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Effect of annual rainfall and temperature on the selection of habitat and overwintering home range of grassland birds

Sierra-Franco, Daniel[1]; Pereda-Solís, Martin Emilio[1]; Salazar-Borunda, Manuel Armando[1]; Strasser H. Erin[2]; Tarango-Arámbula, Luis Antonio[3]; Martínez-Guerrero, José Hugo[1*]

[1] Universidad Juárez del Estado de Durango Facultad de Medicina Veterinaria y Zootecnia, carretera Durango-Mezquital, km, 11.5, 34197 Durango, Mexico.

[2] Bird Conservancy of the Rockies, 14500 Lark Bunting Ln Brighton, Colorado, USA 80603.

[3] Colegio de Postgraduados Campus San Luis Potosí, Salinas de Hidalgo, San Luis Potosí, México, C. P. 78620.

* Correspondence: hugo.martinez@ujed.mx

ABSTRACT

Objective: To determine the effect of annual rainfall and winter temperature on the habitat and size of the overwintering home range of two grassland birds in a native grassland in northern Durango, Mexico.

Design/Methodology/Approach: Using telemetry techniques during four consecutive winters (2016-2019), we estimated the size of the home range (HR; by the Kernel method) of *Centronyx bairdii* and *Ammodramus savannarum*. Likewise, the coverage of grassland, scrubland, bare ground, dead vegetation, and animal excrement was estimated and the seeds available in the soil (biomass, g m^{-2}) of the habitat were counted. We correlated these dependent variables with non-parametric statistics, to the minimum and maximum annual rainfall (mm) and temperature (°C) of the site.

Results: Grassland sparrows used sites with equitable cover of grass, herbaceous plants, shrubs, bare ground and others (Kruskal-Wallis, $p \leq 0.05$). Overall, annual rainfall has no effect on structure and vegetation cover. The HR was negatively correlated (Spearman, $p \leq 0.05$) with the annual rainfall for *C. bairdii* ($r^s = -0.90$, n=45) and for *A. savannarum* ($r^s = -0.80$, n=33). When the maximum temperature was higher, both species had lower HR. In contrast, when the minimum temperature was low, the HR increased for *C. bairdii* and decreased for *A. savannarum*.

Study Limitations/Implications: We demonstrated the importance of considering quantifying the greatest number of variables when research is required on the selection and use of grassland bird habitat.

Findings/Conclusions: This study allowed us to increase our knowledge about the winter ecology of grassland birds and demonstrated that environmental variables such as annual rainfall and temperature influenced the habitat selection of *C. bairdii* and *A. savannarum*.

Keywords: Baird's sparrow, Grasshopper sparrow, wintering grassland birds.

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INTRODUCTION

The irregular distribution of rainfall and temperature rise in recent decades in different regions of the world are consequences of global climate change, which causes an alteration in the functionality of terrestrial ecosystems (IPCC, 2007; Böhning-Gaese *et al.*, 2008).

For the arid regions of North America, it has been modeled that changes and fluctuations in temperature and rainfall are deeper (Huang *et al.*, 2016), thus altering the habitat of plant species (Turnbull *et al.*, 2010) and animals, especially birds (Cohen *et al.*, 2020).

In this regard, the effect on the adaptive response of species (Zuckerberg *et al.*, 2009, Cady *et al.*, 2019) and avian communities (Jarzyna *et al.*, 2015) towards climate change has been documented. As well as the influence of variables such as rainfall in summer, on the abundance and temporal-spatial distribution of wintering grassland birds of the Chihuahuan Desert (Macías-Duarte *et al.*, 2018).

This group of birds in North America presents a strong population decline (−53%) in most of the species that represent it in the last 42 years (Rosenberg *et al.*, 2019). Therefore, to establish habitat conservation priorities at the continental scale (Berlanga *et al.*, 2010) it is necessary to generate and increase knowledge of the winter ecology of grassland birds.

In a similar way, this negative population trend of grassland birds is directly related to habitat loss and fragmentation throughout North America, which are more severe in the different wintering regions in the Chihuahuan Desert (Pool *et al.*, 2014).

