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Research Paper

Updating the distribution of the Sierra Madre Sparrow *Xenospiza baileyi* across central Mexico: historical records, new localities, and conservation perspectives

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ABSTRACT. The Sierra Madre Sparrow (*Xenospiza baileyi*) is an endangered species microendemic to subalpine grasslands of central and northwestern Mexico. Given that land use change is highly dynamic in central Mexico, there is a need for a continuous monitoring of the distribution and conservation status of the species across the region. We here update the distribution of the Sierra Madre Sparrow by surveying the historical sites where the species is known to occur, verifying records from a citizen science database, and identifying potential habitat in the region to find new localities for the species. We also highlight main local threats and discuss potential conservation activities for the sites where we recorded the species. We found that all historical sites are still inhabited by the species and we identified new localities for the Sierra Madre Sparrow. Each locality presents particular threats for the conservation of the species. Common threats to all sites include agriculture and land owners' unawareness about the presence of the species. Particular attention should be focused on providing management guidelines for agricultural practices in the area. Special efforts must be directed to engaging communities into conserving and monitoring subalpine grasslands. Much work should be done to define and apply conservation strategies in cooperation with local governments, institutions, and communities. The identification of new localities for the species reveals the need to expand research beyond traditional study and bird-watching sites.

Mise à jour de la répartition du Bruant des sierras *Xenospiza baileyi* dans le centre du Mexique : mentions historiques, nouveaux sites et perspectives de conservation

RÉSUMÉ. Le Bruant des sierras (*Xenospiza baileyi*) est une espèce en voie de disparition microendémique des prairies subalpines du centre et du nord-ouest du Mexique. Le changement dans l'utilisation des terres étant très dynamique dans le centre du Mexique, il importe de faire un suivi continu de la répartition et du statut de conservation de l'espèce dans la région. Nous avons mis à jour la répartition du Bruant des sierras en revisitant les sites historiques de présence de l'espèce, vérifiant les mentions provenant d'une base de données issue de science participative et identifiant des milieux potentiels dans la région afin d'y de trouver de nouveaux sites pour l'espèce. Nous énumérons les menaces locales et décrivons les activités de conservation qu'il est possible de mettre en place aux sites où l'espèce a été observée. Nous avons constaté que tous les sites historiques sont encore occupés par le Bruant des sierras et avons découvert de nouveaux sites de présence. Chaque site présente des menaces particulières pour la conservation de l'espèce. L'agriculture et l'ignorance des propriétaires fonciers quant à la présence de l'espèce sont des menaces communes à tous les sites. Une attention particulière devrait être portée à fournir des directives d'aménagement ciblant les pratiques agricoles dans le secteur. Des efforts spéciaux devraient être destinés aux communautés afin de les engager dans la conservation et le suivi des prairies subalpines. Enfin, il faudrait définir et appliquer les stratégies de conservation en coopération avec les gouvernements, les institutions et les communautés locales. La découverte de nouveaux sites pour l'espèce révèle l'importance d'étendre la recherche au-delà des sites d'étude traditionnels et des sites d'observation d'oiseaux des citoyens.

Key Words: agriculture; cattle grazing; endangered bird; endemic species; Mexico City

INTRODUCTION

The Sierra Madre Sparrow (*Xenospiza baileyi*) is a microendemic species of Mexico (Meléndez-Herrada et al. 2016) with a range highly restricted to some scattered localities in the Valley of Mexico and western Durango, in the highlands of central and

northwestern Mexico, respectively (Oliveras de Ita and Gómez de Silva 2002, Oliveras de Ita and Rojas-Soto 2006, Martínez-Guerrero et al. 2018). Its major population is located in the southern highlands of Mexico City, central Mexico (Berlanga et al. 2009). This species is a habitat specialist, depending on subalpine grasslands for its life cycle (Cabrera-García et al. 2006,

Oliveras de Ita and Gómez de Silva 2007). In central Mexico, subalpine grasslands range from 3000 to 4300 m a.s.l. and are dominated by *Calamagrostis*, *Muhlenbergia*, *Stipa*, and *Festuca* (Rzedowski and Rzedowski 2005).

