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POSGRADO EN CIENCIAS AMBIENTALES

State of the art of knowledge on winter ecology of grassland neotropical migratory birds and insights into the winter ecology of the Lark Bunting at the southern portion of the Chihuahuan Desert

Tesis que presenta

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Para obtener el grado de

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Director (Codirectores) de la Tesis:

Dr. Leonardo Chapa Vargas

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Thesis Certificate of Approval

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Dedicatoria

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Abstract

Keywords: Bibliometrics,radio-telemetry, Lark Bunting, migratory birds, winter ecology, Mexican Plateau.

North American migratory grassland bird species are declining at an alarming rate. However, very little attention has been placed on these birds in their wintering habitats. I (1) analyzed the current knowledge of the winter ecology of migratory grassland birds and (2) used manual radio telemetry to evaluate various aspects of the winter ecology (movements, bird's behavior, and survival) of a declining grassland bird with priority conservation status: the Lark Bunting (*Calamospiza melanocorys*) in relation to grazing pressures (heavy grazing, moderate grazing, and cattle exclusion) and distance from water sources in populations overwintering in the high plateau of San Luis Potosí. Chapter 1 uses a systematic review and bibliometrics to synthesize the current state of knowledge on the winter ecology of migratory grassland birds based on scientific publications. To investigate overwinter behavior of Lark Buntings, I captured and attached radio transmitters to 32 individuals and tracked them from January to March 2021. In each site, thirty 500 m-long transects were surveyed to detect the presence of birds; all census transects were categorized in relation to management type and distance from livestock water tanks (Chapter 2).

Regarding 1st chapter, the analysis revealed that despite the winter being recognized as a key period of the annual cycle and of great conservation importance for grassland birds' studies on the wintering grounds are scarce. This study report that most studies have been focused on understanding the movement patterns of birds, factors influencing habitat use, winter survival, habitat requirements of some threatened species and some of the threats that

populations face during winter, but more information is needed concerning climate change effects on migratory bird populations, body condition and health, flocking behavior and effects of contaminants and agrochemicals. Additionally, most of the migratory grassland birds are encounter on communal lands (ejidos) making the involvement of land owners, local communities, and local goverments crucial when designing and implementing conservation plans.

In the 2nd chapter I provide novel information pertaining the winter ecology of the Lark Bunting. For instance, of the 32 radio-tagged birds, 4 (12.5%) remained in the area where they were captured, 17 (53.13%) appeared to exhibit nomadic behavior as they were observed only occasionally in their capture site and seen far away (up-to 5 km) and 11 (34.38%) were never seen again despite intense searching across study sites (36,000 ha) and the season. All of the birds were captured and recorded at least once within 500 m of a manmade water sources. Remarkably, the majority of the records (94%) were obtained in the site with high grazing. These results suggest that there is individual variation in their lifestyle behavior (nomadic and sedentary), and that habitat use is higher near livestock water tanks. This pattern may positively affect the movements of Lark Buntings, which may have important implications for developing effective grassland management and conservation practices. Finally, findings are discussed in the context of effectiveness of surveying nomadic populations during winter, and how management and conservation strategies need to incorporate species with unique lifestyle behaviors such as the Lark Bunting.

Resumen

Palabras clave: Bibliometría, radio-telemetría, Gorrión de Alas Blancas, aves migratorias, ecología invernal, Altiplano Mexicano.

Las especies de aves migratorias de los pastizales de América del Norte están disminuyendo a un ritmo alarmante. Sin embargo, se ha prestado muy poca atención a estas aves en sus hábitats de invernada. En este estudio (1) analicé el conocimiento actual de la ecología invernal de las aves migratorias de los pastizales y (2) utilicé radio-telemetría manual para investigar para evaluar varios aspectos de la ecología invernal (movimientos, comportamiento de las aves y supervivencia) de un ave prioritaria para la conservación, el Gorrión de Alas Blancas (*Calamospiza melanocorys*) en relación con distintas intensidades de pastoreo (pastoreo intenso, pastoreo moderado y exclusión de ganado) y distancia a fuentes de agua en poblaciones ivernando en zonas áridas del Altiplano de San Luis Potosí. El Capítulo 1 usa la biblimetría para sintetizar el estado actual del conocimiento sobre la ecología invernal de las aves migratorias de pastizales. Para investigar el comportamiento invernal del Gorrión Alas Blancas, capturé y coloqué radiotransmisores a 32 individuos, mismos que fueron rastreados de enero a marzo del 2021. En cada sitio, se condujeron treinta transectos de 500 m de largo para detectar la presencia de aves; todos los transectos del censo se categorizaron en relación con el tipo de manejo y la distancia a tanques de agua del ganado (Capítulo 2).

En cuanto al primer capítulo, el análisis reveló, a pesar de que el invierno se reconoce como un período clave del ciclo anual y de gran importancia para la conservación de las aves de pastizal, los estudios en las áreas de invierno son escasos. Este estudio informa que la mayoría de los esfuerzos de investigación

se han centrado en comprender los patrones de movimiento de las aves, los factores que influyen en el uso del hábitat, la supervivencia invernal, los requisitos de hábitat de algunas especies amenazadas y algunas de las amenazas que enfrentan las poblaciones durante el invierno, pero aún se necesita más información sobre los efectos del cambio climático en las poblaciones de aves migratorias, condición corporal y salud, comportamiento de bandada y efectos de contaminantes y agroquímicos. Además, la mayoría de las aves migratorias de pastizal se encuentran en tierras comunales (ejidos), lo que hace que el involucramiento de los propietarios de tierras, las comunidades locales y los gobiernos locales sea crucial al diseñar e implementar planes de conservación.

En el segundo capítulo proporciono información novedosanovedosa sobre la ecología invernal del Gorrión de Alas Blancas. De las 32 aves marcadas con radio transmisores, 4 (12,5 %) permanecieron en el área donde fueron capturadas, 17 (53,13 %) aparentemente exhibiendo un comportamiento nómada, ya que fueron observadas solo algunas veces en su sitio de captura y en ocasiones hasta 5 km lejos; 11 (34,38%) nunca fueron vistos otra vez a pesar de la intensa búsqueda en los sitios de estudio (aproximadamente 36,000 ha) y durante toda la temporada. Todas las aves fueron capturadas y registradas al menos una vez a no más de 500 metros de una fuente de agua artificial (tanques de agua para ganado). Estos resultados sugieren que existe una variación individual en su comportamiento (nómada y sedentario), y que el uso del hábitat es mayor más cerca de los tanques de agua para ganado. Este patrón puede afectar de manera significativa los movimientos del Gorrión Alas Blancas, pudiendo tener implicaciones importantes para el desarrollo efectivo de prácticas

locales de manejo y conservación de pastizales. Finalmente, los hallazgos se discuten en el contexto de la efectividad de censar poblaciones nómadas durante el invierno y cómo las estrategias de manejo y conservación deben incorporar especies con comportamientos de estilo de vida únicos, como el Gorrión de Alas Blancas.

PREFACE

Lark Bunting (*Calamospiza melanocorys*)
Female/Immature Male radio-tagged in El Salado, San Luis Potosí
Original photo: Francisco Puente
Edition: Elven Villecourt

Preface

Grassland bird populations have declined in almost 53% abundance over the past five decades (Rosenberg et al. 2019) due to ongoing pressures from anthropogenic activities (Samson & Knopft 1994; Hoekstra et al. 2005) such as urbanization (Fedy et al. 2018), oil and gas extraction (Kreuter et al. 2016), wind energy development (Copeland et al. 2011; Stevens et al. 2013), and fire suppression (Fedy et al. 2018; Agustine et al. 2019). However, most of the research and monitoring of migratory birds has taken place in the breeding grounds (Vickery et al. 1999). Consequently, very little is known about the challenges that these birds face in the other stages of their life including stopover and wintering periods (Drum et al. 2015).

The current study aims to acquire insights into the winter ecology of a migratory grassland bird in steep decline, the Lark Bunting, in a southern portion of the Chihuahuan Desert (Chapter 2). Chapter 1 synthesize the current state of knowledge on the winter ecology of migratory grassland birds based on scientific publications. The objective was to reveal how much is known about the winter ecology of migratory grassland birds, identify research topics and trends, amongst other information useful for designing and developing efficient and effective migratory bird management and conservation strategies. Chapter two focus on the winter ecology of Lark Buntings across representative sites of three rangeland management practices. The objective was to increase understanding pertaining how each of these practices affect their populations during the winter. Manual radio telemetry was used to understand Lark Bunting winter ecology in relation to livestock grazing. Overall, birds are good bioindicators of the ecosystem quality and are useful for monitoring changes within their habitats (Padoa-Schioppa et al. 2006). Thus, is important to understand the effects of livestock grazing on birds overwintering in priority grasslands for their conservation. In this context, investigation of the effects of livestock grazing on migratory grassland birds in southern Chihuahuan Desert are very limited and no research on the winter ecology of the Lark Bunting has been conducted, making this study essential to developing sustainable grazing management practices for the region that benefit grassland bird populations.

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CHAPTER 1

Literature review on the winter ecology of North American migratory grassland birds: research advances and future directions

Chapter 1

Literature review on the winter ecology of North American migratory grassland birds: research advances and future directions

Abstract

Keywords: Chihuahuan Desert, grassland birds, winter ecology, review, climate change.