This decrease is explained, among other causes, by changes in the net primary productivity of the grassland because of the irregular precipitation pattern of the region (Reichmann and Sala, 2014), by affecting the structure and coverage of the vegetation and in turn, the reproductive behavior of the birds (Conrey *et al.*, 2016) and their winter survival (Macías-Duarte *et al.*, 2017).

These effects translate into constant changes in the distribution and winter abundance of birds in the grasslands of northern Mexico (Panjabi *et al.*, 2013), as changing climatic conditions annually modify the structure and coverage of vegetation (comfort and protection against predation), the amount and distribution of food (seed biomass), modifying the territorial needs of birds so that they find and meet their vital requirements (Strasser *et al.*, 2019).

Under the assumption of the existence of a marked effect of climatic events on variables that affect the habitat characteristics of grassland birds; the objective of this study was to determine the effect of annual rainfall and winter temperature on some habitat characteristics (structure and coverage of winter vegetation and seed bank in the soil) and the size of the home range of two focal species (*Centronyx bairdii* and *Ammodramus savannarum*) of grassland birds in a grassland in northern Durango, Mexico, during four winter periods. This study allowed to increase the knowledge in the winter ecology of two species of birds with constant population decline and that this information can be useful in the development of strategies for the conservation of habitat and species.

MATERIALS AND METHODS

Study area

The study was implemented in a native grassland of 208 ha of extension, which is included within the cattle ranch "El Regalo" of the municipality of Hidalgo, north of the state of Durango, Mexico (Figure 1). It is located between the extreme geographical coordinates (26° 20' 11.24" N, 105° 10' 58.11" W and 26° 17' 5.98" N, 105° 9' 15.35" W), during the winter seasons 2015-2016, 2016-2017, 2017-2018, and 2018-2019.

Capture and processing of birds

The capture of the birds was made using bird mist nets on the line, black polyester model KTX of Avian Research Supplies, AFO, 36 mm mesh, 2.6 m high by 12 m long with four bags; eight people helped herding the birds towards the net (Panjabi and Beyer, 2010). For the capture, SEMARNAT granted the appropriate collection permits: SGPA/DGVS/104381/15, 10768/16, 011900/17 and 12947/18.

After the capture, on each of the birds a telemetry transmitter was placed on the back fastened with a harness made of elastic sewing band (Rappole and Tipton, 1991). The model of the transmitters was PicoPip 379 of LOTEK®, weighing 0.6 g, with a battery life of approximately 40 d (Panjabi and Beyer, 2010) and subsequently released at the same capture site.

Bird monitoring with transmitter

The birds were tracked daily by recording the coordinates of their location with a Garmin® GPS navigator model Etrex Vista. A database was generated with the locations