Population growth, urban development, and agricultural sprawling have severely impacted central Mexico (CONABIO and SEDEMA 2016). These threats have also affected subalpine grasslands, which show a destruction trend of 22 ha per year (Vázquez de la Torre 2015). Habitat conversion and devastation have been highlighted as the main threats for the conservation of the Sierra Madre Sparrow (Oliveras de Ita and Gómez de Silva 2007, BirdLife International 2017). As a result, the species has been classified as endangered by both the IUCN (BirdLife International 2017) and the Mexican Government (SEMARNAT 2010).

Given that most of the records of the Sierra Madre Sparrow have been obtained at La Cima and Llano de Morales in southern Mexico City (Berlanga et al. 2015, Gómez de Silva and Oliveras de Ita 2016), conservation initiatives for the species have been mainly focused on the populations at these two localities. Other populations in different sites have received little consideration, probably because of the fact that records are scarce, unverified, or old.

Although the Sierra Madre Sparrow has a highly restricted range, we are not aware of any study searching for all recorded populations of the species across the region using a systematic procedure. Most records of the species in central Mexico come from a few popular spots visited by birdwatchers (eBird 2019) and from site-specific studies at La Cima (Oliveras de Ita 2002, 2011). Although previous research has estimated the distribution of the species using ecological niche modeling methods (González Abraham 2000, Navarro-Sigüenza and Peterson 2007, Vázquez de la Torre 2015), there have been no field surveys confirming the presence of the Sierra Madre Sparrow across environmentally suitable areas in central Mexico. Given that land use change associated with agricultural and urban sprawl is rapidly occurring in the area (CONABIO and SEDEMA 2016), there is a need for a continuous monitoring of the distribution status of the species across the region. In addition, no efforts have focused on maintaining an updated assessment of the regional distribution of the species. This information however, is fundamental for monitoring and determining the conservation status of the Sierra Madre Sparrow, estimating the habitat conversion trend, identifying conservation priorities, and evaluating the impact of management actions for its preservation (Nichols and Williams 2006, Jones 2011, Ortega-Álvarez et al. 2015).

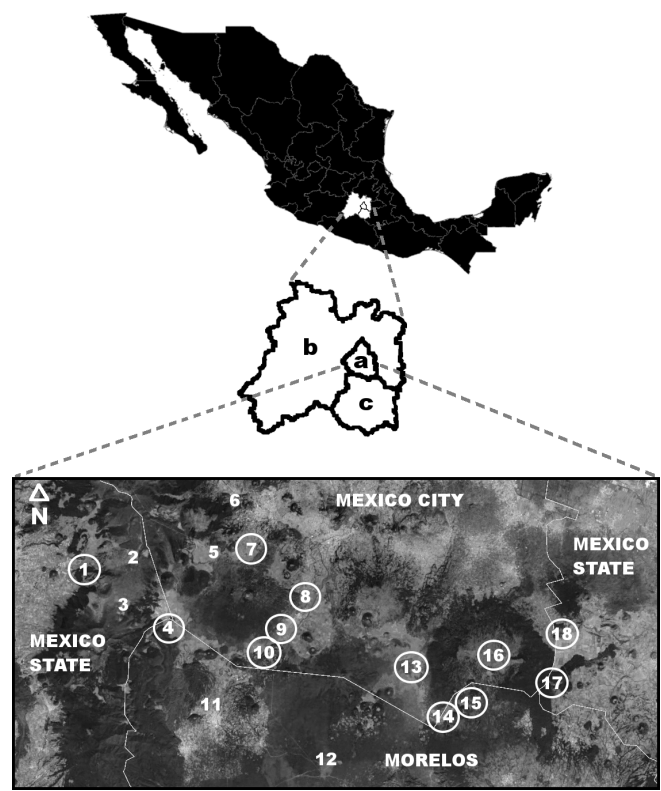
In this study we updated the distribution of the Sierra Madre Sparrow through an extensive search across central Mexico. We visited the historical sites where the species is known to occur to determine if the species is still present in such areas. In addition, we verified relatively recent records from a citizen science database (Sullivan et al. 2009, eBird 2019), and used updated satellite images to identify potential habitat in the region to find new localities for the species. Finally, we highlight main local threats and discuss potential strategies and management activities for each site where the species was recorded. Results in our study may provide critical information to foster conservation actions for the Sierra Madre Sparrow in the region.

