animals is only preferred during the non-breeding season. This study shows that the Southern Lapwing can benefit from anthropic and altered environments, and it contributes to the understanding of this bird's ecology and facilitates conservation measures.

KEYWORDS: *anthropization, grasslands, habitat selection, lapwing, Southern Lapwing, synanthropy.*

RESUMEN.- SELECCIÓN DE MACRO Y MICROHÁBITAT POR *VANELLUS CHILENSIS* (AVES: CHARADRIIFORMES) EN EL SUR DE BRASIL. El Tero Común (*Vanellus chilensis*) es un ave típica del sur de Brasil, pero se encuentra ampliamente distribuida por América del Sur. Es bien reconocido por sus colores característicos, imponente vocalización y comportamientos agresivos. La especie habita en pastizales, que pueden variar local y regionalmente. El objetivo de este estudio es evaluar cómo el tero-tero selecciona sus macro y micro hábitats, lo cual es necesario para comprender mejor la ecología de la especie, su relación con el medio ambiente y la compleja interacción entre comportamiento y territorio. Esta investigación pretende verificar si existe algún tipo de selección para algún ambiente específico y qué factores influyen en la elección de los territorios de alimentación y reproducción. El trabajo de campo se realizó en 40 hectáreas en el estado de Rio Grande do Sul, con 60 puntos de muestreo divididos en seis formaciones vegetales diferentes. Para macrohábitats, analizamos los datos de disponibilidad y uso de la zona a través del índice de selección, mientras que para la selección de microhábitats construimos Modelos Lineales Generalizados (GLM) con las medidas de las variables ambientales para cada punto. El índice de selección indica que hay una fuerte selección de campos impactados, mientras que las aves parecen evitar los bosques y campos arbustivos durante las temporadas reproductivas y no reproductivas. El análisis de microhábitat indica que las aves generalmente seleccionan áreas con baja altura de vegetación y un cierto grado de impacto humano local, pero que solo prefieren la presencia de animales de granja durante la temporada no reproductiva. Este estudio muestra que el tero-tero puede beneficiarse de ambientes antrópicos y alterados, y contribuye a la comprensión de la ecología de esta ave.

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The distribution of animal populations across time and space varies according to a series of ecological variables in a given environment (Bell et al. 1994, Baudains and Lloyd 2007). Habitat selection is a behavioral response in animals, either innate or learned, which allows them to recognize and distinguish various environmental elements, resulting in a

differential use of the available resources (Block and Brennan 1993). This selection is observed through the distribution of species across the various types of environments in which they live, as a result of macro-environmental factors, which encompass the entire environment (Manly et al. 2002). Habitat selection also depends on micro-environmental factors,

such as the selection of specific characteristics that benefit both the species and the individual, like temperature, vegetation height, type of vegetation, water and food availability (Hutto 1985, Block and Brennan 1993, Manly et al. 2002). The decision on where to nest and/or forage, given the variety of available areas, can be complex and significant for the survival of a bird species, since this choice directly affects the individuals' reproductive fitness and survival (Doligez and Boulinier 2008).

The Southern Lapwing *Vanellus chilensis* is a medium-sized bird (255–277g in weight, and 35–37cm full length), whose distribution spans from central-southern Ecuador and central-eastern Brazil to southern Argentina (del Hoyo et al. 1992, Santos 2010). This is a species that inhabits a large variety of environments, commonly occurring in both dry and wet natural grasslands, coastal regions (Santos 2010), anthropized grasslands (Moretti and Evangelista 2008, Kamp et al. 2015) and urbanized areas (Costa 2002). The Southern Lapwing displays a wide array of social and agonistic behaviors (Costa 2002, Delfino and Carlos 2020) related to intraspecific and interspecific interactions, including human beings, resulting from the species' territorial and aggressive characteristics (Delfino and Carlos 2020).