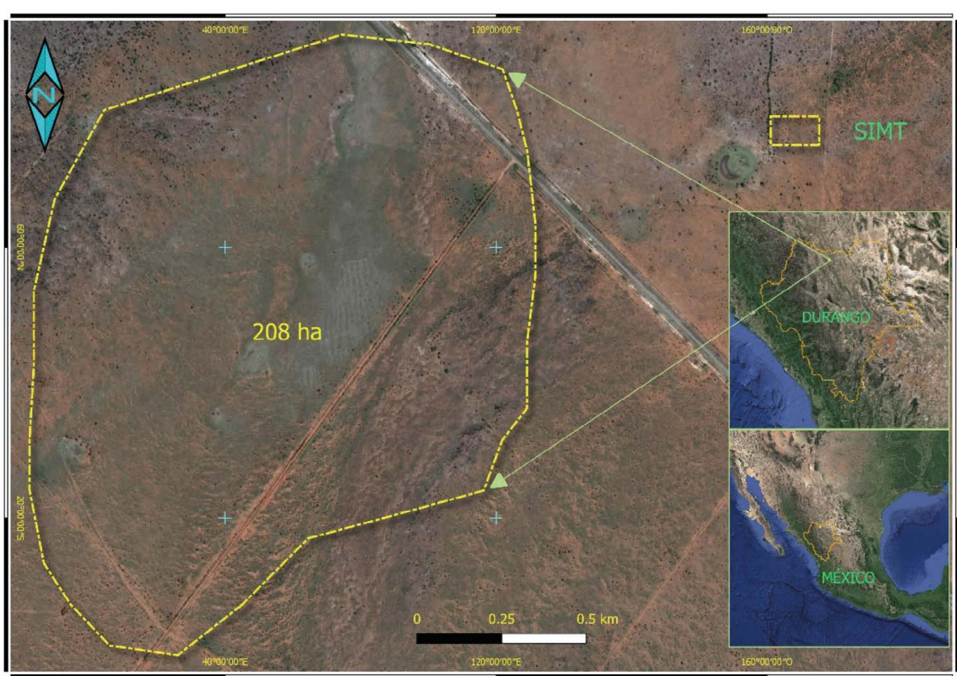

Figure 1. Location of the study site, "El Regalo" cattle ranch, at the municipality of Hidalgo, Durango.

by species and by individual, selecting those birds that had ≥30 detections, which is a fundamental requirement to estimate the home range of the individuals. Likewise, the location sites were also used to quantify the vegetation variables and to do the collection of soil samples to determine the seed biomass.

Estimation of the home range (HR)

The size of the home range (ha) was estimated using the fixed Kernel (K) method of 95% with least squares cross-validation (Seaman and Powell, 1996; Powell, 2000), using the software *adehabitatHR* version 3.3.1 (Calenge, 2006; R Core Team, 2018). To avoid overvaluation caused by occasional bird movements, those location points farther from the center of gravity in the cloud were removed prior to the estimate.

Sampling of vegetation (habitat) and seed biomass in the soil

The coverage percentage of herbs, shrubs, grassland, bare ground and other covers (dead vegetation and animal excrement) was visually estimated (Macias-Duarte *et al.*, 2018). The height of the vegetation was measured with a 1m Robel pole, marked every 2 cm (Robel *et al.*, 1970) in a circular area of 5m radius, around the location point of the birds, whose center was the central point of the geographical reference of the birds.

Seeds were collected at each point of location, using a metal ring of 8.8 cm in diameter; pressing it 0.5 cm deep into the soil and turning it half a turn to the right to recover the soil content (Desmond *et al.*, 2008). Subsequently, with the use of a metal spatula and a brush, the contents were placed on paper envelopes of 10×15 cm, identified with a label.

Seeds were separated from the rest of the soil content at the Laboratorio de Postgrado of the Faculty of Veterinary Medicine and Zootechnics (FMVZ) under the Juarez University of the State of Durango (UJED). Seeds were separated through 1.0 and 0.5 mm mesh sieves, then observed under a 10×20 stereoscopic microscope (Leica®, model EZ4). The seed biomass per unit area (g m^{-2}) was quantified in a Sartorius® analytical balance, model CP224S (Desmond *et al.*, 2008).

Meteorological data collection

The data of annual rainfall (mm) of the years 2015-2019 and of minimum and maximum temperature of the winter months (December to February) of each period, were obtained from the meteorological station "Revolución" of the National Meteorological Service (SMN), of the Federal Government of Mexico. That weather station is near the study site, data was accessed through the National Water Commission (CONAGUA).

Statistical analysis

In this study, to relate the winter periods, the dependent variables (vegetation cover and height, seed biomass and home range) were grouped with the independent variables of annual rainfall (mm) ordered from lowest to highest amount of rain, and with the corresponding maximum and minimum winter temperature (°C) values. The Kruskal-Wallis non-parametric test was used ($p \leq 0.05$).

Additionally, to estimate if annual rainfall, minimum and maximum winter temperatures were correlated to the amount of seed biomass in the soil, a Spearman correlation analysis (r^s) was performed. The statistical analyses were performed with the NCSS® (Number Cruncher Statistical System – Hintze, 2001).

RESULTS AND DISCUSSION

In this research, during the four winter seasons (2015-2019) 78 birds were monitored with telemetry transmitter. Of those, 45 individuals corresponded to *Centronyx bairdii* (BAIS) and 33 to *Ammodramus savannarum* (GRSP) (Table 1).