METHODS

Study area

We focused our surveys on the subalpine grasslands located in southern Mexico City, northern Morelos, and southern Mexico State, in the highlands of the Transvolcanic Belt of central Mexico (Fig. 1), where the Sierra Madre Sparrow is known to occur (Gómez de Silva and Oliveras de Ita 2016). Natural ecosystems throughout the region include oak, pine, fir, and mixed forests, wetlands, shrublands, and subalpine grasslands, all of which are under severe human pressure by the surrounding urban settlements (CONABIO and SEDEMA 2016) and agricultural lands (Cabrera-García 2006, CONABIO and SEDEMA 2016). Remaining natural ecosystems in the region are mostly restricted to high elevations, because the volcanic mountains have acted as a natural barrier for agricultural and urban sprawl (Arriaga et al. 2000).

Fig. 1. Survey sites for searching the Sierra Madre Sparrow (*Xenospiza baileyi*) across central Mexico. Numbers represent different localities and circles denote the presence of the species in the site. (a) Mexico City, (b) State of Mexico, (c) Morelos, (1) Xalatlaco, (2) Ex-Cañada Seca Park, (3) road to El Capulín, (4) El Capulín, (5) Ajusco road, (6) La Rufina, (7) Rancho Tres Vientos, (8) Las Maravillas Park, (9) asphalt factory, (10) La Cima, (11) Tres Marías, (12) road from San Juan Tlacotenco to Coajomulco, (13) Llano de Morales, (14) Llano de Otlayuca, (15) slope of Ololica Volcano, (16) Tlaxcaltenco, (17) CICS Milpa Alta, (18) Xocho Volcano.



Officially protected natural areas with subalpine grasslands in the region include the Cumbres del Ajusco National Park (Mexico City), the Tepozteco National Park (Morelos), and the Chichinautzin Biological Corridor (Mexico City, Morelos, Mexico State). However, most records of the Sierra Madre Sparrow have been obtained in nonprotected areas, within lands owned by rural and indigenous communities of Mexico City (i.e., San Pablo Oztotepec, San Miguel Topilejo), Mexico State (i.e., Xalatlaco), and Morelos (i.e., El Capulín, San Juan Tlacotenco; Oliveras de Ita and Gómez de Silva 2002, Cabrera-García et al. 2006, Berlanga et al. 2009, 2015).

Historical records

We reviewed literature (scientific papers, thesis) and searched in citizen science databases such as eBird (2019) to compile all localities where the Sierra Madre Sparrow has been previously observed. In addition, we conducted field surveys to search for the Sierra Madre Sparrow in historical sites where the species has been recorded, which allowed us both to verify and update its presence in these areas.

Data collection

We conducted fieldwork in the region searching for the Sierra Madre Sparrow with the participation of local community members, i.e., San Pablo Oztotepec, Milpa Alta, who have been involved in community-based bird monitoring projects (for more details see Berlanga et al. 2015 and Ortega-Álvarez et al. 2015). We looked for the species in sites where it has been historically recorded, as well as in the spots where eBird users have observed the species. In addition, we used updated satellite images (from Google Earth Pro), as well as potential distribution maps (González Abraham 2000, Navarro-Sigüenza and Peterson 2007, Vázquez de la Torre 2015), to visually identify areas with suitable habitat, i.e., subalpine grasslands, where the Sierra Madre Sparrow might occur but has not been previously recorded.

