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Population density of the western burrowing owl (*Athene cunicularia hypugaea*) in Mexican prairie dog (*Cynomys mexicanus*) colonies in northeastern Mexico

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Abstract

Background: The western burrowing owl (*Athene cunicularia hypugaea*) occurs throughout western North America in various habitats such as desert, short-grass prairie and shrub-steppe, among others, where the main threat for this species is habitat loss. Range-wide declines have prompted a need for reliable estimates of its populations in Mexico, where the size of resident and migratory populations remain unknown.

Results: Our objective was to estimate the abundance and density of breeding western burrowing owl populations in Mexican prairie dog (*Cynomys mexicanus*) colonies in two sites located within the Chihuahuan Desert ecoregion in the states of Nuevo Leon and San Luis Potosi, Mexico. Line transect surveys were conducted from February to April of 2010 and 2011. Fifty 60 ha transects were analyzed using distance sampling to estimate owl and Mexican prairie dog populations. We estimated a population of 2026 owls (95 % CI 1756–2336) in 2010 and 2015 owls (95 % CI 1573–2317) in 2011 across 50 Mexican prairie dog colonies (20,529 ha).

Conclusions: The results represent the first systematic attempt to provide reliable evidence related to the size of the adult owl populations, within the largest and best preserved Mexican prairie dog colonies in Mexico.

Keywords: Chihuahuan Desert, Distance sampling, Grassland, Mexican prairie dog, Mexico, Population, Western burrowing owl

Background

Rigorous estimates of regional population size are critical for the development and assessment of avian conservation strategies, particularly for species undergoing shifts in their distribution and range. The western burrowing owl (*Athene cunicularia hypugaea*) (Fig. 1), a species with special conservation status throughout much of its range, has experienced range-wide shifts from southern Canada to northern Mexico [1]. Western burrowing owls belong to a grassland bird guild that is threatened by habitat loss [2].

The species uses open habitats such as grasslands, deserts and areas of disturbance [3]. These owls also prefer areas with discontinuous vegetation and low growth shrubs, allowing them to increase visibility for hunting, vigilance against predators and caring of burrows [4, 5].

Published data from owl populations vary within the range of distribution in North America. For example, in the 1990's population estimates of this species in Canada and the United States of America (USA) ranged from as low as 2000–20,000 to as high as 20,000–200,000 individuals [6]. In Canada, the populations have declined abruptly and even disappeared from British Columbia and Manitoba [7]. Previous reports indicate a wide variation of population trends ranging from stable in some

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Fig. 1 Western burrowing owl in the colony of Mexican prairie dog, in Chihuahuan Desert

areas in the USA and Canada, to reduced, extirpated or increasing in others [2, 7–16].

Local density estimates a range of 13–31 owls/km² in Canada (Manitoba, Alberta, Saskatchewan and British Columbia) and the USA (Arizona, California, Colorado, Idaho, Iowa, Kansas, Minnesota, Montana, Nebraska, New Mexico, North and South Dakota, Oklahoma, Oregon, Texas, Utah and Washington) during the western burrowing owl breeding season indicating variation in the density estimates [1, 7, 9, 14, 17–26]. In Mexico, the federal government classifies the western burrowing owl under the category of special protection [27]. Habits of the western burrowing owl such as summer diet, prey selection, movement of juveniles, selection of nesting sites and threats remain poorly known. Densities estimated during the breeding season in 2002 in Mexico include 14.1 owls/km² near Mexicali [28], 3.2 pairs/km² in Yaqui-Mayo Valley, Sonora, 4.5 pairs/km² in Valle del Fuerte, Sinaloa, and 4.7 pairs/km² in Valle de Culiacan, Sinaloa [29]. Winter season density estimates in central Mexico include 11 owls/km² in Guanajuato [30] and 5.2 owls/km² in Nuevo Leon [31].

The western burrowing owl has been strongly associated with two species of prairie dogs in Mexico, the Mexican prairie dog (*Cynomys mexicanus*) and black-tailed prairie dog (*C. ludovicianus*) (Fig. 2) [9, 32–35]. Both of these species are federally listed in Mexico as endangered and threatened, respectively [27]. The black-tailed prairie dog is distributed from Saskatchewan in Canada to southern Montana and Nebraska in the United States to northern Chihuahua and Sonora in Mexico where the colonies are fragmented and isolated. The habitat occupied by the species of prairie dog is herbs, grasses and shrubs. Currently, the regions supporting black-tailed

prairie dog colonies cover 18,500 ha [36]. The Mexican prairie dog is endemic of central and northern of Mexico within the states of Coahuila, Nuevo Leon, Zacatecas and San Luis Potosi, in colonies covering approximately 25,000 ha. These two species of dogs have lost more than 80 % of their original range [37]. Mexican prairie dog colonies provide burrows and foraging opportunities for breeding burrowing owls, which apparently keep the prairie dog population stable, despite disturbance and loss of habitat in prairie dog colonies caused by expanding agricultural and cattle grazing activities [38], the use of pesticides, collisions with vehicles, diseases, predators, and urbanization [1, 2, 7, 11, 32, 39–44].

