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NOTA CORTA / SHORT NOTE

TEMPERATURE AND WIND SPEED DRIVE BIRD SPECIES RICHNESS IN BRAZILIAN ARID HIGHLAND SCRUB

La temperatura y la velocidad del viento determinan la riqueza de aves en matorrales áridos de tierras altas de Brasil

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ABSTRACT

Due to timely and financial hampering in developing nations, field research has been encouraged to use rapid and cost-effective methods without compromising the acquisition of good-quality data. Species richness is a widely used component in ecological studies, especially of birds, which are conspicuous, diurnal, and excellent bioindicators. Birds are also a proper taxonomic group for leading conservation planning. Therefore, conducting efficient bird censuses is of paramount importance worldwide. The aim of this research was to determine abiotic environmental factors that drive the record of species richness and further suggest climatic conditions to improve bird survey efficiency. Species lists were used to census bird communities in four localities in central Bahia, northeastern Brazil, within the Caatinga, an exclusive Brazilian biome. During the beginning of mornings, temperature and atmospheric pressure increased hourly, but wind speed showed no temporal pattern. Species richness was higher when temperatures and atmospheric pressure were lower, but there was no evident tendency between the number of species and wind speed. However, the additive interaction of temperature and wind speed accounted for the most plausible competing model. This suggests that in this Brazilian arid non-forested open-canopy and wind-susceptible habitats, censusing birds will record more species when temperatures are low (~20° C), but wind blows below speeds of ~10 m/s.

Keywords: abiotic factors, atmospheric pressure, Caatinga, survey method evaluation.

RESUMEN

Debido a la falta de oportunidades y a los obstáculos financieros en países en desarrollo, investigaciones científicas en campo han sido alentadas a implementar métodos rápidos y rentables sin comprometer la obtención de datos de calidad. La riqueza de especies es un componente ampliamente utilizado en estudios ecológicos, especialmente de aves, que son conspicuas, diurnas y bioindicadoras. Por lo tanto, realizar censos de aves que sean eficientes es de suma importancia globalmente. El objetivo de esta investigación fue determinar cuáles factores ambientales abióticos determinan el registro de la riqueza de especies y sugerir condiciones climáticas para mejorar la eficiencia de sus estudios. Listas de especies se utilizaron para inventariar las comunidades de aves en cuatro localidades del centro de Bahía, noreste de Brasil, dentro de la Caatinga; un bioma exclusivo de Brasil. Durante el comienzo de las mañanas, la temperatura y la presión atmosférica aumentaron a cada hora. La velocidad del viento no mostró un patrón temporal. La riqueza de especies fue mayor cuando las temperaturas y la presión atmosférica fueron menores, pero no hubo una tendencia evidente entre el número de especies y la velocidad del viento. Sin embargo, la interacción aditiva entre la temperatura y la velocidad del viento representó el modelo más plausible. Esto sugiere que en hábitats áridos no boscosos de dosel abierto y susceptibles al viento de Brasil, el censo de aves registrará más especies cuando las temperaturas son bajas (~20 °C), y cuando el viento sopla a velocidades inferiores a ~10 m/s.

Palabras clave: Caatinga, evaluación del método del censo, factores abióticos, presión atmosférica.

The research has faced significant challenges due to financial constraints, especially in developing countries (Ayalew and Xianzhi, 2019). Nonetheless, there remains pressure on researchers to increase productivity and publish their findings in reputable outlets (Jordão, 2019). To address this, rapid inventory techniques have been proposed and recommended for tropical birds, offering an alternative to time-consuming long-term inventories (Herzog *et al*., 2002; Stevens *et al.*, 2019). It is essential to improve these methods by analyzing abiotic environmental factors that affect bird species records, making them both efficient in terms of species accumulation and cost-effective. For instance, studies have demonstrated the importance of temperature for the occupancy of Australian birds (Einoder *et al*., 2018) and its role in determining species richness along elevation gradients in Bolivia (Montaño-Centellas *et al*., 2021). However, there is no universal rule as temperature (and precipitation) did not show significant associations with species richness in tropical mountains (Hanz *et al*., 2018). It is often necessary to consider novel covariables in the analysis. For example, the slope of a mountain was found to drive differences in bird communities in the Brazilian Atlantic Forest, with fewer species found in steeper terrains (Cavarzere *et al*., 2021).