After identifying areas with suitable habitat and selecting both historical and potential sites, we visited each locality and searched for the species following the methodology proposed by Oliveras de Ita and Rojas-Soto (2006): (a) listening and searching using binoculars during a 10-min period; then (b) performing playbacks of the songs and calls during a 10-min period; and (c) walking throughout the site. The first two steps were performed within unfixed-radius stationary survey points located at the center of patches with suitable habitat. Playbacks were paused every three minutes to facilitate detection. If the species was not detected after the first two steps, walking was performed throughout the surveyed subalpine grassland patch. We concluded surveys at each site as soon as the species was detected or when the site was completely traveled by the observers. If the site consisted of a large patch of subalpine grassland, we repeated on multiple occasions the methodology until the species was detected, or when the whole site was surveyed. Several observers simultaneously searched for the species during surveys, increasing the probabilities of detection. We performed surveys during the peak of the breeding season (9–15 July 2019), when singing males are more conspicuous and responsive to playbacks (Oliveras de Ita and Rojas-Soto 2006, Berlanga et al. 2009). All surveyors, including local community members, were highly trained in visual and aural identification of the Sierra Madre Sparrow. Given that most of the subalpine grasslands in the region have been destroyed or severely degraded

by land use change, we were able to survey most of the areas that are still covered by this habitat, including the largest patches. This method allowed us to perform a cost- and time-efficient first-pass survey to determine if the species was present at each study site, which was the main objective of this study (Table 1).

Following field surveys, we assessed the relative abundance of the Sierra Madre Sparrow for each study site (Table 1) by using these categories (based on Howell and Webb 1995): (a) common, when the species is usually detected at the site, often in large numbers; (b) fairly common, when usually detected at the site, but in small numbers, (c) uncommon, when it is unlikely to be detected, and then only in small numbers, and (d) rare, when it is present but not frequently detected. For assigning a relative abundance category for each site, we considered the following (Table 1): (a) the survey period when we detected the species, assuming that relative abundance might be greater if the species was observed during the first steps of surveys, (b) the number of individuals that we detected because more detected individuals might be related with higher relative abundance, (c) the size of the grassland patch for each site as reported by other studies (Sánchez-González et al. 2019), given that the presence of a larger subalpine grassland patch might increase the relative abundance of the species, (d) the frequency of reports of the species from eBird (2019), which provides information on how often a species is reported on complete checklists within a specified date range and region, and (e) our previous experience on detecting the species at each site. The value for the frequency of reports from eBird (2019) was calculated by averaging the frequency of all months, ranging from January to December from 1900 to 2020 for each study site. Frequency reports from eBird were not available for poorly studied sites, and for those where we recorded the Sierra Madre Sparrow for the first time (Table 2).

RESULTS

We visited 18 sites across Central Mexico (Fig. 1). In four of these sites, the species has been previously recorded (Table 2). Our surveys showed that the Sierra Madre Sparrow still inhabits each of these historical sites (Table 3), including Llano de Morales, Mexico City (Cabrera-García 2006), La Cima, Mexico City (Oliveras de Ita and Gómez de Silva 2007), Xalatlaco, Mexico State (Oliveras de Ita and Gómez de Silva 2002), and El Capulín, Morelos (Cabrera-García 2004).

We also verified the presence of the species in sites indicated in eBird (2019; Table 2). However, we discarded those sites that were geographically misplaced or referred to broad areas, such as Valley of Mexico and Milpa Alta, because it was not possible to identify the precise location where the sighting was made. We also did not take into account records from highly urbanized areas with unsuitable habitat for the species within Toluca and Mexico City, as well as records from the Lerma Marshes, because all of these may pertain to the highly similar Song Sparrow (*Melospiza melodia*) or Lincoln's Sparrow (*Melospiza lincolni*). We also visited a location reported in eBird along the road connecting San Juan Tlacotenco and Coajomulco, but we did not find evidence nor suitable habitat for the species to occur (Table 2). We noticed that most records in eBird were performed by bird-watchers searching for the species in La Cima and Las Maravillas Park located in Mexico City (eBird 2019). Other observations belonged to community-based monitoring and scientific studies that were

Table 1. Survey effort and relative abundance of the Sierra Madre Sparrow for each site. Name, number of detected individuals, survey period when the individuals were detected, number of observers that performed surveys, survey duration, distance traveled during surveys, number of survey points that were used to detect the species, frequency of reports following eBird, surface of subalpine grassland, and relative abundance of the Sierra Madre Sparrow are specified for each site. First survey period consisted in listening and searching with binoculars; during the second period we performed playbacks for attracting the species. Surveys finished during the period when we detected the species for the first time. As the first and second periods were carried out in a stationary survey point, no distance was travelled during such periods. Travelling was only needed for the third period of the surveys.