Based on the problems and the lack of knowledge mentioned above, in this study we estimate the abundance and density of western burrowing owls in colonies of Mexican prairie dog in northeastern Mexico. Density/abundances of western burrowing owls and their association with Mexican prairie dog colonies provide relevant conservation information to ensure the long-term persistence of both species. In addition, this study can be integrated across North America to establish baseline range-wide population estimate(s) to improve our understanding of the recent range-wide shifts in owl populations.

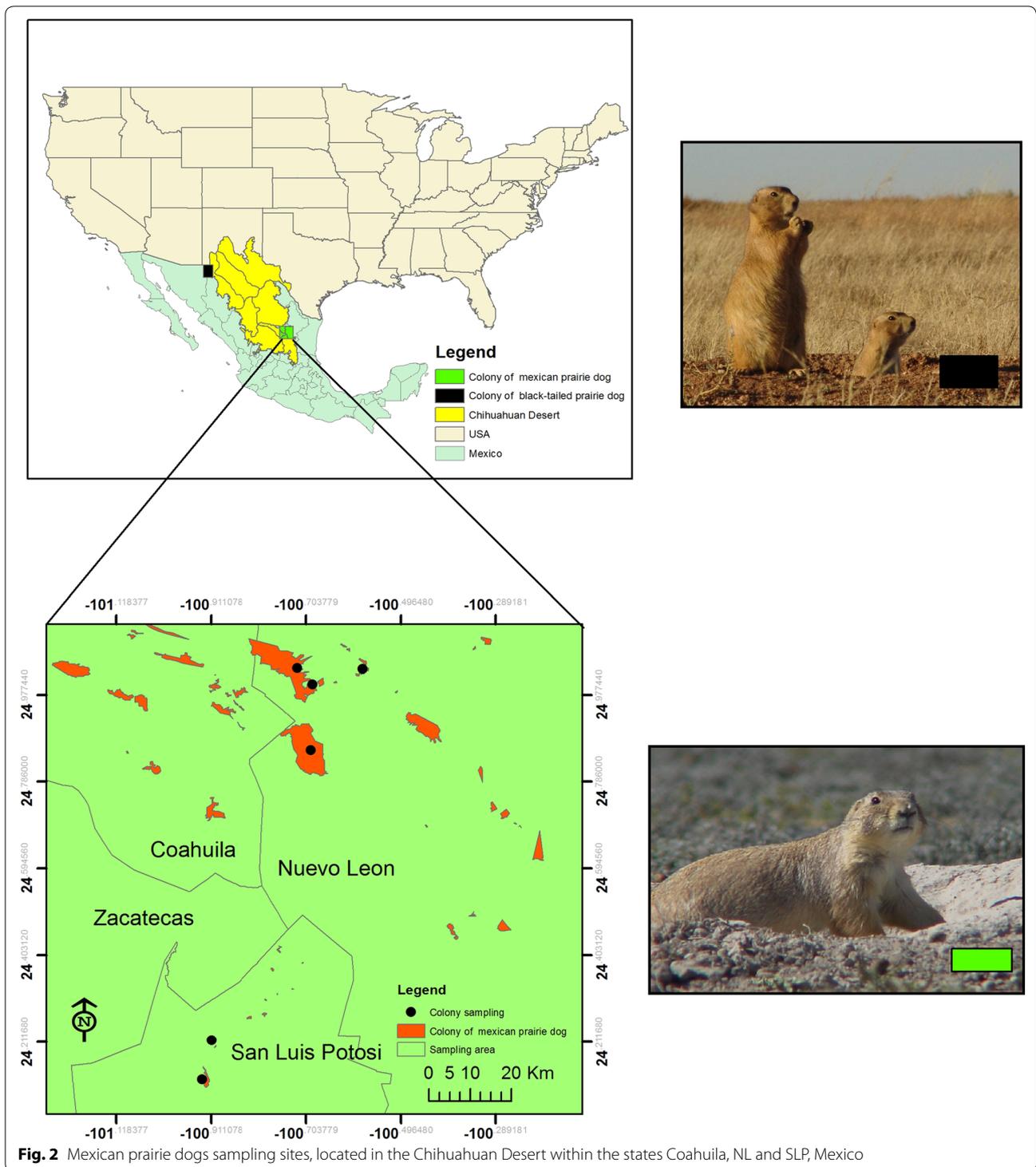
Methods

Study area

Our study sites were located in Nuevo Leon (NL) and San Luis Potosi (SLP) within the Chihuahuan Desert ecoregion [45] (Fig. 2) that is part of the physiographic region known as the Mexican Plateau within the Mexican states of Coahuila, Zacatecas, NL and SLP. The semi-arid climate features temperatures ranging from 6 to 25 °C with an annual average of 16 °C [46]. Average precipitation totals 427 mm [47].

Previously, studies in NL have been conducted in the areas known as Llano de la Soledad (23°53'N, 100°42'W) and Compromiso (23°53'N, 100°42'W). These areas maintain the largest Mexican prairie dog populations, including those at Martha (25°0'N, 100°40'W), Concha (25°1'N, 100°35'W), and Hediondilla (24°57'N, 100°42'W). Western burrowing owls of SLP were studied in Llano del Manantial (24°7'N, 100°55'W) and Gallo (24°12'N, 100°54'W) in the municipality of Vanegas.

The Llano de la Soledad has been provided with several conservation designations by the NL government such as State Natural Protected Area [48], and Important Site for Bird Conservation [49]. This site hosts several vulnerable, endemic and migratory species [50, 51]. The dominant vegetation in Mexican prairie dog colonies is characterized by halophytic grassland and consists largely of *Muhlenbergia villiflora*, *Muhlenbergia repens*, *Pleuraphis*



mutica, *Sporobolus airoides*, *Frankenia gypsophila* and *Dalea gypsophila*. Other coexisting plant communities include microphyllus vascular plants and rosette shrubs [31, 52–56].

From 50 colonies of prairie dogs existing in NL and SLP, nine were selected for sampling. These colonies were selected based on the following characteristics: spatial continuity of the community and a lack of