Several species of grassland birds that migrate every year from the northern United States and Canada to the grasslands of the Chihuahuan Desert are under threat. The loss and degradation of habitat in the grasslands of the Chihuahuan Desert has been suggested as a possible driver of the decline of some grassland birds. Despite the imminent decline of grassland birds and their ecological implications, our comprehension of this phenomenon together with the factors driving it, is yet developing. Here I reviewed the major trends in the study of grassland neotropical migratory birds overwintering in the Chihuahuan Desert. My findings reveal that, to date, little research towards their conservation has been conducted, especially in grasslands embedded in the southern portion of the Chihuahuan Desert. I further identified knowledge gaps on the study of grassland birds winter ecology. I suggest future studies to include the negative effects of an emerging driver of birds declines: climate change. Finally, even though more studies are needed I aim rangeland stakholders to start acting, in order to prevent further declines of migratory grassland birds.

1. Introduction

The central Grasslands of North America have become one of the continent's most endangered biomes as a consequence of ongoing pressures from anthropogenic activities (Samson & Knopft 1994; Hoekstra et al. 2005). While conversion to cropland (Pool et al. 2014) and overgrazing (Jones 2000; Briggs et al. 2005) negatively affect the ecological functionanlity of these ecosystems (Hoekstra et al. 2005; Ceballos et al. 2010), new emerging threats such as invasive plants species (Gaskin et al. 2020), urbanization (Fedy et al. 2018), oil and gas extraction (Kreuter et al. 2016), wind energy development (Copeland et al. 2011; Stevens et al. 2013), and fire suppression (Fedy et al. 2018; Agustine et al. 2019) become more common across the biome (Commission for Environmental Cooperation & The Nature Conservancy 2005). Furthermore, the loss and degradation of these grasslands have led to the loss of biodiversity, depletion of environmental services (White et al. 2000; Millennium Ecosystem Assessment 2005) and changes in grassland plant structure, such as woody-plant encroachment (Macías-Duarte & Panjabi 2013a, 2013b; Macías-Duarte et al. 2017). Not surprisingly, many populations and species that depend on these ecosystems show dramatic declines (Ceballos et al. 2010).

The vast majority of grassland bird species that breed in the Great Plains migrate south during winter to the Chihuahuan Desert of northern Mexico and the southwestern United States (Macías-Duarte et al. 2011; Macías-Duarte & Panjabi 2013a, 2013b). However, most of the research and monitoring of these species has been done during the breeding period (Vickery et al. 1999). Consequently, very little is known about the challenges that these birds face in their winter region (i.e. winter in northern Mexico and southern United States).

Increasing evidence suggests that the Chihuahuan Desert grasslands are perilous wintering areas for migratory grassland birds since the loss and degradation of habitat has been as, or more extensive in grasslands used during winter in southern United States and northern Mexico (Rosenberg et al. 2019, Macias-Duarte et al. 2017; Pool et al. 2014). For example, there is an important association between habitat structure and winter survival (Macías-Duarte & Panjabi 2013a), as the risk of predation may increase in grasslands that have been degraded into shrublands, mainly because shrubs and trees are used for hunting and perching by a variety of avian predators (Macías-Duarte et al. 2017). Additionally, a large portion of the Chihuahuan Desert in northern Mexico has been converted to agricultural lands (Pool et al. 2014), consequently eradicating valuable wintering habitat for migratory birds.

Despite that some of these studies stress importance of researching migratory birds populations during their winter period, as a way to understand more about their population declines, research to date is limited and, to our knowledge, no literature review on the topic has been conducted.

Here, I conducted a systematic literature survey and employed the use of bibliometric mapping analysis (Aria & Cuccurullo, 2017) to synthesize the current state of knowledge on the winter ecology of migratory grassland birds published in the scientific literature. Specifically, I aimed at identifying main research topics addressed in studies focused on the the ecology of migratory grassland birds during winter to pointing out gaps in scientific knowledge and proposing future research priorities in order to enhance conservation practices.

2. Methods

2.1 Literature search and data collection

In order to gather all available published literature focusing on the ecology of migratory grassland birds, I conducted a search in Scopus (www.scopus.com) and Web of Science (www.webofscience.com). For each of these searches I used the following Boolean operator string: "migratory" AND grassland* AND avian OR avifauna OR bird* AND overwinter* OR winter* OR non-breeding OR nonbreeding AND "United States" OR "Mexico" in the titles, abstracts or keywords of papers published before May 2021. These databases yielded a total of 27 and 29 documents, respectively. Then, I screened these documents in order to eliminate those that did not fit the topic of focus for the current study, and to avoid duplicated documents. A total of 20 documents remained for further analyses, which Ie saved for further analysis as BibTex and Text files, respectively.which is allowable for importing into biblioshiny for bibliometrix tools (Aria & Cuccurullo, 2017).

To broaden and complement the search, Ie used Google Scholar (www.scholar.google.com) which provides a greater literature coverage (Harzing & Alakangas 2016; Nakagawa et al. 2019) using the same search string already described. This search contributed 6 additional publications that were used to complement the BibTex file provided by Scopus. I then merged the two subsets of papers using R packages xlsx (Dragulescu 2020) and bibliometrix (Aria & Cuccurullo 2017), resulting in a whole set of 26 papers. Bibliographic information of each selected paper was saved for quantitative and qualitative analyses. In this study, all data were compiled in BibTex format, which allows importing into biblioshiny for bibliometrix tools (Aria & Cuccurullo, 2017). I screened the full text of all the 26 publications to meet the scope of this study. I categorized each document according to predefined categories (Table 1). For publications with multiple entries within a category, e.g.study species, study location, addressed threats or ecological research question each entry was recorded. Consequently, one document could be listed more than once and as a result, the overall sum of all publications in some of the analyses exceeds the total number of reviewed publications.

Category
Species abundance and density
Response to grazing
Habitat use and selection
Response to fire regimes
Habitat associations
Home Range and Movement Patterns
Response to agriculture
Foraging Behavior and Diet
Survival and Fitness
Response to invasive plant species
Response to drought
Site fidelity
Behaviour and social stucture
Health/Stress
Toxicology and disease

Table 1: Categories in which ecological research questions were classified

I also collected information regarding the conservation status of studied bird species addressed in those publications based on a annual trends from North American Breeding Bird Survey 1966–2019 (Sauer et al. 2020), percentage of global population lost (1970-2014) (Rosenberg et al. 2016), species' "half-life" (Rosenberg et al. 2016), species listed as Common Birds in Steep Decline (Rosenberg et al. 2016) and bird species of conservation concern (U.S. Fish and Wildlife Service, 2008) (Appendix 1).

2.2 Data analyses

To identify the trend topics in research pertaining to winter ecology of grassland birds, I developed a word cloud based on author's keywords using the biblioshiny ( ) function included in the bibliometrix R-package software, an open-source software developed by Aria and Cuccurullo (2017) which provides a set of tools for conducting a bibliometric analysis that performs the visual results displayBiblioshiny is a web-base app developed in the Shiny package environment (Aria & Cuccurullo 2020). To synthesize the main ecological research questions I summarized the number of publications for every category (Fig.2) . To visualize how the number of studies vary across different countries and states I mapped the regions and the total number of studies counducted in each using a choropleth map via Excel (Microsoft 365).

3. Results and discussion

3.1 Limited knowledge on the winter ecology of neotropical grassland birds

The scientific production examined up to 2020 reveals that research effort is still limited, since only 26 peer reviewed documents have been published since 1999. Until recently,undergoing declines have stimulated recent research attempting to gain knowledge of the ecological requirements of grassland birds while wintering. Essentially, Arvind Panjabi from the United States and Alberto Macías-Duarte from Mexico have been fundamental in advancing the knowledge of migratory grassland birds, being the pioneers in the telemetry study of grassland birds overwintering in northern Mexican grasslands of the Chihuahuan Desert (e.g. Macías-Duarte & Panjabi 2013a). For instance, their research has focused onstudying the mechanisms and preferences of habitat use by a variety of Sparrows e.g. Vesper Sparrow (*Pooecetes gramineus),* Baird's Sparrow (*Ammodramus bairdii*) and Grasshopper Sparrow (*Ammodramus savannarum*) while wintering in the Chihuahuan Desert. Besides Macías-Duarte and collaborators (2017) found that Grasshopper Sparrows (*Ammodramus savannarum*) in the Chihuahuan Desert had lower survival in grasslands degraded into shrublands (low quality grasslands) since the risk of predation increases (i.e. shrubs provide suitable perches for a variety of raptors and Loggerhead Shrikes to predate upon small grassland bird species), demonstrating he importance of habitat quality in overwinter birds survival.

3.2 *Keyword analysis*

Fig. 1 Word cloud synthesizing the most frequently studied topics of migratory grassland birds overwintering based on the author's keywords of the reviewed publications; word size is proportional to each keyword's relative frequency.

Most research on migratory birds has been conducted in the Chihuahuan Desert, where researchers have been focusing on studying three species: Grasshopper Sparrow (*Ammodramus savannarum*), Baird's Sparrow (*Ammodramus bairdii*) and Vesper Sparrow (*Pooecetes gramineus*). Furthermore, the major research topics regarding winter ecology of grassland birds have been: i) diet, ii) habitat use, iii) diversity and density, and iv) responses to grassland management (e.g., fire). The most widely used techniques for the study grassland birds have been telemetry and remote sensing (Fig.1).

3.2 Ecological research questions

After reviewing all the publications, I extracted and compiled the top 10 most relevant ecological research questions addressed by the authors (Fig.2). Thus, I summarized the major findings in: (i) Dynamics of grassland bird communities (Martinez-Guerrero et al. 2014), (ii) Resource preference (Titulaer et al. 2017; Titulaer et al. 2018), (iii) Anthropogenic limiting factors (e.g. overgrazing, agriculture and fire suppression) (Pool et al. 2014; Grand et al. 2019), (iv) Mechanisms and preferences of habitat selection (Martínez-Guerrero et al. 2011; Macías-Duarte & Panjabi 2013a; Kerstupp et al. 2015; Macías-Duarte et al. 2018 and Strasser et al., 2019), (v) Relationships between survival and habitat associations (Macías-Duarte et al. 2017).