Site	Detected individuals	Survey period	Number of observers	Survey duration	Distance travelled	Number of survey points	Frequency of reports	Grassland surface (ha)	Relative abundance
Llano de Morales	3	First	3	10 min	0 m	1	Not available	1792.10	Common
Llano de Otlayuca	5	First	3	5 min	0 m	1	Not available	99	Common
El Capulín	3	First	2	10 min	0 m	1	Not available	63	Common
Tlaxcaltenco	1	First	2	10 min	0 m	1	Not available	119.4	Fairly common
Rancho Tres Vientos	2	First	2	10 min	0 m	1	Not available	41	Fairly common
Slope of Ololica Volcano	1	Second	3	15 min	0 m	1	Not available	171.4	Fairly common
Las Maravillas Park	1	Second	2	20 min	0 m	1	52.5	39.4	Fairly common
La Cima	1	Second	2	20 min	0 m	1	66.4	19	Fairly common
Asphalt factory	2	Second	2	20 min	0 m	1	Not available	22	Fairly common
Xalatlaco	1	Second	2	20 min	0 m	1	Not available	156	Uncommon
Xocho Volcano	3	Second	11	20 min	0 m	1	Not available	27	Rare
CICS Milpa Alta	2	Second	11	20 min	0 m	1	Not available	6.8	Rare
Road to El Capulín	0	-	2	30 min	200 m	1	-	2	Undetected
Tres Marias	0	-	2	30 min	100 m	1	-	2	Undetected
La Rufina	0	-	2	30 min	150 m	1	-	1.5	Undetected
Ex-Cañada Seca Park	0	-	2	30 min	200 m	1	-	1.5	Undetected
Ajusco Road	0	-	2	30 min	100 m	1	-	1	Undetected
Road San Juan Tlacotenco to Coajomulco	0	-	2	-	-	0	-	0	Undetected

Table 2. Surveyed sites for the Sierra Madre Sparrow (*Xenospiza baileyi*) across central Mexico. The name, state, and the coordinates where the sites are located are specified. Type of sites include historical localities, eBird spots, and localities surveyed because they contained suitable habitat for the species. * Localities where the species was recorded for the first time.

Site	State	Longitude	Latitude	Detection	Type of site
La Cima	Mexico City	-99.20056395	19.10956647	Detected	Historical locality; eBird spot
Las Maravillas Park	Mexico City	-99.16762202	19.15108364	Detected	eBird spot
Asphalt factory	Mexico City	-99.18866531	19.12261838	Detected*	Locality with suitable habitat
Rancho Tres Vientos	Mexico City	-99.21520645	19.18891274	Detected*	Locality with suitable habitat
La Rufina	Mexico City	-99.23184541	19.23228829	Not detected	Locality with suitable habitat
Ajusco Road	Mexico City	-99.24334042	19.18673626	Not detected	Locality with suitable habitat
Tlaxcaltenco	Mexico City	-99.006636	19.10741	Detected*	Locality with suitable habitat
Llano de Morales	Mexico City	-99.075013	19.097115	Detected	Historical locality; eBird spot
CICS Milpa Alta	Mexico State	-98.96194691	19.0854595	Detected*	Locality with suitable habitat
Xocho Volcano	Mexico State	-98.95298495	19.12317164	Detected*	Locality with suitable habitat
Xalatlaco	Mexico State	-99.35472559	19.17240819	Detected	Historical locality
Ex-Cañada Seca Park	Mexico State	-99.31498922	19.17872904	Not detected	Locality with suitable habitat
Road to El Capulín	Morelos	-99.32025432	19.14160833	Not detected	Locality with suitable habitat
El Capulín	Morelos	-99.28180122	19.12759749	Detected	Historical locality
Tres Marias	Morelos	-99.24488556	19.06494005	Not detected	Locality with suitable habitat
Road from San Juan Tlacotenco to Coajomulco	Morelos	-99.14716923	19.02345627	Not detected	eBird spot
Llano de Otlayuca	Morelos	-99.0504	19.06297	Detected*	Locality with suitable habitat
Slope of Ololica Volcano	Morelos	-99.03001	19.06637	Detected*	Locality with suitable habitat

performed within and nearby the subalpine grasslands at Llano de Morales, in Milpa Alta, Mexico City.