Despite the Southern Lapwing's broad geographic distribution across South American grasslands, the open plant formations in South America feature quite heterogeneous characteristics (Pillar et al. 2009) with regional specificities. These range from microclimatic components, such as relative humidity and temperature (Pillar et al. 2009), the presence of certain animal species and distinct plant formations, to varying degrees of anthropic impact and human usage of these ecosystems (Sell and Figueiró 2011). The difference between these environments implies that there may be some selectivity in the criteria employed by the species, favoring certain formations over others during feeding and breeding (Krebs and Davies 1997).

Given the intrinsic relationship between individuals and their environment, it is necessary to identify the preferred habitats of a species to comprehend its ecology (Lorenz 1995), and the complex interaction between behavior and territoriality (Fretwell and Lucas 1969, Murray 1971). This is particularly important in species where aggressive interactions are prominent in their behavioral repertoire, as is

the case for the Southern Lapwing (Delfino and Carlos 2020). Studies on the Southern Lapwing in this sense also support the creation of animal management plans that minimize conflicts in places where this species and human beings overlap, as in parks, squares and football fields (Shwartz et al. 2008, Kamp et al. 2015). Furthermore, this information could help elucidate which factors influence the presence of these birds in certain natural environments, and how changes to it could affect their populations (Krebs and Davies 1997), assisting in the elaboration of management plans for these environments.

Therefore, the goal of this work is to investigate the habitat selection process of the Southern Lapwing within an urbanized area of southern Brazil's Rio Grande do Sul state, verifying (i) its preference for certain phytophysiognomies, or types of environment, at the macro-habitat scale; (ii) which environmental factors affect the decision of feeding and nesting territories, at the microhabitat scale; (iii) and verifying if there is a change in environmental selection between the species' breeding and non-breeding seasons.

METHODS

Study Area

The study was performed in an area of approximately 40 hectares in the municipality of Torres (29°20'07"S, 49°43'37"W), Rio Grande do Sul, during the months of April and July 2018. The region's climate is typically humid subtropical (Peel et al. 2007), with an average temperature of 19.3° C, and an annual relative humidity of 83% (Wrege et al. 2011). The area is located in the countryside, next to the Itapeva State Park, and features a considerable heterogeneity of environments, such as forest, impacted and clean grasslands, fields with bushes, flooded areas, and anthropized areas, the latter represented by roads and a few houses. The area is used for foraging and nesting by a population of Southern Lapwing (Delfino and Carlos 2020). Part of the area is employed as a place for sheltering and raising domestic animals, and for extensive animal husbandry, in addition to presenting a certain degree of anthropization due to previous usage of the area as a disposal area for construction material and waste. Coexisting with the Southern Lapwings, there are farm animals like horses and cattle (HCD, personal observation).

Fieldwork

Habitat selection was evaluated in two categories. The first category at a macro-habitat scale presented six different vegetation physiognomies within the study area's landscape. Sampling was carried out through visual observation of the individuals in the study area and produced presence/absence data. The observations were performed in April 2018 (non-breeding season) and in July 2018 (breeding season). Six kinds of environments were evaluated (Pillar et al. 2009) (Fig. 1), namely:

i. Clean Grassland: characterized by non-woody, herbaceous ground plants and by the absence of bushy formations. Native pastures prevail and the soil is almost entirely covered by vegetation.

ii. Impacted Grassland: also characterized by a predominance of non-woody, herbaceous plants, such as various grasses. Here, there is human impact, such as construction materials and waste, in addition to greater soil exposure, which is sandier, constantly suffering from erosion.

iii. Bushy Field: there is a growth in bushy vegetation in this habitat, with prevalence of juvenile trees and small bushes. There are also large grass clumps, which makes the vegetation higher than in other habitats.

iv. Flooded Areas: consists of clean or impacted grasslands in which there is a prevalence of humid or flooded zones throughout almost the entire year. These regions may occasionally run dry, in places with prolonged droughts, but generally remain supplied with water due to southern Brazil's typical rain cycles.

v. Forest Areas: areas with higher and denser vegetation, featuring a more developed higher and intermediate layer, formed by woody, medium-sized species. Despite it being preserved for the most part, there may be human impact.

vi. Rural Areas under Urban Pressure: comprises areas where there is almost no vegetation, with exposed soil and/or with human infrastructure on the terrain, like houses, yards, and roads.