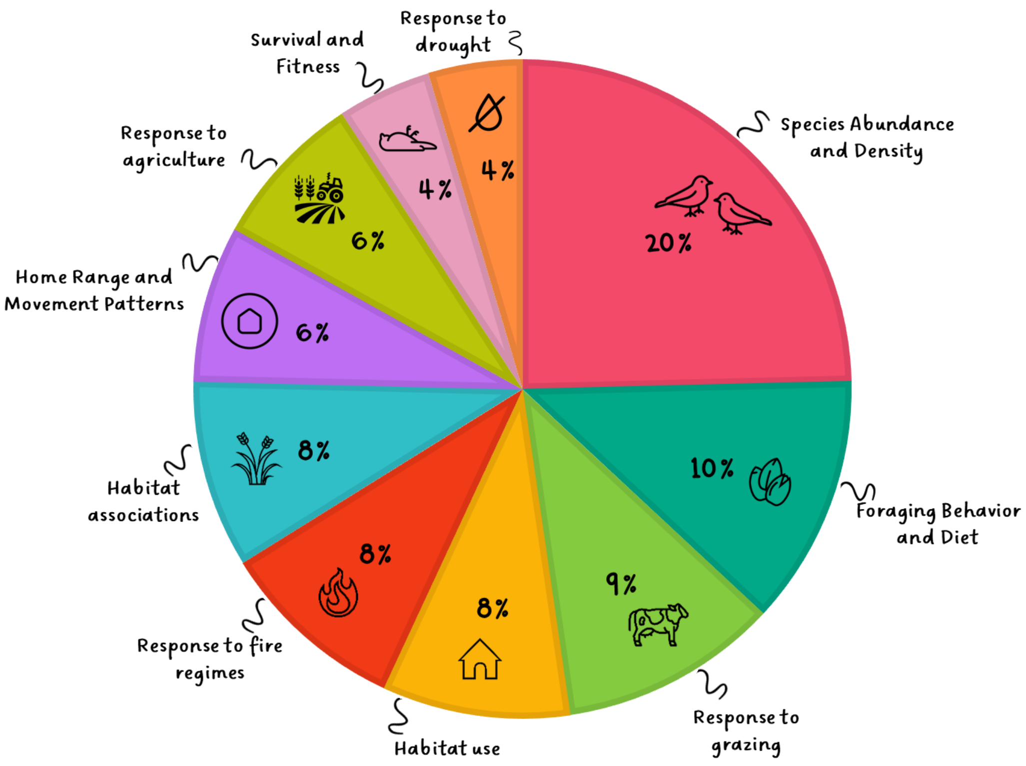

Fig. 2 Main ecological research questions for overwintering grassland birds.

3.3 Locations

There is an imbalance in the number of studies carried out in the winter region. Most of the studies have been conducted in the state of Chihuahua in Mexico, specifically in Janos (Fig. 3), while the US southern region remains largely unexplored. Surprisingly, very few studies have been conducted in the southern region of the United States (Arizona, New Mexico, Texas, Louisiana, Mississippi, and Florida), probably because most studies have focused on studying regions that have the highest bird densities (Chihuahuan Desert Region) (Macías-Duarte et al. 2011; Macías-Duarte & Panjabi 2013a, 2013b). Interestingly, many of the studied were found in communal lands (ejidos) that are priority areas for grassland bird conservation. Thus, efforts to preserve and restore grassland habitats in the Chihuahuan Desert must reconcile the interests of the land owners, community members, local goverments and conservationists.

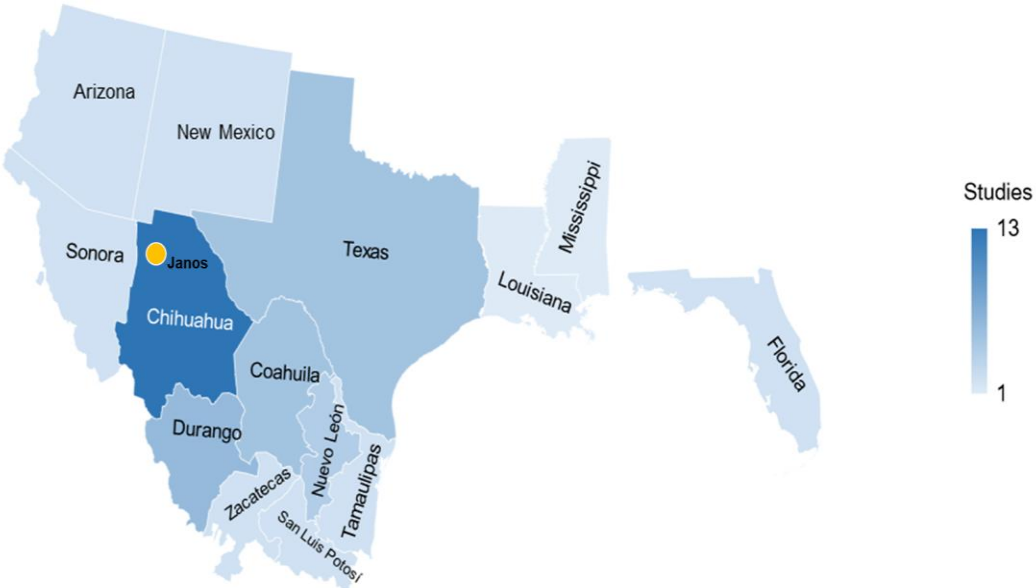

Fig. 3 number of grassland bird studies within US-Mexico wintering range. The intensity of blue scale indicates the frequency of studies. The yellow dot highlights the locality where most of the studies have been carried out (Janos,Chihuahua)

3.4 Study species, their population trends and conservation status

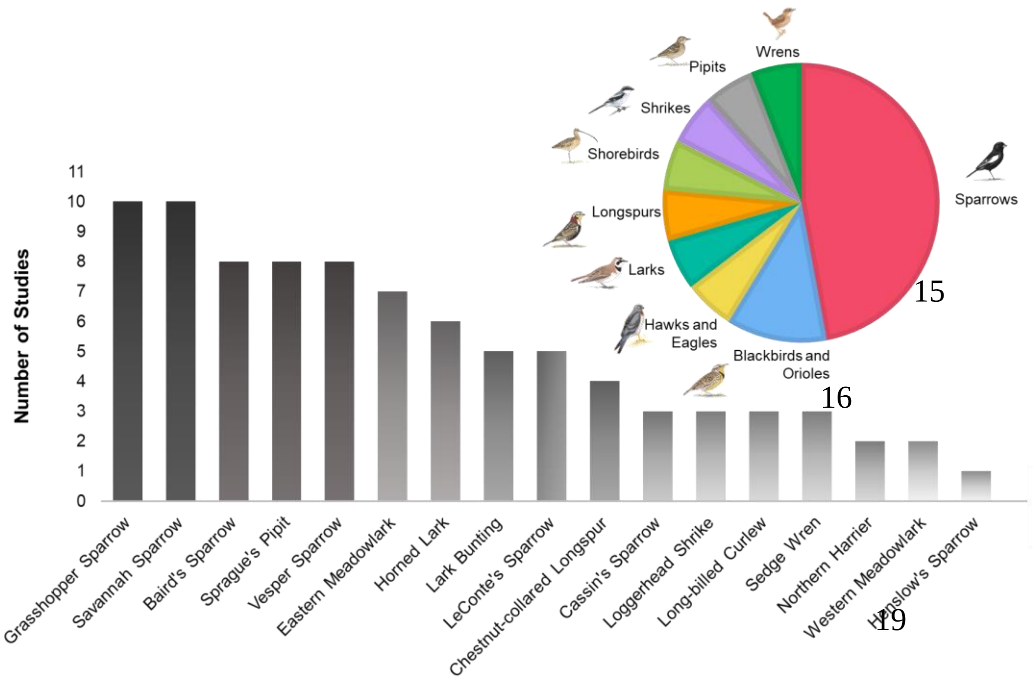

Fig. 4 Species studied in the reviewed literature and the number of publications related to their study. Pie chart shows the proportion of studies by bird groups. Timespan (1999-2020).

A total of 17 grassland bird species were studied in the reviewed literature (Fig. 4). Nevertheless, five species have been used more frequently as a model to understand the relationships between grassland birds and their wintering grounds. These are: Grasshopper Sparrow (Ammodramus savannarum), Savannah Sparrow (Passerculus sandwichensis), Baird’s Sparrow (Ammodramus bairdii), Sprague's Pipit (Anthus spragueii) and Vesper Sparrow (Pooecetes gramineus). Additionally, I compiled the information regarding population trends and conservation status of all the study species (see Appendix 1). I found that: 1) the more studied species are not necessarily the most endangered ones. For example, the Savannah Sparrow, with an annual population decline of 1.1 % (Sauer et al. 2020) and a total population loss of 40%, is one of the most studied species, while the Lark Bunting, a species that has been poorly studied, has lost more than half of its population since 1970 (86% population loss) (Rosenberg et al. 2016). Furthermore, Lark Bunting populations have drastically declined at a rate of 3.7% annually since 1966 (Sauer et al. 2020) and has been designated as a “Common Bird in Steep Decline” by Partners in Flight (Rosenberg et al. 2016), as well as a “Bird of Conservation Concern” by U.S. Fish and Wildlife Service (2008). 2) The vast majority of the study species (n=7) overwinter in the Chihuahuan Desert Grasslands. 3) 5 of the 17 studied species are listed as “Common Birds in Steep Decline” (Rosenberg et al. 2016) and 12 as a “Birds of Conservation Concern” (U.S. Fish and Wildlife Service 2008).