Individuals of *Centronyx bairdii* selected sites with an average grass cover of 4.94%, grass height of 29.5 cm, shrub cover 3.79%, shrub height 42.53 cm, grass cover 75.18%, grass height 34.44 cm, bare ground 9.32% and other covers (dead vegetation and animal excrement) 6.75%.

Their average home range size was 0.80±0.11 ha and the amount of seed biomass in the soil was 2.70 g m^{-2}.

Individuals of *Ammodramus savannarum* used sites with grass cover 4.2%, grass height 29.4 cm, shrub cover 3.54%, shrub height 51.8 cm, grass cover 74.3%, grass height 32.4 cm, bare ground 9.1% and other covers (dead vegetation and animal excrement) 8.8%.

The size of the home range was 0.68 ha on average and the amount of seed biomass in the soil was 2.50 g m^{-2}.

Table 1. Number of birds studied by species and by winter season (year) in Durango, Mexico.

Winter season	*Centronyx bairdii*	*Ammodramus savannarum*
2015-2016	13	6
2016-2017	10	6
2017-2018	6	8
2018-2019	16	13

Table 2. Effect of annual rainfall on winter habitat characteristics, home range and seed biomass for *Centronyx bairdii* in a natural grassland in northern Durango, Mexico.

Variable	2015-2016	2017-2018	2018-2019	2016-2017
Annual rainfall (mm)	421.6	518.2	579.5	616.5
Herbs cover (%)	2.36 ± 0.8^{b}	3.70 ± 0.7^{b}	7.06 ± 1.0^{a}	6.63 ± 0.5^{a}
Herbs height (cm)	28.60 ± 3.2^{ab}	31.96 ± 3.1^{ab}	34.26 ± 1.5^{a}	23.60 ± 1.4^{b}
Shrubs cover (%)	6.33 ± 1.2^{a}	1.26 ± 0.2^{c}	2.63 ± 0.6^{bc}	4.93 ± 0.6^{ab}
Shrubs height (cm)	61.15 ± 10^{a}	30.83 ± 4.9^{b}	47.90 ± 10^{ab}	30.26 ± 1.8^{b}
Grass cover (%)	78.03 ± 3.2^{ab}	71.86 ± 1.7^{b}	71.26 ± 1.6^{b}	79.56 ± 1.1^{a}
Grass height (cm)	39.66 ± 2.5^{a}	38.26 ± 1.7^{a}	38.53 ± 2.6^{a}	21.3 ± 1.1^{b}
Bare ground (%)	7.63 ± 1.8^{b}	9.46 ± 0.8^{ab}	13.43 ± 1.3^{a}	6.76 ± 0.7^{b}
Other cover (%)	5.63 ± 1.0^{b}	13.7 ± 1.0^{a}	5.60 ± 0.7^{b}	2.1 ± 0.2^{c}
Home range (ha)	1.78^{a}	1.2^{a}	0.04^{b}	0.19^{b}
Soil seedbank (g/m^2)	0.99^{d}	1.69^{c}	4.79^{a}	3.35^{b}

Different letters among columns indicate significant difference (K-W, $p \leq 0.05$).

Table 3. Effect of annual rainfall on overwintering habitat characteristics, home range and seed biomass for *Ammodramus savannarum* in a natural grassland in northern Durango, Mexico.

Variable	2015-2016	2017-2018	2018-2019	2016-2017
Annual rainfall (mm)	421.6	518.2	579.5	616.5
Herbs cover (%)	2.36 ± 0.8^{b}	3.70 ± 0.7^{b}	7.06 ± 1.0^{a}	6.63 ± 0.5^{a}
Herbs height (cm)	26.30 ± 3.4^{a}	27.60 ± 2.0^{a}	29.70 ± 1.8^{a}	21.90 ± 1.4^{a}
Shrubs cover (%)	4.86 ± 0.8^{a}	1.50 ± 0.2^{b}	3.60 ± 0.4^{a}	4.20 ± 0.5^{a}
Shrubs height (cm)	45.65 ± 5.0^{b}	52.30 ± 7.6^{b}	72.80 ± 6.0^{a}	36.56 ± 2.9^{b}
Grass cover (%)	82.76 ± 2.2^{a}	67.20 ± 2.3^{b}	61.40 ± 1.1^{b}	80.83 ± 1.7^{a}
Grass height (cm)	41.43 ± 2.9^{a}	36.83 ± 1.8^{a}	33.83 ± 1.1^{a}	17.46 ± 1.1^{b}
Bare ground (%)	6.63 ± 1.3^{bc}	15.00 ± 1.8^{a}	9.66 ± 0.5^{b}	5.33 ± 0.7^{c}
Other cover (%)	4.26 ± 1.0^{b}	14.4 ± 1.0^{a}	12.90 ± 0.7^{a}	3.63 ± 0.6^{b}
Home range (ha)	1.52^{a}	1.09^{b}	0.06^{c}	0.07^{c}
Soil seedbank (g/m^2)	1.33^{b}	3.38^{a}	1.76^{b}	3.54^{a}