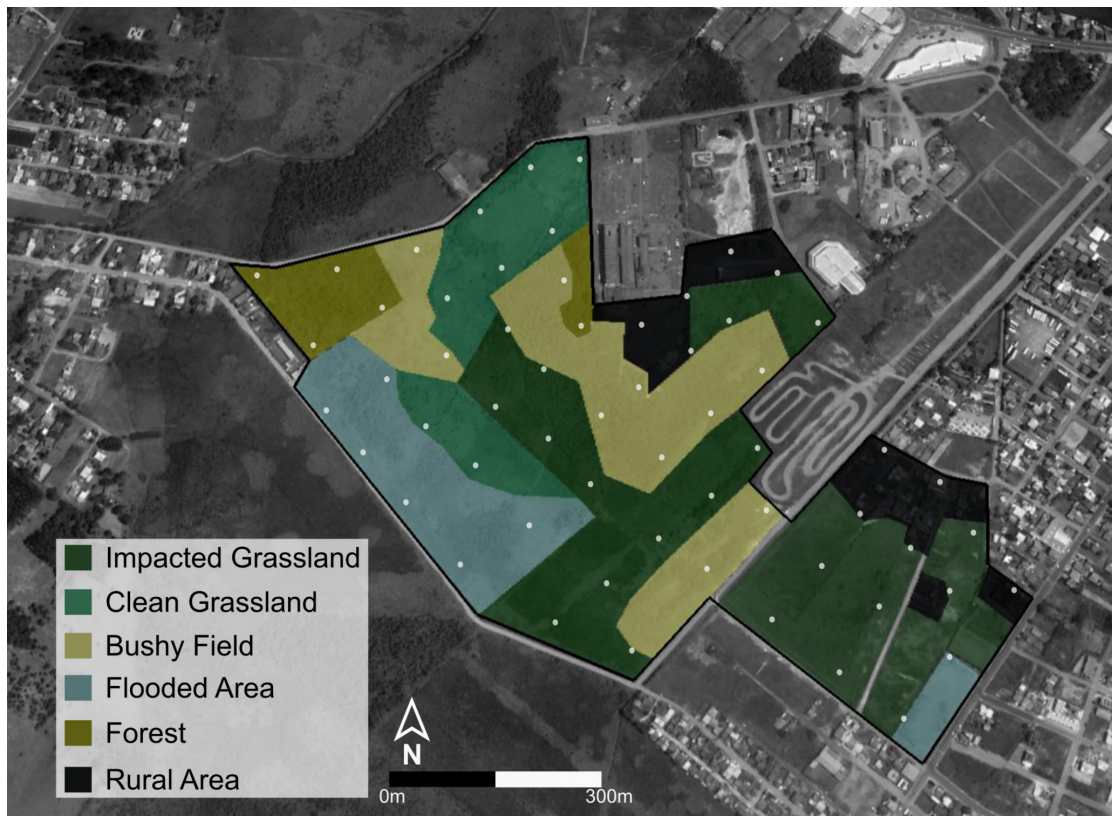


Figure 1. Map showing the six different types of environment that were analyzed in macro-habitat selection, in the limits of Torres city, southern Brazil. The white points indicate the sampling points of micro-habitat variables, distributed over the study area.

Table 1. Selection index (W) calculated from use and availability data of each environmental category, according to Neu et al. (1974) and Manly et al. (2002). Values below 0.85 indicate negative selection, values above 1.15 indicate positive selection, and values between 0.85 and 1.15 indicate neutral selection.