3.5 Population limitation in grassland birds: the role of habitat loss and degradation

Within the scientific literature reviewed, most discussion on the factors that limit populations during winter is based on food and water resources, predators, pesticides and sites for cover. Overall, bird populations have been limited by the amount and distribution of high quality winter habitats. However the Chihuahuan Desert has undergone high levels of habitat loss and degradation, due to grazing (Bock & Bock 1999; Macías-Duarte et al. 2017) and agriculture (Pool et al. 2014) eliminating important wintering habitat.

For instance, loss of wintering habitat is due principally to conversion of grasslands to agriculture and developed areas. Pool and collaborators (2014) demonstrated a steep and ongoing rate of cropland expansion in a region of the Chihuahuan Desert grassland and reported evidence of habitat loss for both migratory and resident grassland bird populations. Furthermore, construction of wind energy facilities not only directly reduces grassland habitat , but also has a strong influence on bird distribution as birds are displaced by the presence of the infrastructure (Stevens et al. 2013).

Fire is an important disturbance for some grassland birds creported the importance of fire regimes for some species of grassland birds, which showed to be highly tied to plant species that depend on disturbance, concluding that the needs of some bird species would be best met by periodic fires (i.e. birds may select recently burned areas) because richness and seed production of plant species are highest immediately following low intensity fires (Buckner & Landers 1979) and they can move nearest to the ground as burning probably improves foraging conditions by removing plant litter (Butler et al. 2009). Therefore, fire suppression leads to woody plant encroachment and buildup of plant litter that can make grassland structure less attractive to some bird species (Askins 2000, Askins et al. 2007) and reduce bird survival (Macías-Duarte & Panjabi 2013a, 2013b; Macías-Duarte et al. 2017).

Besides, clearing natural lands contributes significantly to climate change by releasing carbon into the atmosphere, i.e. nearly 22% of the world's anthropogenic greenhouse gas emissions in 2019 where attributed to land clearing and farming (IPCC 2022). Climate change have detrimental effects on birds i.e. warmer temperatures force birds to shift their ranges in search for areas with better thermal conditions (Crick 2004) but their survival and fitness may be compromised in such areas. Moreover, droughts due to lack of rainfall and warmer temperatures are expected to increase accelerating bird population declines (Wilsey et al. 2019). In this contex, the lack of rainfall during summer is one of the main limiting factors for grassland birds, as quantity of rainfall directly impacts food supply and grass height, thus, birds may be at risk of starvation and predation when rainfall reduces (Bock & Bock 1999; Macías-Duarte et al. 2009; Macías-Duarte & Panjabi 2013a).

In addition to habitat loss and degradation, grassland birds are threatened by improper use of pesticides .For instance, it can be letal from exposure and reduce the arthropod abundance, thereby reducing food availability and preventing birds from reaching their minimum energy requirements. Moreover, birds that also rely upon vertebrate prey, such as Loggerhead Shrikes (*Lanius ludovicianus*) can alternate prey resources, including more frequently in their diet grassland bird species such as Baird’s Sparrow (*Ammodramus bairdii*), Grasshopper Sparrow (*Ammodrammus savannarum*), and Cassin’s Sparrow (*Peucaea cassinii*) (Kerstupp et al. 2020).

4. Conclusions and future directions

In this review I have synthesised the available knowledge on the winter ecology of migratory grassland birds. My findings revealed that studies aimed to understand the ecology of migratory grassland birds wintering in the Chihuahuan Desert are scarce and elucidate potential future research priorities. For instance, is urgent to understand habitat needs and populations limiting factors for both, overwintering migrants and local species, as only few studies have scaled the analysis to the community level. The main current knowledge comes from studies conducted in the northern region of the Chihuahuan Desert, while the southern portion remains largely unexplored, which does not allow us to understand if the threats faced by these birds in the northern grasslands are the same down south. Moreover, it is evident that studies are biased towards the study of Baird's, Grasshopper, and Savannah Sparrows, possibly because they are common species in northern wintering areas. On the contrary, species with alarming decline rates such as the Lark Bunting are not being studied, probably because the species is very difficult to study in the wintering grounds as they exhibit nomadic behavior making its true distribution unknown. Therefore, the results of these studies may not be successful when designing conservation strategies for birds overwintering in southern Chihuahuan Desert.

Due to the accelerated expansion of farmlands in northern Chihuahuan Desert (Pool et al. 2014), most research efforts have been focused in understanding how land-use change due to agriculture impacts migratory grassland bird populations. However, the Mexican Plateau has a long mining (Monzalvo-Santos 2016; Chapa-Vargas et al. 2010) and ranching history. Therefore, studies focusing on the impacts of anthropogenic toxicants such as heavy metals on grassland bird populations could enlighten our understanding of how these pollutants drives populations declines. Besides, it would be advisable that future studies explore the effects of livestock grazing practices on the winter ecology of migratory populations overwintering in the region.

Additionally, climate change has beed proposed as an emerging driver of bird population declines globally (BirdLife International 2018). Thus, in other to achieve the goal of protecting grassland birds across all their range, I recommend that future research priorities should give more attention on the effects of increasing temperatures and changes in precipitation patterns on birds phenological shifts, movement patterns and winter survival. As this may have important implications for land management activities exploring correlations between livestock grazing-agricultural practices and climate shifts could enrich our comprehension of this complex phenomenon.

Finally, one question remains: how can we promote research on migratory grassland birds to fill the remaining knowledge gaps? In my opinion, researchers must involve Mexican government and aim to obtaing funding through persuading rangeland stakeholders (i.e. Goverments, NOGs, policymakers, and local communities) about the importance of migratory grassland birds for improving human wellbeing, economy and food production, specially because many populations of endangered grassland birds are found in communal lands used for agriculture and ranching. Further, it is a need for scientific results to be converted into action.

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CHAPTER 2

Insights into the winter ecology of Lark Bunting (*Calamospiza melanocorys*) in a Southern grassland of the Chihuahuan Desert

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Insights into the winter ecology of Lark Bunting (*Calamospiza melanocorys*) in a Southern grassland of the Chihuahuan Desert

Abstract

Keywords: Lark Bunting, Chihuahuan Desert, manual radio-telemetry, livestock grazing, winter ecology.

The grasslands in the Chihuahuan Desert have been negatively impacted by the establishment of agricultural lands and livestock ranches threatening wintering grassland birds populations that migrate every year to Chihuahuan Desert grasslands. This research used manual radio-telemetry to investigate the overwinter ecology of a declining priority grassland bird, the Lark Bunting (*Calamospiza melanocorys*) and examinated their responses to livestock grazing. I attached radio-transmitters to 32 Lark Buntings overwintering in the high plateau of San Luis Potosí and tracked them from January to March 2021. I found that the presence of livestock water tanks influenced Lark Bunting abundance and distribution throughout the region. Lark Bunting populations showed nomadism and sedentary lifestyle. My results suggest that habitat management for wintering Lark Bunting populations should focus on create heterogenous landscapes while providing water resources and preserve moderate disturbed habitats. Finally, I suggest to conduct long-term studies and use autonomous telemetry to track the birds longer distances since the species has a nomadic behavior during the winter.

1. Introduction

Over the last decades North American grassland bird populations have received substantial attention from the scientific community (Peterjohn 2003, Grand et al. 2019). The vast majority of research and monitoring of grassland birds have focused on the breeding grounds (Vickery et al. 1999). However, declining population trends may be influenced by events occurring not only on the breeding grounds, but also during migration, and/or on the wintering grounds (Latta & Baltz 1997). Many grassland bird species are migratory and winter in grasslands of the Chihuahua Desert in northern Mexico (Macías-Duarte et al. 2011).

Grasslands of the Chihuahua Dessert have diminished significantly due to land-use intensification practices including conversion to croplands (Macías-Duarte et al. 2009; Pool et al. 2014) as well as woody plant encroachment and reduction of grass cover due to overgrazing (Macías-Duarte and Panjabi 2013a; Macías-Duarte et al. 2004). The southern region of the Chihuahua Dessert – “El Tokio” - harbors a portion of the Grasslands Priority Conservation Area (GPCA) (Commission for Environmental Cooperation & The Nature Conservancy 2005; Pool et al. 2011) which is one of the largest Chihuahuan Desert grassland complexes, including nearly 1,936,400 ha of the Chihuahuan Desert scrublands, grasslands, and woodlands of southern Coahuila, southwestern Nuevo Leon, northeastern Zacatecas, and northern San Luis Potosí, all states in north-central Mexico. These grasslands are well-known for containing all the remaining habitat for the Mexican prairie dog (*Cynomys mexicanus*), while supporting a robust wintering bird community, including species such as Long-billed Curlew (*Numenius americanus*), Mountain Plover (*Charadrius montanus*) and the endemic resident Worthen’s Sparrow (*Spizella wortheni*) (Macías-Duarte et al. 2011). These rangelands have been heavily impacted through excessive grazing pressures (La Baume and Dahl, 1986) which have led to the loss of almost 70% of the grasslands in the region (Estrada-Castillón et al. 2010). As a result, many grasslands in this region are invaded with woody species (Yeaton & Flores 2009). Moreover grasslands in this region have been exploited by local people as common-use rangelands (“ejidos”) for a long period of time (Silva-Herzog, 1998, Yeaton & Flores 2009). In this context, Mellink and Riojas-López (2020). the authors identified three major periods of rangeland management during the last 500 years: 1) cattle, 2) sheep, a period characterized for grasslands changing from tall to short grasses (i.e., in the year 1630, grasslands in San Luis Potosí were heavily stocked with sheep, with herds ranging from tens to thousands of animals (Frye, 1986, 2000) and, 3) mixed livestock (goats, horses, sheep, asses and some cows) resulting in a serious grassland degradation by the mid-20th Century. Consequently, grasslands in the region have been strongly affected by overgrazing. Excessive grazing pressures have reduced grassland livestrock capacity, and more importantly, they have negatively impacted birds (Mellink and Riojas-López 2020). In this Connection,, Mellink and Valenzuela (1992) found that birds occupying grasslands in San Luis Potosí strongly depend upon plant heterogeneity, as well as on vegetation cover and composition (Mellink & Valenzuela, 1995).