We surveyed 12 sites containing suitable habitat but where the species has not been previously recorded (Table 2). We found the presence of the Sierra Madre Sparrow at seven of these sites, three of which are located in Mexico City (asphalt factory, Rancho Tres Vientos, and Tlaxcaltenco), two in Mexico State (CICS Milpa

Alta, Xocho Volcano), and two in Morelos (Llano de Otlayuca, slope of Ololica Volcano; Table 3). Most of our records were performed during the second surveying period (playback period; 7 of 12 sites), which reduced the travel distance needed to detect the species (Table 1). Because the Sierra Madre Sparrow was always efficiently detected during the first two periods of the surveys, we needed a unique survey point at each site where we recorded the species (Table 1). No survey points were located in

Table 3. Major threats and suggested conservation actions for the Sierra Madre Sparrow (*Xenospiza baileyi*) at each locality where we detected the species across central Mexico.

Site	Major threats for the species	Conservation action
La Cima	Farming Forestation of grasslands Vandalism	Determine management guidelines for farming Stop forestation programs within the grassland Engage community and government in surveillance activities
Las Maravillas Park	Community's unawareness about the species presence Leisure activities	Engage community in monitoring and conservation Promote leisure activities outside grasslands
Asphalt factory	Urban development	Stop urban development
Rancho Tres Vientos	Citizen's unawareness about the species' presence Urban development Farming Citizen's unawareness about the species' presence	Engage private land owners in monitoring and conservation Stop urban development Determine management guidelines for farming Engage private land owners in monitoring and conservation Acquire private land for conservation
Tlaxcaltenco	Community's unawareness about the species presence	Engage community in monitoring and conservation
Llano de Morales	Farming Cattle grazing Fire Community's unawareness about the species' presence Land tenure conflicts	Determine management guidelines for farming Regulate cattle grazing Address fire management strategies Engage community in monitoring and conservation Seek for political mediation and negotiation
CICS Milpa Alta	Farming Forestation of grasslands Citizen's unawareness about the presence of the species	Determine management guidelines for farming Stop forestation programs in the grassland Engage land owners in monitoring and conservation
Xocho Volcano	Farming Community's unawareness about the species' presence	Determine management guidelines for farming Engage community in monitoring and conservation
Xalatlaco	Farming Cattle grazing Unplanned tourism Forestation of grasslands Community's unawareness about the species' presence	Determine management guidelines for farming Regulate cattle grazing Regulate touristic activities in the area Stop forestation programs in the grassland Engage community in monitoring and conservation
El Capulín	Farming Community's unawareness about the species' presence	Determine management guidelines for farming Engage community in monitoring and conservation
Llano de Otlayuca	Land tenure conflicts Community's unawareness about the species' presence	Seek political mediation and negotiation Engage community in monitoring and conservation
Slope of Ololica Volcano	Farming Community's unawareness about the species' presence	Determine management guidelines for farming Engage community in monitoring and conservation

the road of San Juan Tlacotenco to Coajomulco because we did not find suitable habitat for the species (Table 1).

Relative abundance of the Sierra Madre Sparrow is variable among study sites (Table 1). The species is common in three sites, including Llano de Morales, Llano de Otlayuca, and El Capulín. Among these sites, Llano de Morales is the most important because it contains the largest surface of subalpine grassland across the region. The Sierra Madre Sparrow showed to be fairly common and rare in the sites where we report the species for the first time, with the exception of the Llano de Otlayuca.