Environmental Category	Non-Breeding Season		Breeding Season	
	W	Selection Type	W	Selection Type
Clean Grassland	1.15	Neutral	1.13	Neutral
Impacted Grassland	1.42	Positive	1.6	Positive
Bushy Fields	0.36	Negative	0	Negative
Flooded Areas	1.11	Neutral	0.75	Negative
Rural Areas under Urban Pressure	2.12	Positive	2.5	Positive
Forest Areas	0	Negative	0	Negative

The percentage estimation for each of the habitat types was done based on on-site observation and analysis of satellite and aerial images from software such as Google Earth®.

The second category at a micro-habitat scale took on-site environmental variables into consideration, where breeding or non-breeding individuals were observed. As in the previous category, these variables were gathered in April 2018, during the species' non-breeding season, and in July 2018, during its breeding season. The identification of the life cycle stage of the individuals follows the behavioral descriptions of Delfino and Carlos (2020). Environmental characteristics that potentially influenced the occurrence of Southern Lapwings were logged at each point: soil cover, vegetation height, edaphic arthropod diversity, number of farm animals (e.g., cattle and horses) and degree of anthropization in the area. To obtain data at the micro-habitat scale, 60 points were sampled throughout the area, with 100 m between each point, and with caution to avoid overlap in data collection and assure sampling independence (Fig. 1).

Vegetation height and soil arthropod richness and diversity were estimated with the aid of a 30 x 30 cm board. Vegetation height was measured on the four sides of the board for subsequent averaging (Freitas and Magalhães 2012), while edaphic arthropod richness and diversity was accounted through the collection of a portion of the soil's surface and tallying the total number of organisms and orders found for 5 minutes at each point (Copatti and Daudt 2009).

Soil cover was determined on a scale from 0 to 100, where the first value corresponds to fully ex-

posed soils, and the last is fully covered by vegetation (Brower et al. 1997, Santos and Nucci 2019). The extent of anthropization was applied in a subjective manner by the observer, on a scale from 1 to 3, being: (1) native terrain; (2) partially affected land; and (3) lands highly altered by human activity, completely modified relative to the original vegetation. This scale takes three aspects into consideration: natural elements (e.g., fauna and flora), artificial elements (e.g., waste and pollutants) and human usage of the area (adapted from de Lima et al. 2004). The quantity of farm animals at each point was tallied through directly counting the number of cattle and horses in a radius of 50 meters from each point. Other types of farm animals do not occur in the area. Data collection was made by the same observer and followed procedures and protocols described in the literature to avoid biased evaluations (de Lima et al. 2004).

The occurrence of Southern Lapwing across the 60 points was assessed by direct observation of the birds by the same observer during five minutes per sampling point on five occasions in the month of April 2018 (non-breeding) and on another five occasions in July 2018 (breeding season), noting the presence or absence of the individuals through visual identification in a radius of up to 50 meters from the center of the point (Sutherland et al. 2004). All the observations were made during stable climatic conditions, without rain and strong winds, and during the afternoon. Flying birds were not counted (Sutherland et al. 2004).

Data analysis

To analyze macro-habitat selection, usage and availability of each environment type was examined

(Neu et al. 1974), comparing the number of present individuals in each environment to the number of expected individuals, by applying the chi-squared test (Krebs 1999). This data was also submitted to the Index Selection calculation (Manly et al. 2002), to verify which macro-habitat was selected or rejected by the birds, considering a tolerance range based on the dataset's standard error.

For analysis at the micro-habitat scale, during both non-breeding and breeding seasons, multicollinearity was verified by using Spearman's rank correlation and variance inflation factor (VIF) tests (Zuur et al. 2010). We sequentially removed highly significant correlated covariates, as well as covariates with the largest VIF (> 5). Subsequently, a generalized linear model (GLM) analysis was performed to verify the species' likelihood of presence at a given point, according to the study's variables. The models were made with the presence and absence data (Loeys et al. 2012) and were analyzed using the function `occu` from the UNMARKED package (Fiske and Chandler 2011).