fragmentation, conservation status of the site, vegetation type that was homogeneous enough to contain at least one complete transect. The sampled colonies covered about 55 % of the area available for all colonies of Mexican prairie dogs in the southern Chihuahuan Desert. Sampling was conducted between February and April in both 2010 and 2011. The transect line method was used [57]. Fifty transects (each 2 km long \times 0.3 km wide and ≥ 0.5 km apart from each other) were traveled using the remote sampling method by the observer as described below to estimate the density of adult owls [58]. The number (n) of transect routes for each area was: Soledad ($n = 28$) and Compromiso (15), Marta (2) and Concha (2) in NL; Manantial (2) and Gallo (1) in SLP. We walked each transect at a constant rate using a global positioning system (GPS) to ensure a straight survey line. Owls were detected visually or with binoculars. Then, the perpendicular distance from the transect line route was measured using a laser rangefinder (15–815 m, Leica Rangemaster 900, Optics Planet, Inc. Northbrook, IL, USA). To meet the assumptions of distance sampling, only adult owls were recorded on the ground outside the burrows or without movement [58, 59]. If the bird under observation moved because of the presence of the observer, registering the perpendicular distance was performed at the original site without the observer leaving their sighting transect travel line. Those adult owls flying with an unknown initial location were not documented. To reduce bias and avoid an overestimation of population density, only adult owls were recorded. Considering the extreme desert climate, personal observations made during previous years and different criteria of previous authors related to the activities of owls, the field observations were conducted from 0600 to 1200 h [20, 23, 60, 61].

Data analysis

We used program *DISTANCE* ver. 6.0 to obtain western burrowing owl density estimates from distance sampling [62]. *DISTANCE* calculates density and abundance using modeling detection probability as a function of the perpendicular distance to the transect in a series of monotonic models. Several standard detection functions (uniform, half-normal, or hazard-rate) with cosine series adjustment were evaluated using the Akaike information criterion (AIC). We used the AIC to select the model with the most parsimonious detection function in *DISTANCE* [58, 59, 63]. We pooled all data to estimate a single detection function (probability of detection, $g(x)$, at a given distance (x) from the transect) because we did not anticipate effects of environmental features on detection, such as *age* (adult) and factor *STATE* (levels: NL and SLP). We considered serial adjustments of one to three

parameters. We did not truncate the data because the frequencies of long distances observations were better maintained in this manner [4].