Different letters among columns indicate significant difference (K-W, $p\leq0.05$).

The results of the effect of minimum and maximum temperature during the winter months on habitat selection, home range (ha) and availability of seed biomass in the soil (g m^{-2}) are shown in Table 4 for *Centronyx bairdii* and in Table 5 for *Ammodramus savannarum*. Winters are compared within minimum temperatures (°C) (the coldest and the less cold) and maximum temperatures (the warmest and the less warm), for the other two winters there were no temperature differences between them.

For *Centronyx bairdii* (BAIS) overwintering home range (OHR) had a negative correlation (r^s) of -0.90 with the annual rainfall (AR), which indicates that the greater the amount of annual rainfall the size of the home range is smaller. There were other correlations, 0.94

Table 4. Effect of the minimum and maximum temperature during the winter months (December–February) on the characteristics of the winter habitat, home range and seed biomass for *Centronyx bairdii* in a grassland in northern Durango, Mexico.

Variable	Winter minimum (°C) temperature		Winter maximum (°C) temperature	
Average record	-10.3	-3.1	23.0	28.1
Herbs cover (%)	2.36 ± 0.8^{b}	7.06 ± 1.0^{a}	3.70 ± 0.7^{b}	7.06 ± 1.0^{a}
Herbs height (cm)	28.60 ± 3.2^{a}	34.26 ± 1.5^{a}	31.96 ± 3.1^{a}	34.26 ± 1.5^{a}
Shrubs cover (%)	6.33 ± 1.2^{a}	2.63 ± 0.6^{b}	1.26 ± 0.2^{a}	2.63 ± 0.6^{a}
Shrubs height (cm)	61.15 ± 10^{a}	47.90 ± 10^{b}	30.83 ± 4.9^{a}	47.90 ± 10^{a}
Grass cover (%)	78.03 ± 3.2^{a}	71.26 ± 1.6^{a}	71.86 ± 1.7^{a}	71.26 ± 1.6^{a}
Grass height (cm)	39.66 ± 2.5^{a}	38.53 ± 2.6^{a}	38.26 ± 1.7^{a}	38.53 ± 2.6^{a}
Bare ground (%)	7.63 ± 1.8^{b}	13.43 ± 1.3^{a}	9.46 ± 0.8^{a}	13.43 ± 1.3^{a}
Other cover (%)	5.63 ± 1.0^{a}	5.60 ± 0.7^{a}	13.7 ± 1.0^{a}	5.60 ± 0.7^{b}
Home range (ha)	1.78^{a}	0.04^{b}	1.2^{a}	0.04^{b}
Soil seedbank (g/m^2)	0.99^{b}	4.79^{a}	1.69^{b}	4.79^{a}

Different letters among columns and temperatures indicate significant difference (K-W, $p\leq0.05$).

Table 5. Effect of the minimum and maximum temperature during the winter months (December-February) on the characteristics of winter habitat, home range and seed biomass for *Ammodramus savannarum* in a grassland in northern Durango, Mexico.