DISCUSSION

We detected the Sierra Madre Sparrow in every single site where it has been historically recorded. However, we observed that its relative abundance varied among surveyed sites. As expected, Llano de Morales is a key place for the conservation of the Sierra Madre Sparrow because it contains the largest patch of subalpine grassland across the region and, following our surveys, the species may be considered as common there. We noted that all sites face severe anthropogenic threats, mainly related to agriculture (Table 3). Although the Sierra Madre Sparrow currently has a quite restricted range and is considered as a globally endangered species, we were able to identify new localities for the species by using both potential distribution maps and satellite photography,

highlighting the use of these technologies for conservation purposes, i.e., locating unrecorded populations. Our results suggest that further research is needed beyond the sites where the species has been historically recorded and studied, whereas new records of the species provide insights and opportunities for tackling its conservation and management needs, e.g., acquiring private lands (Table 3).

Our observations showed that all of the historical sites still harbor populations of the Sierra Madre Sparrow. Llano de Morales is therefore of prime importance for the species because it contains the largest surface of subalpine grassland across the region and the species is common in the site. Despite this, the best-studied population of the Sierra Madre Sparrow is located at La Cima (Oliveras de Ita 2002, Gómez de Silva and Oliveras de Ita 2016), which is also very popular among bird-watchers (eBird 2019). Nevertheless, the subalpine grassland has been extremely reduced in this site (19 ha), which threatens the local conservation of the species. Clearly, there is an urgent need to expand research beyond La Cima to assess the size and status of other populations of the species across the region. As soon as some of these parameters become available, working with local communities to attend threats would be critical (Cabrera-García and Frias 2004).

Different surveyed localities, including Las Maravillas Park and the asphalt factory, could prove important for the Sierra Madre

Sparrow. On the one hand, the species is fairly common in both sites, and on the other hand, these sites may act as natural corridors connecting populations from larger grassland patches in the region. Las Maravillas Park has received a lot of attention by bird-watchers in recent years (eBird 2019). In fact, the discovery and exploration of this locality is relatively recent (~ four years ago), and it has become highly attractive for birdwatching because of good security conditions. The park is close to La Cima (~5.5 km), which may allow individuals of local populations of the Sierra Madre Sparrow to move among sites. The asphalt factory was one of the sites where we recorded the Sierra Madre Sparrow for the first time. This locality is situated between La Cima and Las Maravillas Park, therefore may also function as a corridor for the species (Cabrera-García 2004, Gómez de Silva and Oliveras de Ita 2016).

Rancho Tres Vientos is found within an area of privately owned lands located in Tlalpan, close to Cumbres del Ajusco National Park (INE 1997). Here, old and large patches of subalpine grassland intermingle with crop fields, farms, and scattered houses. The site is quite interesting for conservation purposes because the species is fairly common and it is the only locality across the region where land might be acquired to protect the habitat for the species. Moreover, the habitat seems to be in good condition for the Sierra Madre Sparrow because it contains large and clustered bunches of grass (Cabrera-García et al. 2006). Grasslands here might be connected with those from La Cima and Las Maravillas Park because they are not far away from each other (~6.7 km).

New localities for the Sierra Madre Sparrow in Mexico State included the land owned by the Interdisciplinary Center of Health Sciences of the Instituto Politécnico Nacional (CICS Milpa Alta with its Spanish initials) and the crater of the Xochco Volcano. The land of CICS Milpa Alta contains the local campus of the university, which is surrounded by small and scattered highly disturbed subalpine grassland patches, agricultural areas, and pine forests. The species has been unnoticed given that little birdwatching has been performed in the area and the Sierra Madre Sparrow is rare; therefore involvement of this educational institution is necessary to ensure the protection of the local habitat and the population of the Sierra Madre Sparrow.