The estimator of density (\hat{D}) is given by the expression:

$$\hat{D} = \frac{\hat{n}\hat{f}(0)}{2L}$$

where $\hat{f}(0)$ is the probability density function of detection distances from the line evaluated at zero distance, calculated in *DISTANCE* as the average number of individuals per detection [62]. The standard error of density $SE(\hat{D})$, assuming a Poisson distribution of counts, can be approximated using the delta method as follows [58]:

$$SE(\hat{D}) = \hat{D} \sqrt{\frac{1}{n} + \frac{Var(\hat{f}(0))}{\hat{f}(0)^2}},$$

where $Var(\hat{f}(0)) = (SE(\hat{f}(0)))^2$ also is a direct output of *DISTANCE*. The component cluster size was omitted from the above formulas because virtually all detections were individual records. Estimates of density and their standard errors were used to test statistical differences in density between states and years using a Wald test [64]. Values are presented as mean \pm SE.

Overall estimates of western burrowing owl density (and their SE) at the nine sampled colonies (9620 ha) were obtained by pooling detection distance data by year. These estimates were then multiplied by the total area of the 50 colonies of the Mexican prairie dog described for the southern part of the Chihuahuan Desert to provide yearly estimates of owl population size through the range of Mexican prairie dog: 38 in NL (19,802 ha) and 12 in SLP (727 ha) [37]. On average, 55 % of the surface reported for the Mexican prairie dog colony complex was sampled [37].

Results

Density and population size

Colonies were stable during the years 2010–2011 and were not destroyed or fragmented (agriculture, livestock) during this time. During the 2010 and 2011 sampling periods, 235 detections of at least one owl were recorded. The estimates of western burrowing owl density in the 50 prairie dog colony complex were 9.8 ± 1.0 ind/km² (CV 0.107) in 2010 and 9.8 ± 1.0 ind/km² (CV 0.108) in 2011. The owl density estimate for NL was 8.8 ± 1.0 ind/km² (CV 0.114) in 2010 and 7.3 ± 0.9 ind/km² (CV 0.123) in 2011. For SLP, the owl population density was 26.7 ± 6.2 ind/km² (CV 0.236) in 2010 and 47 ± 8.4 ind/km² (CV 0.180) in 2011 (Table 1). No significant differences were found among western burrowing owl densities (Wald test, $p = 0.431$) and the paired states of NL ($p = 0.967$) and SLP ($p = 0.635$).

Table 1 Western burrowing owl population density between 2010 and 2011 in Mexican prairie dog colonies in NL and SLP, Mexico

| Model ^a | D ^b | N ^c | Estimated density (owl/ha) | | | CV ^f | No. colony ^g | Area (ha) |
|--------------------|----------------|----------------|----------------------------|----------------------|----------------------|-----------------|-------------------------|-----------|
| | | | Average | 95 % IC ^d | 95 % IC ^e | | | |
| Global 2010 | 0.1 | 119 | 949 | 788 | 1039 | 0.107 | 9 | 9620* |
| | | | 2026 | 1765 | 2326 | | 50 | 20,529** |
| 2011 | 0.09 | 116 | 944 | 783 | 1035 | 0.108 | 9 | 9620* |
| | | | 2015 | 1753 | 2317 | | 50 | 20,529** |
| NL 2010 | 0.08 | 100 | 809 | 698 | 937 | 0.114 | 6 | 9170* |
| | | | 1747 | 1508 | 2024 | | 50 | 20,529** |
| 2011 | 0.074 | 82 | 678 | 578 | 794 | 0.124 | 6 | 9170* |
| | | | 1464 | 1248 | 1716 | | 50 | 20,529** |
| SLP 2010 | 0.26 | 19 | 118 | 37 | 87 | 0.236 | 3 | 450* |
| | | | 190 | 60 | 141 | | 12 | 727** |
| 2011 | 0.47 | 34 | 211 | 48 | 167 | 0.180 | 3 | 450* |
| | | | 341 | 170 | 397 | | 12 | 727** |

* Total area of sampled colonies

** Total area of colonies in SLP and NL

^a Model base done AIC criteria: half-normal + cosine

^b Western burrowing owl density (owl/ha)

^c Total number of detections in both years

^d Upper confidence intervals

^e Lower confidence intervals

^f Variation coefficient for the estimated density

^g Number of Mexican prairie dog colonies

Applying the overall yearly estimates of western burrowing owl density to the entire area of the 50-colony complex of prairie dogs in NL and SLP resulted in a population size of 2026 (CV 0.173) in 2010 and 2015 (CV 0.213) in 2011. For colonies in NL, an average population size of 1747 (CV 0.178) was obtained in 2010 and 1464 (CV 0.218) for 2011, while in SLP, population estimates were between 190 (CV 0.312) and 341 (CV 0.322) for each year.