The selection of models was done using the stepwise regression method, employing the Akaike Information Criterion (AIC), arranging them based on the criterion's weight (Burnham and Anderson 2002). A chi-squared test was performed to compare the variables' weights between non-breeding and breeding seasons (Krebs 1999). All data was normalized independently for each variable (Zar 2010) and all analyses were carried out in R software (R Core Team 2015).

RESULTS

Macro-habitat Selection

The study area was mainly composed of impacted grassland (29.4%), bushy (24.5%) and clean (22%) grasslands. The flooded areas contributed to 9.4%, forests to 8.4% and human areas to 6.2% of the total study area. With the goal of standardizing the study, changes in these proportions were disregarded between the two observed occasions (April and July), since there were no meaningful differences ($\chi^2 = 30$, $df = 5$, $P = 0.2243$).

We recorded 70 observations of Southern Lapwing individuals during the non-breeding season and 44 during the breeding season. Macro-habitat analysis indicated that the birds do not haphazardly

distribute themselves across the six habitats, but actively select certain environments of the landscape, during both the breeding season ($\chi^2 = 43.96$, $df = 5$, $P < 0.05$) as well as the non-breeding season ($\chi^2 = 58.27$, $df = 5$, $P < 0.05$).

The calculation of the selectivity index (Table 1) suggested that there is a positive selection related to human areas and impacted grasslands, whereas forested areas and "bushy" fields featured a negative selection, suggesting that individuals avoid these formations. In the case of "clean" grasslands and flooded areas, there was a neutral selection, which suggests that birds occupy these regions on occasion. Between non-breeding and breeding seasons, there was a fluctuation in habitat selection only for flooded areas: while during the non-reproductive season the selection was neutral, during the reproductive season it was avoided by the lapwings.

Micro-habitat Selection

Regarding micro-habitat selection, the correlation analyses indicated that there was a direct correlation between arthropod diversity and the other variables, a tendency that was confirmed by calculating the VIF, which surpassed the limit considered acceptable for the work (i.e., $VIF = 5$). This variable was therefore excluded from subsequent analyses. Fifteen models were obtained with the remaining variables, including all combination possibilities between them for non-breeding and breeding seasons, totaling thirty models analyzed (Table 2).

The generation of models and gradual stepwise selection through AIC indicated that the best model to explain the components that affect the occurrence of Southern Lapwing in the study area during the non-breeding season ($AIC = 189.13$, $AICw = 0.5$) is the one that includes vegetation height ($K = -2.84$, $P < 0.05$), the presence of farm animals (cattle and horses) in the area ($Z = 2$, $P = 0.03$) and the degree of human impact ($Z = 1.82$, $P = 0.04$) (Table 3). The first component was negatively related to the presence of the species, suggesting that there is a selection for environments with low vegetation, in addition to a positive correlation with more disturbed environments and environments with farm animals, showing a certain preference for these types of habitats.

During the breeding season, the most suitable model ($AIC = 187.92$, $AICw = 0.34$) included vegetation height ($Z = -2.34$, $P = 0.02$) and presence of farm

Table 2. All the models that were taken into consideration in the micro-habitat selection analysis. The models were constructed combining all four environmental variables remaining after correlation analyses and applied both in the non-breeding and the breeding season (hveg = vegetation height; numdom = number of farm animals; imphum= degree of anthropization; gcov= soil cover).

Model	Variables	Model	Variables
1	hveg	9	gcov + imphum
2	gcov	10	numdom + imphum
3	nundom	11	hveg + gcov + numdom
4	imphum	12	hveg + gcov + imphum
5	hveg + gcov	13	hveg + numdom + imphum
6	hveg + numdom	14	gcov + numdom + imphum
7	hveg + imphum	15	hveg + gcov + numdom + imphum
8	gcov + numdom		

animals in the area ($Z = -1.76$, $P = 0.08$) (Table 3). The species presented an affinity for low-vegetation environments during breeding but avoided places with the highest presence of large-sized farm animals during this period.