Rangeland management practices in the Chihuahua dessert consist of different grazing intensities by different animals. These practices facilitate woody plant encroachment, reduce grass cover and affect all avian species but in different ways. While we recognize that birds are vulnerable in all stages of their life cycles, including breeding, migration, and winter; the latter is a period that lacks basic information on grassland bird ecology, challenging the development of effective conservation strategies. In this context, domestic livestock limits the availability of resources for many grassland-associated species (Derner et al. 2009). In fact, the livestock-grazing process has been demonstrated to influence vegetation associatiations for birds (Knopf 1996; Fontaine et al. 2004) by causing shifts in vegetation composition (i.e. proliferation of woody species and exotic grasses) (Southern et al. 2019). Additionally, livestock water tanks and troughs combined with localized grazing pressure often diminishes spatial heterogeneity (Fontaine et al. 2004). Although spatial homogeneity and the presence of domestic livestock may provide appropriate habitat (i.e., concentrated resource patches such as water and food) for some bird species this management practice may not benefit species that apper to be very sensitive to grazing pressures (Knopf 1996; Samson et al. 2004; Derner et al. 2009).

Grazing regimes influences in grassland bird habitat affecting bird populations in all stages of their life due to the wide range of habitat requirements that this species group have, i.e., plant structure and composition have a profound effect on birds behavior and where they forage (Lima 1990), directly influencing birds presence in an area (Knopf 1996).While the impacts on breeding grassland birds (non-wintering area) due to domestic grazing have been documented (Askins et al. 2007; Fuhlendorf et al. 2006; Jansen et al. 1999), to date, little research regarding the impacts on wintering populations has been conducted. For instance, Macías-Duarte and Panjabi (2013a) have demonstrated the importance of habitat structure on grassland bird winter survival, as the risk of predation is higher in grasslands degraded into shrublands (Macías-Duarte et al. 2017). Additionally, low-quality grasslands may force birds to search for areas whith more resources (e.g., water, food, shelter) (Macías-Duarte & Panjabi, 2013b; Strasser et al. 2019) which in turn may impact their fitness and movements. However, the relevance of grazing ecosystems in the grasslands of northern Mexico where migratory birds overwintering is largely unknown.

Thus, it is particularly important to generate knowledge that can help guide rangeland management practices for the benefit of both, species affected by changes in their winter habitat, and those apparently better adapted to the loss and deterioration of the desert grasslands (Phillips et al. 1964; Macías-Duarte et al. 2009).

Among the many species of interest, one of particular importance is the Lark Bunting (*Calamospiza melanocorys*). Lark Bunting is one of the only six passerines endemic to the North American grasslands, and one of the most abundant of the Great Plains (Shane 2020). It’s winter range encompasses Texas, Arizona, and the high plateau of northern Mexico (Neudorf et al. 2006; Shane 2020). Their population densities are highly influenced by preceding summer rains, since these alter the structure and composition of grassland vegetation during the winter season i.e. grass productivity is directly linked to rainfall events, thus grass and forb seeds are available during the winter period (Macías-Duarte et al. 2009; Macías-Duarte and Panjabi 2013a), benefiting granivorous species such as the Lark Bunting.In addition, the species has shown a strong dependence on water sources (Fontaine et al. 2004). Therefore, Buntings often wander in very large flocks that stay on the move until they are able to find an abundant winter food and water supply, which explains their nomadic lifestyle (Shane 2020), what makes difficult to study the demography of the species whose winter behavior is relatively less known than other migratory grassland birds. During winter, they usually forage in very large and cohesive flocks (Baird et al. 1874), feeding mainly on small seeds, grains, and insects (Ligon 1961). While Lark Buntings remain relatively common in their overall distribution, there is growing concern for the species, as its populations have declined by an estimated 86% from 1970 to 2014, being designated as a “Common Bird in Steep Decline” by Partners in Flight (Rosenberg et al. 2016). Lark Buntings have shown a widespread, long-term (1966-2020) decline of 3.7% per year (Sauer et al. 2020).

Lark Bunting is a grassland generalist on the winter grounds (Pool et al. 2012) and thus may not be highly susceptible to changes in its wintering habitat (Macías-Duarte et al. 2009). They evolved in the Great Plains in association with bison (*Bison bison*) populations, so the species come from a grazed ecosystem with heterogeneous landscapes created by a combination of large native ungulates, small mammals (e.g., prairie dogs), and fire (Nicholoff 2003). However, very little is known about how t livestock grazing practices affect their populations during winter. For the Lark Bunting, as it is for most grassland passerines, limited information about its ecology during winter is available (Shane 2020).

The goal of this study was to evaluate various aspects of the winter ecology (movements, bird’s behavior, and survival) of the Lark Bunting in relation to grazing pressure (heavy grazing, moderate grazing, and cattle exclusion) and distance from water sources. I expected that this would allow us to understand how each of the grazing practices affect their populations during winter and the relative importance of water availability. Surveying Lark Bunting populations during winter require to apply a technology that allow us to track the birds longer distances i.e. automated telemetry systems.

2. Methods

2,1 Focal species

The Lark Bunting (*Calamospiza melanocorys*) is a migratory grassland bird species that breeds on grasslands from the southern parts of central Canada through the Great Plains of the central United States and winters in Texas, Arizona, and the high plateau of Mexico (Shane 2020; Neudorf et al. 2006). The species begins to migrate very early in the year, with some appearing south of the breeding range by late July (Kaufman 1996), arriving at their winter grounds in Mexico as early as August (Russell & Monson 1998); some remain in wintering grounds into May (Kaufman 1996). Lark Buntings are gregarious during the wintering and migrating seasons, occurring in very large flocks, sometimes in mixed flocks (Lima 1990; Shane 2000). In Durango, Mexico, buntings occur in open habitats, such as dry lake beds (playas). Large flocks can also be found in prairie-dog (*Cynomys ludovicianus*) colonies (Manzano-Fischer et al. 1999).

2.2 Study area

From January to March 2021, I surveyed Lark Buntings in the southern portion of the Chihuahua Desert in grasslands at the ejido “El Salado" in the municipality of

Vanegas in the Mexican San Luis Potosí state (24°17'02" N' 100°47'03" W) (Fig.1).

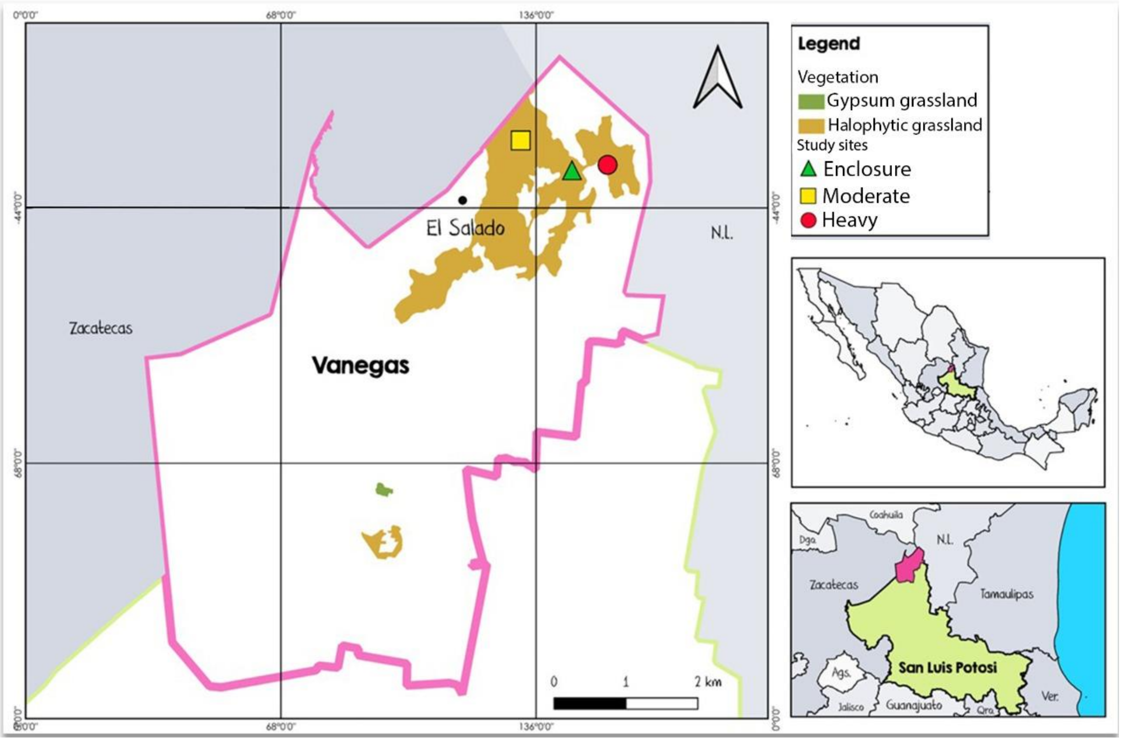

Fig.1 Study area and the study sites for monitoring of Lark Bunting on their wintering grounds