We detected the Sierra Madre Sparrow at the crater of the Xochco Volcano, representing the easternmost record of the species in the region. We found the species to be rare and restricted to the crater, as its slopes and the surrounding areas are completely dominated by agricultural lands and a few patches of oak and pine forests. Because extinct volcanoes are widespread across the area (Rzedowski and Rzedowski 2005), we suspect that other populations of the Sierra Madre Sparrow might find suitable habitat at their peaks. In fact, the Ololica Volcano is another example of a volcanic locality that acts as a refuge for the sparrow. This volcano is located in Morelos, just at the border with Mexico City. We surveyed two localities there, the Llano de Otlayuca and the slope of the Ololica Volcano, both representing a continuum of the subalpine grasslands of the Llano de Morales. We found the species to be common at Llano de Otlayuca, a plain with large, old, and largely undisturbed subalpine grasslands found in the intersection of the Tepozteco National Park and Milpa Alta. The slope of the Ololica Volcano is adjacent to the Tepozteco National

Park, but land there is owned and managed by the community of Tlalnepantla. Hence, working with communities is imperative to foster the conservation of the species in this area, which is still fairly common in the site.

Because of the socio-political heterogeneity that characterizes the region, each locality presents particular threats for the conservation of the Sierra Madre Sparrow (Table 3). Nevertheless, some threats are common to all sites including land use change for farming practices and land owners' unawareness about the presence of the Sierra Madre Sparrow (Cabrera-García et al. 2006, Berlanga et al. 2015). Thus, major attention should be focused on providing regional management guidelines to achieve a sustainable use of the landscape, specifically by adjusting farming practices, i.e. potato and oat production, and regulating cattle grazing in the area (Cabrera-García 2004). Also, more attention should be made to engaging citizens and communities into conserving and monitoring local subalpine grasslands (Cabrera-García and Frias 2004). Current efforts performed by local community-based monitoring groups are essential for these tasks (Berlanga et al. 2015).

Our assessment of the relative abundance of the Sierra Madre Sparrow might prove useful as a first approach to understand how the population varies among sites across the region. In this sense, urgent conservation actions might be taken in those sites where the species is uncommon and rare, i.e., Xalatlaco, Xochco Volcano, and CICS Milpa Alta, given that the species might be more susceptible to disappearing in the near future. Nevertheless, future studies should focus on performing specific analyses to understand the biotic and abiotic factors that influence the population parameters of the Sierra Madre Sparrow, to define particular actions for preserving the species across central Mexico.

CONCLUSION

We here provided a wide view of the problems affecting each of the sites inhabited by the Sierra Madre Sparrow across central Mexico. However, more detailed evaluations of the local habitat and threats must be performed to determine site-specific management actions for conserving the species. In this sense, much work must be done to define and apply local conservation strategies in cooperation with local governments, institutions, and communities, given that the region is small but quite heterogeneous from a sociopolitical perspective.

At a regional scale, the habitat of the Sierra Madre Sparrow is mainly threatened by land use conversion promoted by agriculture. Thus, there is an urgent need to define management guidelines for this productive activity, with the aim of conserving the habitat for the species while providing economic revenues for human communities. Because most of the distribution of the Sierra Madre Sparrow lies within communal lands, conservation strategies for the species must include the active participation of local communities when defining management actions, conservation policies, and research agendas. In addition, much governmental work must also be done, as contradictory activities promoted by institutional programs, e.g., forestation programs for the grasslands, reduce the habitat quality for the species and dissuade the trust and participation of local communities in restoring and conserving the grasslands. We believe that it is important to create a regional agenda for conserving the species

by including the multiple actors that have an impact on the preservation of the grasslands, e.g., communities, governmental institutions, or enterprises, and consider several management actions at multiple scales, e.g. local, regional, and federal.

Although the Sierra Madre Sparrow is an endangered species with a very restricted range, we were able to detect new localities for the species across central Mexico. This reveals the need to focus the research on the sparrow beyond sites that have traditionally received more attention by researchers and bird-watchers. Expanding the known range of the species and having a first assessment on the relative abundance of the species across the region, provides new opportunities for developing conservation strategies involving different actors. Still, further knowledge on the ecology and natural history of the species is required to understand factors enabling it to inhabit unexpected sites across the region. Future research needed for the Sierra Madre Sparrow includes density and occupancy estimations, studies on population dynamics, and movement analyses.

Responses to this article can be read online at:
<http://www.ace-eco.org/issues/responses.php/1573>

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