Birds, being conspicuous, predominantly diurnal, and responsive to environmental changes, have received substantial attention in ecological studies (Pizo and Tonetti, 2020) and they serve as a valuable taxonomic group for planning conservation actions (Stralberg *et al*., 2019). Therefore, meticulous study of birds is of paramount importance for obtaining rapid and high-quality data (Vergara-Tabares *et al*., 2020). Few studies tried to evaluate the influence of abiotic factors on bird detection. Thus, I wished to investigate whether temperature, wind speed and atmospheric pressure drive the detection of bird species to suggest climatic conditions that will optimize resources while ensuring efficient surveys. I hypothesize increasing values of temperature, wind speed and atmospheric pressure should account for fewer bird species.

Chapada Diamantina, located in the state of Bahia, northeastern Brazil, is situated within the Caatinga, an exclusive Brazilian biome. It represents the northern section of the Espinhaço Range, which stretches south to the state of Minas Gerais; encompassing an area of 60000 km² it covers inland regions in Bahia, ranging from 10° to 15° S and 40° to 44° W (Nóbrega and Boas, 2020). The average annual temperature is 19.5° C and the precipitation varies between 500 and 1300 mm per year, with the majority of rainfall occurring from November and March. The elevations in this area can reach up to 1200 m (Nóbrega and Boas, 2020). Across the four study areas, namely Damacena, Maniçoba, Pedra, and Veredão, which are at least 6 km apart, the vegetation exhibits considerable similarity and is predominantly characterized by caatinga. The landscape features scattered small trees, with some reaching a height of up to 7 m, and in certain transects, shrubs and pastures are also present, particularly in Veredão, where the vegetation does not form a continuous canopy.

Bird surveys were conducted in the municipality of Mulungu do Morro, Bahia, from September 2 to 5, 2013. The surveys utilized 5-species-lists, in which the observer completes lists of five species without repeating species in the same list. Species that are detected again can be annotated in sequential lists. Five-species-lists were used because it took longer to complete lists with 10 or more species. By doing this, more lists, which are the sampling effort, were accumulated (Herzog *et al*., 2002). Each locality was visited during a single morning. Birds were identified visually with 8 x 40 mm binoculars, and aurally. Censuses started at 6 am and lasted for 4 h, except at Damacena, where the survey began at 5 am. At each hour three abiotic covariables were collected: temperature, humidity, and atmospheric pressure. Measurements were obtained using a digital thermometer, hygrometer, and barometer, respectively. In addition, the average wind speed was acquired from a nearby anemometer station. The collinearity among the covariables was verified with a Pearson test and "humidity" was excluded for being highly and negatively correlated with "temperature" (p = 0.05, r = 0.95). Wind speed values were log10-transformed. Competing models were then created considering individual covariables and their interactions. Model comparison was performed using Akaike's Information Criteria (AIC) corrected for small samples. Plausible models were identified based on a ΔAICc value < 2.

A total of 66 5-species lists[1] were accumulated, with an average of 17.0 ± 5.5 SD (ranging from 11 to 24 list per locality). In total, 69 bird species were recorded, including seven Caatinga endemics (Appendix 1). Species richness varied per locality from 26 to 48

Appendix 1. **Bird species recorded in the municipality of Mulungu do Morro, Bahia, northeastern Brazil, and their endemic status in the Caatinga. Localities: 1 = Damacena, 2 = Maniçoba, 3 =Pedra, 4 = Veredão.**

Species	Localities	Caatinga endemism
Leptotila verreauxi	2,3,4	
Columbina minuta	1	
Columbina squammata	2	
Columbina picui	1,2	
Guira guira	1	
Anopetia gounellei	1,2,3,4	X
Heliomaster squamosus	1	
Chlorostilbon lucidus	1,3,4	
Eupetomena macroura	1,2	

1 I used 5-species lists, meaning each list contained 5 different species. Overall, I accumulated 66 lists that contained five species each