Temperature in the area range from 8.5 °C to 26.9 °C, the mean annual rainfall in this area is 343 mm, with an average of 45.5 days with rain (Servicio Meteorológico Nacional 2021). Grasslands in the area are dominated by gypsophile perennial grasses (*Bouteloua chasei, Aristida purpurea and Muhlenbergia villiflora*) (Estrada-Castillón et al. 2010), interspersed with patches of bare ground and woody plants such as creosote bush (*Larrea tridentata*), honey mesquite (*Prosopis glandulosa*) and *Yucca filifera* (Rzedowski 1955; Meyer et al. 1992). Our study was conducted in three sites with different grazing management and habitat types (heavy grazing, moderate grazing, and cattle exclusion). I characterized each of the sites in terms of grazing management by interviewing landowners about the type and relative numbers of animals stocked within different management schemes within the ejido, and the timing of stocking. According to information provided to us by local inhabitants the area has been exploited as common-use rangeland for many years, annually varying the numbers of cattle, horses, goats and sheeps. The ejido “El Salado” is a 36,595 ha area of communal land, grasslands in the area are mainly grazed by free-ranging cows that are scattered throughout the ejido, varying in number throughout the year (approximately 1,400 animals). The ejido have an enclosure area, which is 2,000 ha in size, where livestock has been excluded for 4 years. The study site with moderate grazing is grazed currently by 200 to 250 free-ranging cattle and horses. The study site with high intensity of grazing is grazed mainly by cattle (approximately 400 animals) and by tended, transient herds of approximately 40 goats and 10–20 sheep from a local family. Though the number of goats and sheep in this site is currently low, more than 30 years ago, herds included as many as 3,000 goats and sheeps (Juan Rosales, pers. comm.). The management varies spatially depending on water availability and rainfall, that directly influences pasture condition, i.e. if previous year’s rains were scarce, the ranchers (“ejidatarios”) move their cattle to more favorable grazing places or where cattle water tanks are established (Fig. 2). Therefore, the stocking rate varies from year to year (Baltazar Montoya, local inhabitant, pers. comm.).These sites were selected to assess potential Lark Buntings' responses to different management regimes and how birds’ movements change with increasing distance from cattle water developments.

Fig. 2 Livestock water tank in the site with high grazing pressure, providing winter habitat for the Lark Bunting *Calamospiza melanocorys*. All the individuals were radio-tagged here when arrived at the site for foraging or drinking. Photo by Claudia Rosales.

2.3 Vegetation and bird surveys

In each site, I characterized the vegetation structure by measuring local-scale vegetation at fifteen points randomly located within 2 km of capture sites. At each point, we recorded structural variables using a modified circular plot technique (11.28 m radius; James & Shugart 1970). I measured the total linear cover (all species combined) of grasses and shrubs along two 11.28 m transects placed perpendicularly to one another within the survey plot. A densiometer was used to record the cover of live vegetation at 20 random points within the circular plot. Ground cover was quantified as the percentage of points with living vegetation. In each plot, I also measured the diameter at breast height of all trees ≥ 2 m tall with a dbh ≥ 5 cm in order to obtain the basal area of each tree. Additionally, because tree density is low in the area, I considered a larger area for a second measure of tree density. Therefore, the number of trees within a 50 m radius was recorded (see Table 1 for summary of all vegetation measurements).

I used Generalized Linear Models (GLM; Nicholls 1989) to assess potential differences in plant structure among the tree types of management:

enclosure, moderate grazing, and heavy grazing. The response variables were number of shrubs per hectare, percentage of herbaceous cover, and number of trees per hectare. Normality of the error terms was verified using histograms. These analyses were performed using R 4.1.0 (R Development Core Team 2021).

Table 1. Mean (±SE) vegetation measurements for each of the three management types where bird surveys were conducted.

Habitat	Percent ground cover	Number of shrubs/ha
Enclosure	55 ± 4.5	5526 ± 1302.9
Moderate	61.6 ± 11.02	5732.8 ± 3145.4
Heavy	32.3 ± 11.02	8865.2 ± 3145.4

Given that the variable of number of trees per hectare did not fulfill the assumption of normality (Shapiro-Wilk W= 0.80; p=0.0000026), I excluded this variable from our analysis. Moreover, the number of trees in the sites was very low (tree cover <10% in all sampling points) and was observed that trees were not relevant for Lark Buntings.

In each site, thirty 500 m-long transects were surveyed to detect the presence of birds. Thus, a total of ninety line transects were surveyed during the winter season (December 2020 to March 2021). In order to maximize detectability, transects were walked at moderate speed. To guarantee independence among samples, the minimum distance between transects was 200 m. Surveys were conducted when weather conditions were not expected to impair our ability to detect birds. Birds were identified with binoculars by sight (e.g., foraging, perched in vegetation, in flight if crossed the transect) and by their vocalizations. I measured and recorded wind speed, temperature, and relative humidity data using an anemometer (Kestrel 3000, Kestrel Meters Inc.).

2.4 Bird capture and radiotelemetry

Male and female Lark Buntings were captured using a flush-netting technique made up of an array of five 12 × 2.5 m mist nets. Individuals were banded with uniquely numbered aluminum and colored plastic leg bands. Morphometric measurements (wing cord, tail length, culmen length, tarsus length, scored fat), sex, age (when possible) and weight were recorded for all individuals. A total of 30 individuals were outfitted with PIP Ag376 VHF Tags weighing 0.7 g (75-day battery, Lotek Wireless Inc.) (Fig.3A), total weight did not exceed 5% of birds' average weight (37.6 g) (Dunning 2008). Transmitters were placed on birds' backs with a leg-loop harness made with elastic thread adapted from Rappole and Tipton (1991) and Streby and collaborators (2015) (Fig. 3B).

Fig.3 A) Illustrative image of transmitter size. B) Lark Bunting outfitted with a radio-transmitter. Photos by Francisco Vega.

Birds were radio tracked every week from January to March while conducting bird surveys, birds were also tracked doing random searches by walking, and from a slow-moving vehicle where dirt roads were available. The tracking was conducted using a hand-held three-element yagi antenna (maximum detection range 0.5-1 km) , and an ATS radio receiver (model IC-R20, Icom America Inc.). The location of each tracked bird was recorded using a hand-held GPS unit.

2.5 Behavior

When a radio-tagged bird was located, behavioral observations of birds were conducted overperiods of 5 minutes For each observation, bird coordinates, distance to the bird, habitat type, vegetation type and behavioral sequences were registered. To conduct the observations, five account behavioral categories were considered: Foraging, Locomotion, Self-maintenance, Flocking behavior and Social.

2.6 Lark Bunting detections in relation to habitat management and distance from water

Although we had a large number of individual Lark Buntings detected, most of these detections consisted of large flocks. As a result, the number of occasions in which the species was recorded, was small relative to the number of transects surveyed. Therefore, habitat occupancy models could not be conducted. Instead, I categorized all census transects in relation to management type and distance from water. For distance from water, I used eight distance categories. I also report management types and distances from water for detections from our telemetry work.

The number of Lark Buntings registered in each distance category from water, and among management classes, was compared to the expected number of records assuming a uniform distribution of individuals among distance-to-water categories and between management classes. For this purpose, following procedures described in Ziefler (2011), a chi squared statistic was calculated using Monte Carlo simulations based on 10,000 replicate samples from the dataset obtained from field observations. A correction proposed by Davison and Hinkley (1997) was applied to avoid potential underestimation of the p value.

3. Results

3.1 Lark Bunting detections in relation to habitat management and distance from water

None of the 10,000 replicates produced through the Monte Carlo simulation yielded extreme effects comparable to our observed frequencies of Lark Buntings within each distance from water categories and management types. Therefore, I concluded that abundance of Lark Buntings was not distributed uniformly in relation to water sources (P_{value} for Ho=0) and management type (P_{value} for Ho=0). Abundance of this species was highest within 500 m from water sources and quickly decreased as this distance from a water source increased. Remarkably, the majority of the records (94%) were obtained in the site with high grazing intensity (Fig.4).

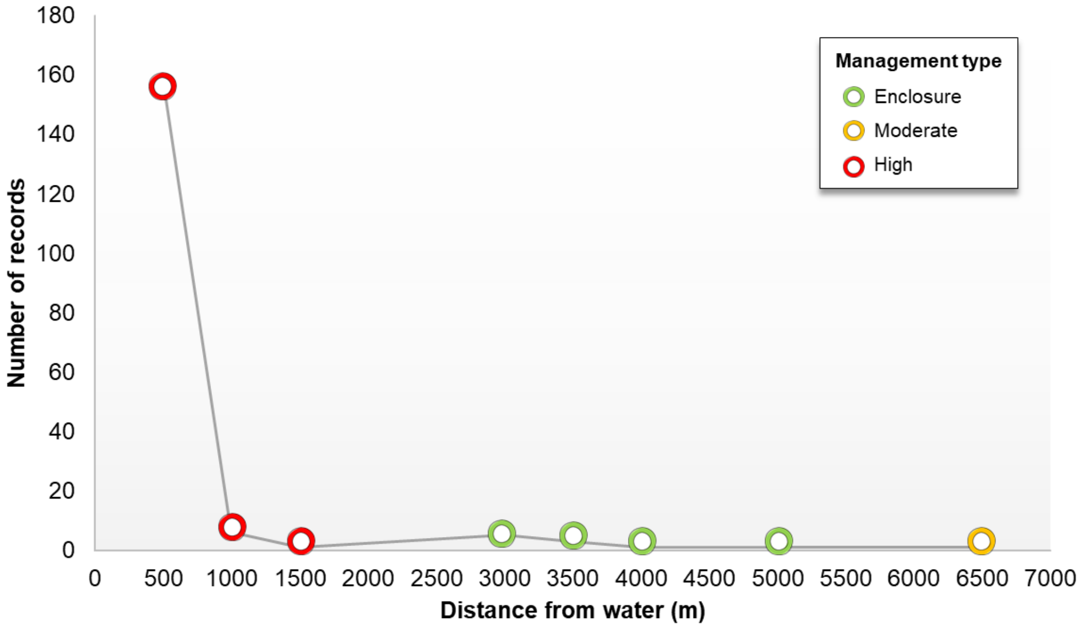

Fig. 4 Bird records as a function of distance from livestock water developments and type of grazing management.