The comparison between breeding and non-breeding seasons revealed that, concerning the human impact and presence of farm animals, there was a considerable difference between seasons ($t = 8.82$, $df = 90.34$, $P < 0.05$). However, the variable vegetation height, which tends to be one of the most selected in the models across both seasons, did not significantly differ between the sampled periods ($t = 0.60$, $df = 114.34$, $P = 0.55$).

DISCUSSION

In spite of Southern Lapwing being described as a species “typical of low altitude grasslands [...] where undergrowth prevails, but also tolerating degraded habitats and human presence” (Santos 2010), no study had been performed to gauge the bird’s habitat selection. Analysis at the macro-habitat scale confirms that the species possesses a strong affinity for impacted grasslands and urban area environments, which was strengthened by micro-habitat analyses showing that factors such as human impact and presence of farm animals, in addition to vegetation height, are part of this species’ selection process. This demonstrates that there is a relationship between the occurrence of this species and human activity, even if the causes of this relationship are not yet fully understood.

Many species of animals are considered synanthropic, benefitting from environments occupied by human beings (Marzluff et al. 2001). These benefits may arise due to three interrelated reasons: (1) greater resource availability provided by the large volume of organic waste which can be used for feeding (Faeth et al. 2005); (2) protection against predators (Rodewald et al. 2011), since there is a tendency towards lesser predation pressure in urbanized environments (Sorace 2002), and (3) diminished interspecific competition, as fewer species occupy these environments (Shochat et al. 2010). Indirect beneficial relationships can also emerge, where some species flock to urban environments due to the presence of domestic or farm animals (Rodewald 2012).

Human occupation and habitation have created a new ecological niche in natural environments, which seems to be little exploited by some bird species (Rodewald 2012, Santos and Cademartori 2015), but may be advantageous for generalist species with preferences for low vegetation, such as the Southern Lapwing. With the opportunity to occupy these new territories, there may be benefits regarding greater access to food resources and protection from predatory birds (Faeth et al. 2005). This could be a result not only of habitation of areas where human construction occurs, including the presence of buildings and roads, but also by occupying grasslands where farm animals are raised (Cardoni et al. 2015). In addition, the Southern Lapwing’s high capacity for surviving in environments under severe environmental pressure (Santos 2010), in contrast with other more sensitive birds (Stanton et al. 2018), and its territorial, typically aggressive behavior (Delfino and Carlos 2020), grants

Table 3. Best three Generalized Linear Models (GLM) during both non-breeding and breeding seasons, with AIC score, delta AIC and the cumulative weight of each model, respectively (hveg = vegetation height; numdom = number of farm animals; imphum = degree of anthropization; gcov= soil cover).

Season	Models	AIC	deltaAIC	Cumulative wt.
Non-breeding season	hveg + numdom + imphum	189.14	0.00	0.5
	hveg + numdom	191.09	1.96	0.68
	hveg + gcov + numdom + imphum	191.12	1.99	0.87
Breeding season	hveg + numdom	187.92	0.00	0.34
	hveg + numdom + imphum	189.55	1.64	0.5
	hveg	189.56	1.64	0.65

them greater reproductive and survival success in these environments (Saracura 2003).