Species	Localities	Caatinga endemism
Chionomesa lactea	1	
Vanellus chilensis	1,2	
Cathartes burrovianus	2,3,4	
Rupornis magnirostris	1,2,3	
Nystalus maculatus	1	
Picumnus pygmaeus	1,2,3	x
Veniliornis passerinus	1,2,3	
Celeus flavescens	2	
Piculus chrysochloros	1,2	
Colaptes melanochloros	2	
Cariama cristata	1,2,4	
Herpetotheres cachinnans	3	
Milvago chimachima	1,2,4	
Falco femoralis	1	
Forpus xanthopterygius	2,3,4	
Eupsittula cactorum	1,2,3,4	x
Myrmorchilus strigilatus	1,2,3,4	
Formicivora melanogaster	2,3,4	
Sakesphoroides cristatus	1,3,4	x
Thamnophilus capistratus	1,2,3,4	
Thamnophilus pelzelni	1,2,3	
Radinopsyche sellowi	1,2,3,4	
Hylopezus ochroleucus	3	x
Lepidocolaptes angustirostris	1,2,3,4	
Megaxenops parnaguae	1,2	
Synallaxis hellmayri	1,3	x
Synallaxis frontalis	1,2	
Todirostrum cinereum	1,2	
Hemitriccus margaritaceiventer	1,2,3,4	
Stigmatura napensis	1,2,3	
Camptostoma obsoletum	1,2	
Phaeomyias murina	2	
Myiarchus tyrannulus	2,4	
Pitangus sulphuratus	1,3	
Megarynchus pitangua	1	
Myiophobus fasciatus	2	
Cyclarhis gujanensis	1,2,3	
Hylophilus amaurocephalus	1,3,4	
Cyanocorax cyanopogon	2	
Pygochelidon cyanoleuca	4	
Stelgidopteryx ruficollis	1,3	
Troglodytes musculus	2	
Cantorchilus longirostris	1,2,3,4	
Polioptila atricapilla	1,2,3,4	
Turdus leucomelas	4	
Turdus rufiventris	2	
Euphonia chlorotica	1,2,4	
Zonotrichia capensis	1,2,3	
Icterus jamacaii	3	
Gnorimopsar chopi	1,3	
Cyanoloxia brissonii	1,2,3	
Saltatricula atricollis	1,2,4	
Saltator similis	4	
Coereba flaveola	1,2,3,4	
Volatinia jacarina	1	
Coryphospingus pileatus	1,2	
Tachyphonus rufus	1,3,4	
Paroaria dominicana	2	x
Thraupis sayaca	2	
Stilpnia cayana	1,2	

(with a mean of 38.5 ± 10.8). Temperatures exhibited a wide range, from 18.9 to 31.2° C (24.1 ± 4.2), while atmospheric pressure (mean of 901.4 mmHg ± 1.4) and wind speed (mean of 8.7 m/s ± 2.4), showed a narrower amplitude (Table S1).

Individually, there was a tendency for species richness to decrease with increasing temperature and atmospheric pressure, while no clear trend was observed regarding wind speed (Fig. 1). However, an additive interaction between temperature and wind speed was detected, which was the most plausible model (Table S2).

Temperature is a well-known abiotic factor that influences the detection and occurrence of birds (Einoder *et al*., 2018; Montaño-Centellas *et al*., 2021; Ramesh *et al*., 2022). Although hourly variations of bird records suggest forest species are more detectable during the first morning hours (Blake, 1992), I was unable to find research specifically examining the effect of temperature on the record of higher or lower species richness over time. It has been suggested that birds tend to avoid warmer microclimates (Jirinec et al., 2022). Also, the energy storage stochasticity hypothesis proposes that birds have surplus energy reserves in the morning due to overnight temperature fluctuations (McNamara *et al*., 1987). Thus, birds invest this left-over energy singing (Hutchinson, 2002; Barnett and Briskie, 2007), enhancing their conspicuousness during the early hours of the day. Such observations corroborate the notion that in this Brazilian arid highland scrub, as time progresses, the rising temperatures during the early morning hours may result in fewer bird records. The effect of atmospheric pressure on bird species is also straightforward, as birds are highly sensitive to its variations (Kreithen and Keeton, 1974). I tended to record fewer bird species during low atmospheric pressure, which aligns with the fact that migratory