Variable	Winter minimum (°C) temperature		Winter maximum (°C) temperature	
Average record	−10.3	−3.1	23.0	28.1
Herbs cover (%)	1.46±0.1[b]	7.04±0.6[a]	1.90±0.3[b]	7.04±0.6[a]
Herbs height (cm)	26.30±3.4[a]	29.70±1.8[a]	27.60±2.0[a]	29.70±1.8[a]
Shrubs cover (%)	4.86±0.8[a]	3.60±0.4[a]	1.50±0.2[b]	3.60±0.4[a]
Shrubs height (cm)	45.65±5.0[b]	72.80±6.0[a]	52.30±7.6[b]	72.80±6.0[a]
Grass cover (%)	82.76±2.2[a]	61.40±1.1[b]	67.20±2.3[a]	61.40±1.1[a]
Grass height (cm)	41.43±2.9[a]	33.83±1.1[a]	36.83±1.8[a]	33.83±1.1[a]
Bare ground (%)	6.63±1.3[a]	9.66±0.5[a]	15.00±1.8[a]	9.66±0.5[b]
Other cover (%)	4.26±1.0[b]	12.90±0.7[a]	14.4±1.0[a]	12.90±0.7[a]
Home range (ha)	1.52[a]	0.06[b]	1.09[a]	0.06[b]
Soil seedbank (g/m^2)	1.33[a]	1.76[a]	3.38[a]	1.76[b]

Different letters among columns and temperatures indicate significant difference (K-W, $p \leq 0.05$).

with the minimum winter temperature (mWT), which suggests that this species requires larger territories when the winter months are colder; −0.80 with the maximum winter temperature (MWT), negative relationship that indicates that when the winter months are warmer the birds use smaller territories; and −0.86 with the amount of seed biomass, which explains that this species makes use of smaller spaces when it finds a greater amount of seeds ($p \leq 0.05$) (Figure 2).

For *Ammodramus savannarum* (GRSP) the OHR is also negatively and significantly related ($p \leq 0.05$) r^s of −0.80 with the AR; correlated −0.94 with the mWT; −0.80 with the MWT; and -0.40 with the amount of seed biomass.

Overall, there were no significant differences between the characteristics of the winter vegetation used by both sparrow species, except shrub height; where GRSP on average selected sites with greater height than BAIS (51.8 cm *vs.* 34.8 cm). In this regard, Macías-Duarte *et al.* (2017) in Janos, Chihuahua reported that GRSP used shrubs taller than BAIS (105 cm *vs.* 49.9 cm), regardless of the botanical composition of both sites.

The average overwintering home range (OHR) for the years of study was higher ($p \leq 0.05$) for BAIS (0.8 ha) than for GRSP (0.6 ha). In this regard, Pérez-Ordoñez (2019) in the grasslands of Marfa, Texas reported that the OHR of BAIS was 6.58 ha, and that of GRSP, 4.74 ha. Rechetelo *et al.* (2016) mentioned that the movement patterns of these sparrow species are irregular and changeable year after year. As well as the size of the overwintering home range, especially in species of granivorous birds called "extensive nomads", is due to the spatial and temporal variability of the distribution of seeds and rain. This also explains the behavior of that variable (AR) for both species, the greater the amount of rain, the lower the space requirement.

The size of the home range, the movements pattern and habitat use depend on the abundance, distribution, and availability of resources (Jenkins, 1981). During this study,