In rural areas, the main human impacts on natural vegetation are caused by agriculture and animal husbandry (Albaladejo 2006, Wagner et al. 2013). In animal husbandry, large and medium sized animals are frequently raised in an extensive manner across native grasslands, a historically widespread practice in southern Brazil (Crawshaw et al. 2007). These animals, bovines and equines for the most part, use the area for foraging and as a consequence drastically alter the landscape of the native grasslands (Brown and McDonald 1995). The major observed change is the considerable reduction in vegetation height when compared to places where there is no grazing activity, nor farmed animals (Adler and Hall 2005). Thus, the usage of native grassland areas for extensive animal husbandry results in grasslands with lower vegetation height and less arboreal and shrub species (Hendricks et al. 2005). Furthermore, the presence of cattle directly modifies the physicochemical attributes of the soil (Rodríguez-Medina and Moreno-Casasola 2013, Carvalho et al. 2018), which benefits part of the area's edaphic fauna, primarily certain groups of invertebrates, such as Coleoptera, Hymenoptera (Formicidae), and Diptera (Cunha Neto et al. 2012, Hoffman et al. 2018), that comprise the main food source of the Southern Lapwing (Santos 2010).

The presence of farm animals directly influences two of the main characteristics selected by Southern Lapwing: vegetation height and soil arthropod richness. This explains the bird's high affinity for environments with husbandry activity and could also explain its expansion towards northern Brazil (Santos 2010).

The progress of deforestation and husbandry activities in the region (Rivero et al. 2009, Domingues and Bermann 2012) ends up creating territories where Southern Lapwings can forage and establish breeding populations. Additionally, behavioral studies suggest that a positive relationship between Southern Lapwings and cattle or horses may be established during the non-breeding season (Delfino and Carlos 2020). However, during the breeding season the tendency is reversed and the presence of large animals within the nesting grounds becomes detrimental, seeing as there is a risk of trampling of their eggs and chicks (Mandema et al. 2013, Sabatier et al. 2015).

The rejection of environments with higher arboreal layers, such as bushy fields and forests, supports the hypothesis of preference by Southern Lapwings for open formations, which goes back not only to the species' behavioral aspects, but also aspects shared by its congeners: most of the species in the *Vanellus* genus are species of grassland environments and typically low-vegetation areas (Bolton et al. 2007, Düttmann et al. 2018, Mishra et al. 2018, Cantlay et al. 2019). In such environments, these birds can more easily watch and protect their nests (Saracura 2003).

The primary predators of Southern Lapwing adults and chicks are birds of prey like the Southern Caracara (*Caracara plancus*), Chimango Caracara (*Milvago chimango*), Savanna Hawk (*Heterospizias meridionalis*), Long-winged Harrier (*Circus buffoni*), Burrowing Owl (*Athene cunicularia*), as well as the Black Vulture (*Coragyps atratus*) (Belton 1994, Costa 2002, Santos 2010), which often employ aerial attacks. Thus, inhabiting open environments with low vegetation allows the Southern Lapwing to have more space for ob-

servation and more time for defensive reaction, such as escape or successful agonistic response against the attacker (Delfino and Carlos 2020).

The use of clean and flooded grasslands was neutral during the observed period, especially during the non-breeding season, when these environments were occasionally utilized for foraging (HCD, personal observation). However, the negative selection of flooded field environments during breeding season can be explained by the dynamics and architecture of nest building. Southern Lapwings place their eggs directly on the soil (Saracura 2003), in simple and open nests with few deposited materials (Simon and Pacheco 2005). As such, flooded environments pose a potential risk for the nests' reproductive success, and are consequently avoided during that time of the year.

The study also demonstrated that, despite vegetation height being the most impactful for habitat and territory selection, there is a plasticity that varies with the species' breeding cycle, as the environment's selected characteristics begin to change between breeding and non-breeding seasons. Ultimately, this work elucidates the intrinsic relationship between human beings, the rural environment and the Southern Lapwing, relating environmental factors to the species' behavioral aspects and the ecological dynamics of these environments. It also supports the elaboration of hypotheses on why the species has been strikingly expanding its area of distribution in tandem with the Brazilian agricultural frontier and why, unlike its Old World congeners (Galbraith 1988, Baines 1990, Peach et al. 1994), this species tends to have its life cycle increasingly intertwined with human activities, be it in rural or urban areas.

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