3.2 Movements

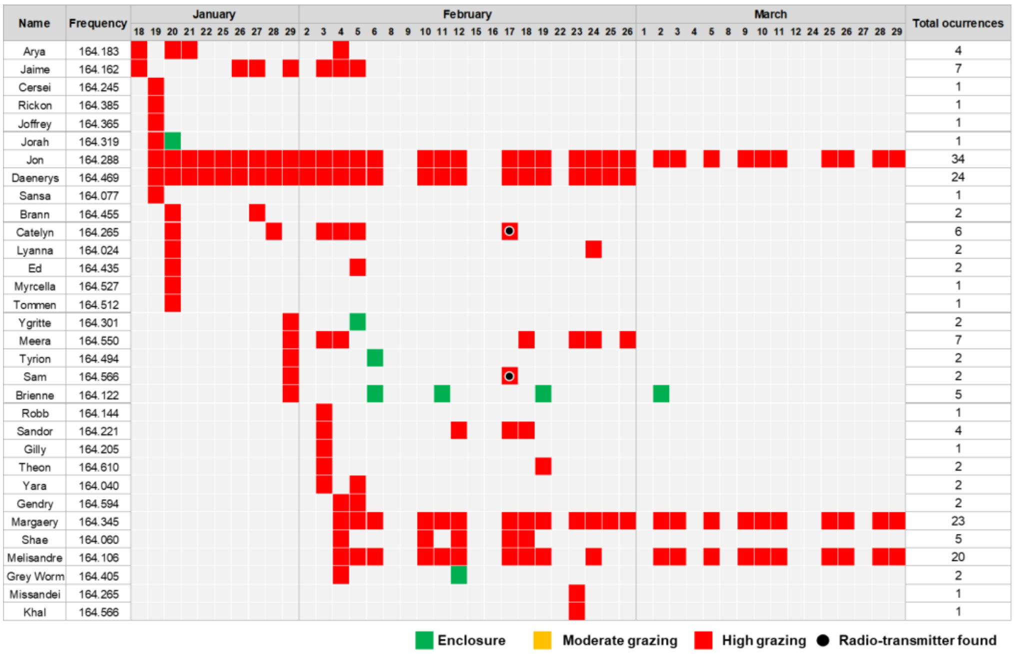

Fig 5. Bird occurrences over the course of the season. Each color bar represents the type of habitat where the bird was encountered, from the date of radio-transmitter deployment to the date a radio was found (black dot).

Of the total of the 32 radio-tagged individuals, four (12.5%) remained in the same area where they were captured the whole season (i.e., apparently showing a sedentary behavior). Seventeen individuals (53.13%) were observed again only occasionally in their capture site, therefore, we assumed that they were exhibiting nomadic behavior; some of these individuals were recorded up to 5 kilometers away from the capture site (Fig. 5). The remaining 11 individuals (34.38%) were never recorded again, despite intense searching across the study sites and season. Therefore, I assume that these individuals were passing through our sites when I was capturing birds, or they left the site in their search for more suitable habitat.

3.3 Behavior

Foraging-. Lark Buntings spent 100% of the time hopping on the ground (jumping while looking for food). Buntings were often seen in open areas where cattle were common, presumably searching for insects or seeds from cow dung (Fig. 6A). When foraging, Buntings move cohesively in single flocks of between 10 and 50 individuals. In contrast, despite “nomad” Buntings also forage from cow dung, they tend to wander in mixed flocks with local (i.e., *Amphispiza bilineata* and *Haemorhous mexicanus*) and migratory species (i.e., *Spizella breweri*), apparently searching for food and water supplies.

Locomotion-. Lark Buntings were observed moving through walks or hops when searching for food, usually in flocks (Fig. 6G). When flying, they moved most of the time in cohesive flocks, swooping low over the ground (Fig. 6F). Typically, birds performed very distinctive calls when they are flying.

Self-Maintenance-. Regarding bathing, Buntings use cattle water tanks (Fig. 6D), troughs or small pools originated when water falls into holes created by cattle while walking. Usually, they touch the surface of water with the breast and lower mandible while fluttering their wings. When the tanks are at their maximum water capacity, they took advantage of the water that runs off the edges by placing themselves down, letting the water fall over their backs. For preening and sunbathing, they usually perch on bushes (e.g., Larrea tridentata), fence wires, cacti (e.g., *Cylindropuntia imbricata*) or trees (e.g., *Prosopis glandulosa*) (Fig. 6B-C).

Flocking behavior-. All Lark Buntings were observed in flocks. All observed birds were feeding, moving, and interacting with other species including: Brewer's Sparrow (*Spizella breweri*), Black-throated Sparrow (*Amphispiza bilineata*), House Finch (*Haemorhous mexicanus*), Scaled Quail (*Callipepla squamata*), Killdeer (*Charadrius vociferus*) and Say's Phoebe (*Sayornis saya*) (Fig. 6E). I did not observe any territoriality or antagonistic interactions among individuals with individuals of the same species or with those from other species.

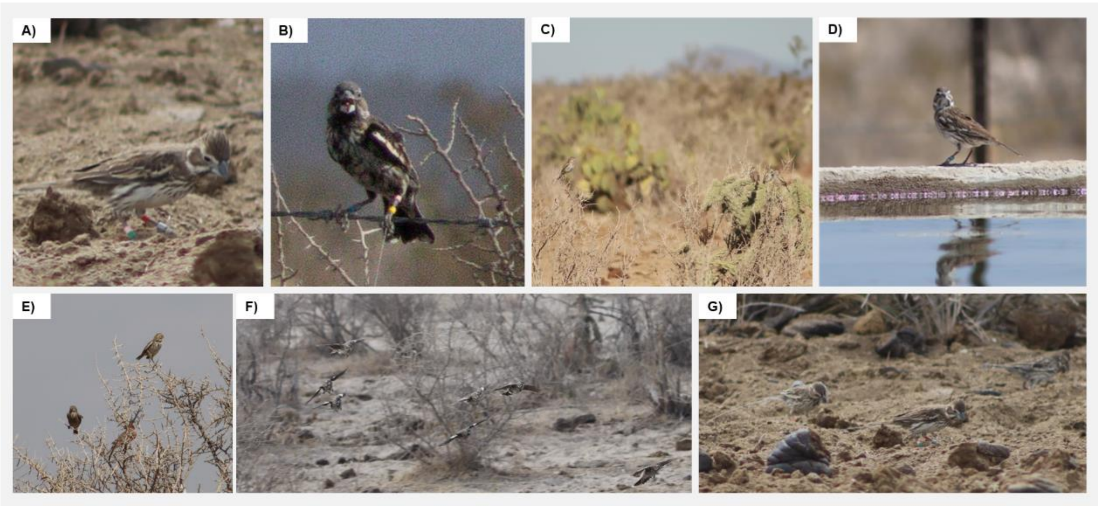

Fig. 6 A) Foraging: individual 164.106 searching for food near cow dung; B) Self maintenance: individual 164.162 perched on a fence wire, apparently sunbathing; C) Self maintenance: single flock while sunbathing and preening on a cacti and bushes; D) Self maintenance: individual approaching to a cattle water tank for drinking; E) Flocking behavior: individual arrived at the area in a mixed flock, composed of male and female House Finches. F) Locomotion: "sedentary" individuals 164.288, 164.345 and 164.106 flying as a cohesive unit while swooping low over the ground covered with cow dung. G) Locomotion: single flock while walking and hopping when searching for food supplies. Photos by Francisco Vega.

Social-. All the individuals considered sedentary (4 individuals) belonged to the same single flock. The flock was relatively small (12 individuals) and very cohesive. When foraging, one or two individuals perched on cacti and bushes, remaining alert while the other members of the flock foraged.

In contrast, most of the individuals considered nomadics were frequently observed in mixed flocks with Brewer's Sparrow (*Spizella breweri*), Black-throated Sparrow (*Amphispiza bilineata*) and/or House Finch (*Haemorhous mexicanus*). While foraging, they kept alert for the movements of the individuals in the flock. Interestingly, when the “resident” species *Amphispiza bilineata* flushed away in response to a potential predator, the Buntings flew a short distance and perched on woody vegetation or they hid under bushes and cacti, sometimes returning to the foraging area. After finishing foraging, they separated from the mixed flock. Mixed flocks were usually large, up to 100 birds in one flock, and in most cases only a small portion of birds were Lark Buntings.

3.4 Mortality

Of the 32 birds tagged, and 21 birds that were seen again (4 sedentary and 17 nomadics), only one individual death was recorded. This individual was killed by an unidentified predator. I found the carcass attached to the radio transmitter three days after the individual was captured and radio tagged in a location near the capture site.

4. Discussion

This study provides novel information pertaining the winter ecology of the Lark Bunting. For instance, all the individuals were observed mainly in the site with high grazing pressure. Since domestic cattle were common, the area was characterized by having high bare ground, a sparse woody vegetation, such as creosote bush (*Larrea tridentata*), honey mesquite (*Prosopis glandulosa*), and short grasses. I hypothesized that grasslands with relatively high livestock pressure may provide ideal microhabitat for foraging, as Buntings prefer to forage in flat open areas, strongly avoiding areas with high cover presumably because cover may affect their visibility when escaping (Lima 1990). In that case, grasslands degraded into shrublands due to overgrazing may not be a favorable winter habitat for the species, as it appeared to avoid habitats that are invaded by woody vegetation, where not just bovines are present, but also horses and goats are widespread. Indeed, no individuals were recorded in this type of habitat while conducting surveys and radio-telemetry tracking.In fact, no individuals were recorded in grasslands that have been invaded by shrubs in spite of intensive census survey efforts throughout the season. In this context, because Buntings evolved with American Bison (Bison bison) and other large native grazers on their breeding range (Neudorf et al. 2006), sustainable grazing by domestic cattle may provide suitable winter habitat for habitat generalist birds, such as the Lark Bunting. However, more research is needed to develop appropriate recommendations. Furthermore, incidental observations of Lark Buntings near our study sites showed their presence in agricultural fields, which has also been reported by Russell and Monson (1998), who observed the species feeding on waste grain and weed seeds in Sonora, Mexico.