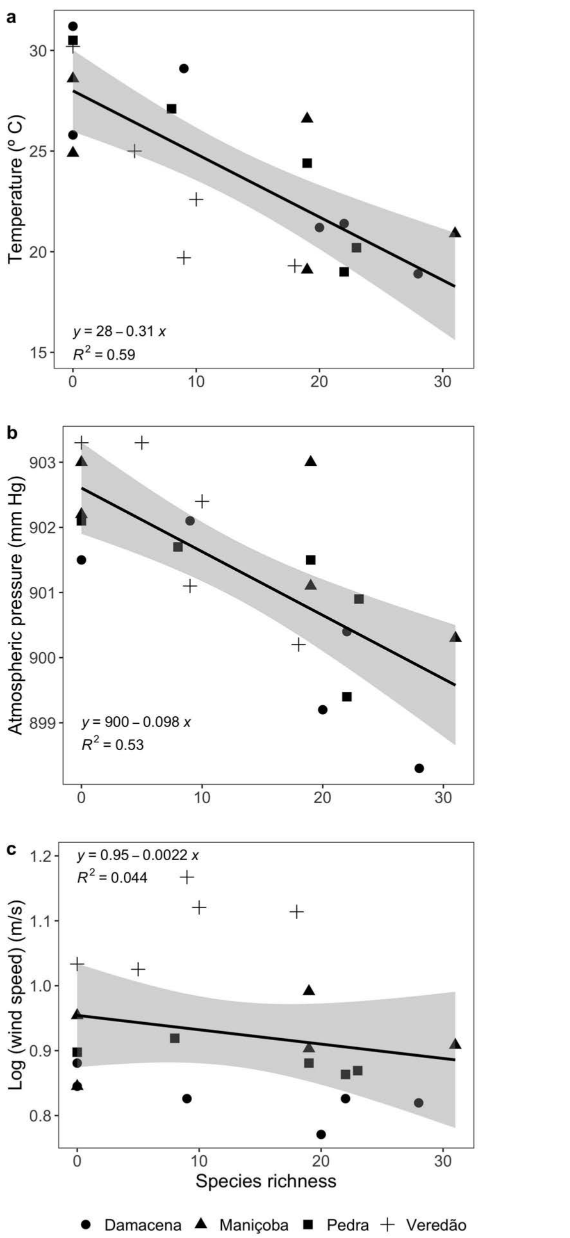

Figure 1. Linear regressions with shaded 95 % confidence intervals between species richness and (a) temperature, (b) atmospheric pressure, and (c) wind speed.

movements are often reduced when atmospheric pressure drops (Liechti *et al*., 2018). Individually, the wind speed did not exhibit a significant effect on species richness. However, lower species richness observed at Veredão suggests that high wind conditions compromise bird detection (Wiest and Shriver, 2016). In Veredão, the vegetation was more open, lacking a continuous canopy, therefore more susceptible to gusts of wind.

Given the significance of bird surveys in ecological studies and conservation planning, it is crucial to employ rapid inventories effectively, considering suitable abiotic conditions, to yield efficient and timely results. For future censuses in Brazilian arid highland scrubs, which are prone to temperature increases in the morning and high wind speeds, it is recommended to assess the temperature (below ~20° C) and wind speed (< 10 m/s) before initiating fieldwork. This approach will help to optimize resources and ensure maximum efficiency bird surveys.

Table S1. Hourly records of bird species and measurements of abiotic factors in the municipality of Mulungu do Morro, Bahia, northeastern Brazil.

Locality	Morning hour	Species richness	Temperature (° C)	Pressure (mmHG)	Wind speed (m/s)
Damacena	5	28	18.9	898.3	6.6
	6	20	21.2	899.2	5.9
	7	22	21.4	900.4	6.7
	8	0	25.8	901.5	7.6
	9	9	29.1	902.1	6.7
	10	0	31.2	902.1	7.0
Maniçoba	6	31	20.9	900.3	8.1
	7	19	19.1	901.1	9.8
	8	0	24.9	902.2	9.0
	9	19	26.6	903.0	8.0
	10	0	28.6	903.0	7.0
Pedra	6	22	19.0	899.4	7.3
	7	23	20.2	900.9	7.4
	8	19	24.4	901.5	7.6
	9	8	27.1	901.7	8.3
	10	0	30.5	902.1	7.9
Veredão	6	18	19.3	900.2	13.0
	7	9	19.7	901.1	14.7
	8	10	22.6	902.4	13.2
	9	5	25.0	903.3	10.6
	10	0	30.2	903.3	10.8

Table S2. Model selection showing the values of Akaike's Information Criteria corrected for small samples (AICc), delta AICc, and weights and cumulative weights of each model.

Models	AICc	ΔAICc	AICcWt	Cum. Wt
temperature+Wind	140.7	0.0	0.72	0.72
temperature+win-d+pressure	144.2	3.5	0.12	0.84
temperature+pressure	145.5	4.7	0.07	0.91
Temperature	145.5	4.7	0.07	0.98
Pressure	148.0	7.3	0.02	1.00
wind+pressure	151.1	10.3	0.00	1.00
null model	161.3	20.5	0.00	1.00
Wind	163.1	22.4	0.00	1.00

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CONFLICT OF INTEREST

The author declares no conflict of interest.

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