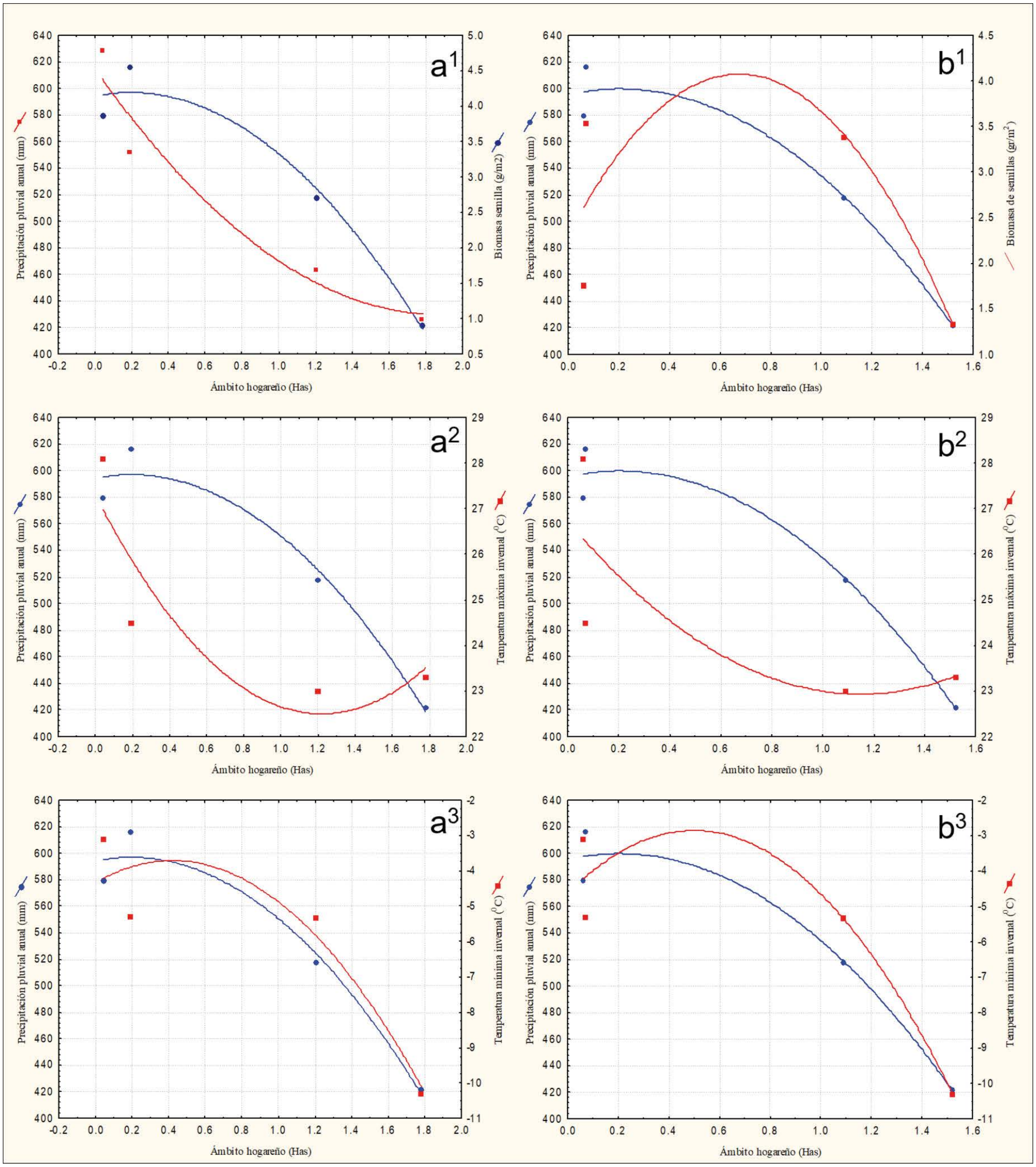

Figure 2. Correlations of the size of the overwintering home range of *Centronyx bairdii* (a) and *Ammodramus savannarum* (b) to annual rainfall, in regard to seed biomass (1) minimum winter temperature (2) and maximum winter temperature (3) in a grassland of northern Durango, Mexico. NOTE: (ha) is the correct SI unit to use for the overwintering home range (OHR), instead of (ha) in this figure.

both species used sites on average with the same amount ($p\leq0.05$) of seed biomass (BAIS 2.7, and GRSP 2.5 g m^{-2}), data that differs with those quantified by Cabanillas (2016) who recorded 1.65 g m^{-2} for BAIS and 2.22 g m^{-2} for GRSP; and those of Salazar-Sánchez *et al.* (2021) who found other values in the same region (BAIS 1.69, GRSP 3.38 g m^{-2}). Studies indicate a trend of *A. savannarum* compared to *C. bairdii* to use sites that have more seeds in the soil, which is consistent with our data. However, the values of the number of seeds in the soil were much lower than those estimated by Méndez-González (2010) at sites used by grassland sparrows in New Mexico, USA with seed amount values of 4.0 and 14.0 g m^{-2}.