Moreover, Lark Buntings monitored in this study showed a strong dependence on livestock water tanks as most of the records (92.9 %) were obtained within 500 m of livestock water tanks located in high grazing sites. This behavior was also reported by Fontaine and collaborators (2004), who assessed the potential effects of livestock grazing in some species of grassland birds, suggesting that cattle grazing likely benefit the species mainly because it maintains the short vegetation structure preferred by the species (Pool et al. 2021) while providing water. However, these results also imply the need to assess how changes in grassland conditions (e.g., spatial homogeneity in plant structure and composition) due to the construction of water tanks may affect negatively wintering populations. Additionally, the species also shows a strong dependence on cattle feed lots for foraging, as reported by Shane and Seltman (1995).Our findings support earlier conclusions reported by Shane (2000) that Lark Bunting exhibit nomadic behavior, probably because they are habitat generalists (Pool et al. 2012), which allows them to cope with life in arid regions, moving freely during the season to where resources (e.g., food and water) are available. Nomadism is characterized by individuals that wander the entire season mainly tracking high-quality resources (Dean 2004). This behavior may be also related to the strong dependance that birds have on water sources (Fontaine et al. 2004). We hypothesized that birds in winter tended to wander in flocks with local species in search of food supplies. This strategy may be part of a survival strategy, as this increases knowledge of the area (i.e., patches where food supplies and water are available). However, even though in our study birds spent most of their time near the cattle ranch area, I cannot assure if their habitat preference was driven by the water tanks that are available for the cattle, or if they were in that area due to the habitat conditions that livestock created, as many birds were seen feeding from cow dung.

The lifestyle of the Lark Bunting is very unique and any method for their survey and strategy for its conservation needs to consider that the species has sedentary and nomadic populations during winter and that they possibly spend their winter seeking suitable resources. My results are consistent with those reported by Stewart (1975) and, by Andrews and Righter (1992) who found that Lark Buntings nomadic movements are influenced by habitat conditions and resources availability,which are directly influenced by rainfall.

This study provided general inshights on the ecology of the species and how grazing regimes may influence avian movements. Besides, winter mortality of Lark Buntings is low since I could only register mortality of one out of the 32 individuals. However, further research on winter distributions and movement strategies of the species is indispensable to assess the potential negative effects of winter habitat conditions (e.g., grazing pressure and/or change in precipitation patterns).

While manual telemetry allowed us to enhance our knowledge Lark Bunting wintering populations, it represented important technical and logistical constraints, especially due to the nomadic nature of the species.In this regard, the volume of telemetry and census data was very limited, which leaves many questions unanswered regarding Lark Bunting winter ecology and the factors limiting their populations during winter. I recommend to survey Lark Bunting populations for a long-term to asses yearly variability. For instance, I suggest the following topics as priority research needs:

1) Use an automated radio telemetry system combined with behavioral data to more accurately document movement patterns and describe activity patterns on the wintering grounds.
2) Investigate winter diet and quantify potential food resources through time and across the landscape .
3) Assess changes in body condition and health (e.gs. ecological stress) and how these parameters change throughout the winter. And investigate if migratory populations have been exposed to anthropogenic toxicants such as heavy metals and pesticides.

4) Investigate the interaction between livestock grazing-agricultural practices and changes in timing and amount of rainfall on vegetation structure and composition and assess the effects on bird movement patterns, winter survival and winter behavior.
5) Examinate inter- and intraspecific relationships more closely (i.e. dominance hierarchies, flocking behavior, competition)

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5. Conclusions and management implications

The current study demonstrates the importance of water availability in determining Lark Bunting abundance and distribution throughout the region. In this regard, the abundance of Buntings in the region was correlated with livestock water developments that were located in grazed habitats, which implies that the species may select disturbed habitats where water sources are available and open areas are available to feed in association with cattle. Besides, birds move into adjacent low disturbed habitats (i.e. enclosure site) for foraging. birds

It is likely that the species operate in two different ways while wintering: nomadism and sedentary lifestyle. Sedentary birds have greater fidelity to sites where resources are superabundant (water and food). Birds tend to form single-species or mixed-species foraging flocks. Large flocks are frequently formed by nomadic individuals, wintering migrants, such as the Brewer's Sparrow and residents, such as the Black-throated sparrow and House finch with smaller flocks formed by sedentary individuals. The formation of large mixed-species flocks may increase survival during the winter period. Both, nomadic, and sedentary populations are markedly gregarious.

My results suggest that habitat management for wintering Lark Bunting populations should focus on maintaining the remaining natural grasslands in the region and improve grassland quality by creating heterogenous landscapes while providing water resources, whether natural or artificial. Because the species prefers to feed away from cover I recommend to create a mosaic of habitat conditions with short to medium native grasses intersparced with open areas, moderate to high percentages of bare ground and moderate disturbed patches by native and non-native grazers. In this context, the Lark Bunting is considered to be associated to habitats where Black-tailed prairie-dog colonies exist (Manzano-Fischer et al. 1999) , thus land owners should aim to preserve the remaining colonies in the region of the Mexican prairie dog (*Cynomys mexicanus*) an endangered species that is endemic to the northeastern mexican grasslands (Merriam 1892). Additionally, cattle livestock rotation among pastures and vary stocking rates is recomended.

The contribution of the current study is significant since it provides a general understanding on the winter ecology of Lark Bunting helping to close the gaps in knowledge regarding the winter ecology of migratory grassland species.

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Supplementary material

Appendix 1

Common Name[a]	Scientific Name[a]	Group[b]	Winter Range[c]	BBS Trend (1966-2019)[d]	Population Loss[e]	Half-Life (Years)[f]	Common Bird in Steep Decline?[g]	Bird of Conservation Concern?[h]	Number of Studies[i]
Grasshopper Sparrow	*Ammodramus savannarum*	New world sparrows	Southern U.S./Mexico	-2.49	-68%	> 50	Yes	Yes	10
Savannah Sparrow	*Passerculus sandwichensis*	New world sparrows	Southern U.S./Mexico	-1.11	-40%	> 50	No	No	10
Baird's Sparrow	*Centronyx bairdii*	New world sparrows	Chihuahuan Grasslands	-0.96	-71%	> 50	No	Yes	8
Sprague's Pipit	*Anthus spragueii*	Pipits	Chihuahuan Grasslands	-3.25	-75%	27	No	Yes	8
Vesper Sparrow	*Pooecetes gramineus*	New world sparrows	Chihuahuan Grasslands	-0.84	-30%	> 50	No	No	8
Eastern Meadowlark	*Sturnella magna*	Blackbirds and Orioles	Southeastern U.S.	-2.56	-77%	23	Yes	No	7
Horned Lark	*Eremophila alpestris*	Larks	Widespread U.S./Mexico	-1.91	-65%	40	Yes	Yes	6
Lark Bunting	*Calamospiza melanocorys*	New world sparrows	Chihuahuan Grasslands	-3.7	-86%	16	Yes	Yes	5
LeConte's Sparrow	*Ammospiza leconteii*	New world sparrows	Southeastern U.S.	-0.4	-61%	43	No	Yes	5
Chestnut-collared Longspur	*Calcarius ornatus*	Longspurs	Chihuahuan Grasslands	-2.58	-85%	21	No	Yes	4
Cassin's Sparrow	*Peucaea cassinii*	New world sparrows	Chihuahuan Grasslands	-0.39	-43%	> 50	No	Yes	3
Loggerhead Shrike	*Lanius ludovicianus*	Shrikes	Southern U.S./Mexico	-2.56	-74%	24	Yes	Yes	3
Long-billed Curlew	*Numenius americanus*	Shorebirds	Southern U.S./Mexico	0.05	-	-	No	Yes	3
Sedge Wren	*Cistothorus platensis*	Wrens	Southeastern U.S.	1.28	-	-	No	Yes	3
Northern Harrier	*Circus hudsonius*	Hawks and Eagles	Widespread	-0.79	-37%	> 50	No	No	2
Western Meadowlark	*Sturnella neglecta*	Blackbirds and Orioles	Chihuahuan Grasslands	-0.88	-42%	50	No	No	2
Henslow's Sparrow	*Centronyx henslowii*	New world sparrows	Southeastern U.S.	-1.94	-10%	> 50	No	Yes	1

Table 1. Studied bird species and their population trends.

a Common and scientific name follow AOU 7th edition, 54th supplement
b Species groups following BBL authorized on Federal Bird Banding and Marking Permits
c Winter range reported in Partners in Flight Landbird Conservation Plan: 2016 (Rosenberg et al. 2016)
d Annual trend from North American Breeding Bird Survey 1966–2019 (Sauer et al. 2020)
e Percentage of global population lost (1970-2014) (Rosenberg et al. 2016)
f Estimated number of years until an additional 50% of the global population is lost (species' "half-life") if current population trends continue into the future (Rosenberg et al. 2016)
g PIF Common Birds in Steep Decline: species that are still too numerous or widely, but that are experiencing drastic long-term declines. These species have lost ~ 50% to 90% of their populations since 1970, and most are projected to lose another 50% within the next 20-25 (Rosenberg et al. 2016)
h Birds of Conservation concern 2008 (U.S. Fish and Wildlife Service, 2008)
i Number of documents that have conducted research in order to investigate the winter ecology of the species'