Discussion

To date, many density estimates have been made for the western burrowing owl in Canada and the USA, with quite variable results [1, 6, 7, 9, 11–15, 20–23, 25, 26]. The resulting variation in the population sizes can be attributed to the size of sample area, methodology, analytical

precision, timing, observer skill, and so on; these have contributed to an inexact picture of the density of the western burrowing owl populations [6, 15]. Therefore, a comparison of our results with those of the USA and Canada could be difficult.

During the last 30 years, the North American Breeding Bird Survey has estimated a negative trend for the western burrowing owl population for Canada and the USA. Similarly, the United States Geological Survey (2014) has reported the same negative trend in the Chihuahuan Desert region [16].

Even though Mexico has not established systematic surveys that allow the establishment of a population trend, some studies (the present one included) can form the basis to achieve this goal of documenting population trends in the future.

In NL and SLP, the average density of breeding pairs (9.8 ind/km²) in 2010 and 2011 is greater than that reported by Macias-Duarte in Sonora (6.4 ind/km²) and similar to the Sinaloa average (9.2 ind/km²) [29]. However, in Baja California, Itubarria-Rojas reported an average of 14.1 ind/km², which is a value higher than that determined by the present study [28]. This difference could be caused by the habitat quality among sites as reported in NL and SLP where burrow competition is related to the abundance of prairie dogs per colony or Baja California where the owls use irrigation canals to create burrows.

Our overall estimates of population size for western burrowing owls reveal the relative importance of Mexican prairie dog colonies to owl population viability. No previous data related to population size estimates in owls is available for the study area. However, the precision of these estimates must be taken with caution because of the variability between sites. However, we believe the extrapolation is correct because we sampled over 55 % of the current area with the active prairie dog colonies in both states. The range of the western burrowing owl in north-eastern (NL, SLP, and Coahuila) Mexico includes viable colonies of Mexican prairie dogs. These areas provide an optimal habitat for the prairie dogs to feed on grasses and this contributes to a low height of herbaceous plants and allows the owls greater visual access to the foraging area. This species uses prairie dog colonies as a place for nesting, protection against climatic factors (extreme temperatures, flooding by rain, and strong winds). The owls also respond to alarm calls by prairie dogs, alerting them to the presence of predators. The western burrowing owl colonies in Mexico have declined from 88 colonies to 53, equivalent to a loss of 37 % in 10 years (1992–2003) [37, 38].

Many of the problems in northeastern Mexico that involve the western burrowing owl are directly related to loss of habitat from agriculture, but some direct mortality has been caused by collisions with vehicles. However, another possible cause of morbidity and mortality could be the direct or incidental (by bioaccumulation) exposure to pesticides used in neighboring areas.

Conclusions

These results represent the first systematic effort to address the conservation status of the western burrowing owl populations in Mexican prairie dog colonies located in northeastern Mexico. This geographic area is considered to contain the largest preserved Mexican prairie dog colonies in the country and deserves attention from the scientific and conservation communities. Furthermore, these results contribute new information to our understanding of the population dynamics of this

kind of species across North America, and highlight the urgent need to preserve grasslands, particularly those in the southern part of the Chihuahuan Desert, which harbor many bird species cataloged as threatened or endangered.

Abbreviations

Regions

USA: United States of America; NL: Nuevo Leon; SLP: San Luis Potosi.

Units

km: kilometers; ind/km²: individual per square kilometer; ha: hectare; *n*: number of line transects; m: meters; mm: millimeter; °C: celsius; hr: hours.

Statistical

*g*_x: probability of detection; *x*: given distance; ± SE: standard error; CV: coefficient variation; *p*: probability; AIC: akaike information criterion; IC: confidence intervals.

Orientation

N: north; W: western; GPS: global positioning system.

Authors' contributions

GRA conceived of and designed the study, collected the data and performed data analysis. AOK, AMD, AGV and JIGR contributed to study design and provided advice for data collection and analysis. All authors participated in drafting the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

Data are available in the Dryad database (<http://dx.doi.org/10.5061/dryad.pm362>). Description of supplementary files can be found at [65].

Ethics

All protocols were performed according to the ethical guidelines adopted by the ethic committee of the Facultad de Ciencias Biologicas of the Universidad Autonoma de Nuevo Leon, as well by the current environmental Mexican laws. Only field observations were made. There was no animal handling. However in order to comply with the Mexican regulations we have a permit (SGPA/DGVS/01588/10), granted by the Secretaria del Medio Ambiente y Recursos Naturales/Subsecretaria de Gestion para la Proteccion Ambiental/Direccion General de Vida Silvestre.

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