The effect of AR on the variables of land cover and vegetation structure for both species was not noticeable, the values coincide with those reported by Martínez *et al.* (2011) and Sierra *et al.* (2019); highlighting these obligate grassland birds selection sites with more than 60% of grass cover (USDA-NRCS, 1999).

In that sense, AR influenced the amount of seed biomass in the soil (g m^{-2}) and consequently on the size (ha) of the overwintering home range required, since rainfall is a key factor for the functionality of arid and semi-arid ecosystems; in addition, the composition and dynamics of vegetation depend on rainfall quantity and seasonality (Dudney *et al.*, 2017).

Rainfall affects the physiology of grasses (Connor and Hawkes, 2018). Dry years produce stress on plants, reduce their size and surface of their leaves, which reduces their photosynthetic capacity, causes hypoxia and nutritional deficiency (Steffens *et al.*, 2005). These alterations decrease growth, net primary productivity, and the ability of plants to produce seeds (Reichmann and Sala, 2014). Conversely, rainy years increase seed and biomass production in pastures while reducing the amount of herbs coverage (Dudney *et al.*, 2017). During this study, such an effect was observed only for seed production at sites used by birds. Seed availability influences the selection and space that birds require over the winter. Due to this, protection against predation, thermal coverage, and the availability of food (seeds), are the main elements that define the size of the territory that a species needs (Powell and Mitchell, 2012). Therefore, birds are excellent indicators of changes caused by severe environmental conditions such as droughts (Cady *et al.*, 2019) and extreme temperatures (Cohen *et al.*, 2020).

Similarly, the variation in the amount of rainfall accumulated annually at the study site affected the availability of necessary resources that birds require for wintering and the size of their territories. For example, birds required more space in years with less rainfall to meet their food needs; this behavior has also been recorded during the breeding season of grassland birds, where their reproductive success was greater in years preceded by greater rainfall (Zuckerberg *et al.*, 2018).

The effect of the minimum and maximum winter temperature (°C) on the size of the overwintering home range for both species was similar, birds use larger sites when the winter months are colder. However, *C. bairdii* preferred sites with greater cover and shrub height, without significant differences among the four years of study for the variables height and grass cover when combined the minimum and maximum temperatures were minor. Unlike *A. savannarum* which covered the requirement of thermal comfort in sites with greater grass cover.

In this regard, Cohen *et al.* (2020) indicated that bird species respond differently to extreme temperature events; small-sized species such as those in our study are more sensitive due to their low thermal inertia compared to larger birds, which have a faster adaptive response (Huey *et al.*, 2012). Low temperatures and poor vegetation cover during the winter limit the survival of both bird species (Perez-Ordoñez *et al.*, 2022).

CONCLUSIONS

There was evidence that during four winter seasons in a grassland in northern Durango, Mexico, annual rainfall, minimum and maximum temperature in the winter months determined habitat selection, the size of the home range and the amount of seed biomass in the soil, as a potential food for *Centronyx bairdii* and *Ammodramus savannarum*.

The selection of the winter habitat of both species was oriented towards sites with good vegetation cover, and low proportion of bare ground. A strong effect of rainfall was not observed on some specific characteristics such as grass cover for *C. bairdii*, but for *A. savannarum*, which used sites with a lower proportion of this type of cover.

The overwintering home environment of the sparrow species studied had a negative correlation with rainfall. Birds tended to use smaller territories in the years of higher annual precipitation, the amount of precipitation also caused that wintering sites with a greater number of seeds in the soil were selected. This phenomenon was more marked in *C. bairdii* than in *A. savannarum*; however, for both species these values were statistically significant.

The effect of the minimum and maximum winter temperature on the home range of the studied species was evident. Both reacted to extreme cold events using larger areas, even tough did not contain much potential food (seeds). However, in the face of warmer events (higher maximum temperature) in the winter, only *C. bairdii* used smaller spaces, but with more seeds; unlike *A. savannarum* that although also used smaller spaces, those contained smaller amounts of seeds.

Although annual rainfall had the most prominent effects to provide the best survival conditions for birds, it is recognized that the selection and use of territories by the sparrow species studied may have been due to a synergistic effect of the environmental variables studied.

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