

Patrones de riqueza de especies y detección de mamíferos en la Reserva de la Biosfera Sierra la Laguna

Patterns of species richness and detection of mammals in the Sierra la Laguna Biosphere Reserve

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Resumen

Este estudio analiza las tendencias en la riqueza de especies y detección de mamíferos en la Reserva de la Biosfera Sierra la Laguna, Baja California Sur, México. Utilizando cámaras trampa en diferentes altitudes, tipos de vegetación y proximidad a asentamientos humanos, documentamos doce especies, incluyendo mamíferos nativos e introducidos. Confirmamos la prevalencia de ungulados, carnívoros y otras especies nativas, aunque a pesar de los reportes locales sobre la presencia de puma, las cámaras no lograron capturar evidencia de este. Los resultados mostraron una correlación negativa significativa entre la riqueza de especies y la elevación, mientras que la proximidad a ranchos, la temporada y el tipo de vegetación, no tuvieron impacto aparente en la riqueza de especies y su detección. Además, la presencia de especies introducidas de ungulados fue persistente, lo que genera preocupación sobre sus efectos en las comunidades vegetales. Nuestros hallazgos contribuyen a la comprensión de la dinámica de las comunidades de mamíferos y ofrecen información actualizada y valiosa para la gestión de especies introducidas y la conservación de mamíferos medianos y grandes en esta área protegida.

Palabras clave

Biosfera. Cámaras trampa. Conservación. Gradiente altitudinal. Mamíferos.

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Abstract

This study analyzes trends in mammal species richness and detection in the Sierra la Laguna Biosphere Reserve, Baja California Sur, Mexico. Using camera traps at various altitudes, vegetation types, and distances from human settlements, we documented twelve species, including both native and introduced mammals. We confirmed the prevalence of ungulates, carnivores, and other native species; however, despite local reports of cougar presence, the cameras failed to capture evidence of this species. Results showed a significant negative correlation between species richness and elevation, while proximity to ranches, season, and vegetation type did not appear to impact species richness or detection. Additionally, the persistent presence of introduced ungulate species raises concerns about their effects on plant communities. Our findings contribute to understanding mammal community dynamics and provide valuable, updated information for managing introduced species and conserving medium- and large-sized mammals in this protected area.

Keywords

Altitudinal gradient. Biosphere. Camera traps. Conservation. Mammals.

Introduction

Sierra la Laguna was designated as a biosphere reserve in 1994 by the Mexican Government (CONANP, 2003) due to its unique biodiversity, mineral and forest resources, as well as its critical role in providing essential ecosystem services to both people and wildlife in the southern Baja California Peninsula. These services include water capture through its forested catchments, habitats for pollinators that support local agriculture, refuge for thousands of plant and animal species, and outstanding opportunities for research and recreation (Arriaga *et al.*, 2000; CONANP, 2003; Ortega-Rubio, 1992).

The main objective of the reserve is to conserve and sustainably use its natural resources through collaborative participation of communities and other stakeholders. To achieve this, it is essential to maintain up-to-date information on physical, biological, and social parameters, generate performance indicators, and monitor changes. This ongoing data collection allows for the evaluation

of management practices and, when necessary, the implementation of adjustments to ensure effective stewardship of the area (CONANP 2003).

One key motivation behind the reserve's creation was the need to protect its mammal species, which face threats from habitat degradation and illegal hunting (Arnaud *et al.*, 2012; CONANP, 2003). Overgrazing, particularly by introduced ungulates, has affected the vegetation, intensifying risks for native mammals (CONANP 2003). Monitoring the mammal community is therefore crucial for assessing management effectiveness and ensuring the protection of these vulnerable species.

Despite the importance of mammals in the reserve's ecology, comprehensive studies on mammal fauna have been sparse since 1981, with only a few publications addressing rodent density (Woloszyn and Woloszyn, 1981), mammalian diversity (Arriaga and Ortega, 1988), deer demography (Gallina *et al.*, 1991), coyote diet (Arnaud, 1992), and the impact of introduced ungulates (Arnaud *et al.*, 2012). Some of these studies were foundational in shaping the reserve's management plan (Ortega-Rubio and Argüelles-Méndez, 1999) and highlight the need for updated community assessments to assess the effectiveness of the reserve.

In early 2024 staff from the National Commission for Protected Natural Areas (CONANP) and Colorado State University (CSU) in Todos Santos, started conversations with the aim to find ways to collaborate in projects to benefit the management of the reserve and engage CSU faculty and students on local research and conservation projects. One of such projects builds up from a camera-trap project conducted by the reserve's staff, with support of local landowners and ranchers, since 2021.

The main objective of this study is to use the images taken by these camera traps to analyze the richness and abundance trends of mammals, including corroborating the presence of cougars in the reserve. Currently, the only evidence of cougar presence comes from droppings found in the forest and accounts from ranchers, but no factual evidence has confirmed these sightings (Galina-Tessaro *et al.*, 2019). Given that camera traps were widely distributed within the reserve, this research also aims to explore the relationships between mammal abundance and environmental factors such as altitude, vegetation type, season, and proximity to human settlements, contributing to the understanding of mammal community dynamics in the region and providing valuable insights for the management of introduced species and habitat conservation in the reserve.

Materials and methods

A total of twenty six camera traps equipped with motion detectors and infrared flash (Bushnell Trophy Cam HD, Bushnell Outdoor Products; Browning Pro Scout Max, Browning Trail Cameras; Moultrie Edge, Moultrie Mobile; Cuddeback Model KT-001, Cuddeback) were deployed across various sites within the Sierra la Laguna Biosphere Reserve (extreme coordinates of the reserve's polygon: 23°42'–23°20'N, 109°46'–110°11'W) in the state of Baja California Sur, Mexico (Fig. 1). The cameras were set by the reserve's park rangers with the aid of local ranchers and landowners, who participated in the Program for the Protection and Restoration of Priority Ecosystems and Species (PROREST) of CONANP, in the years 2021, 2022 y 2023. Cameras were distributed in both pine-oak forest areas (fourteen cameras) and tropical deciduous forest areas (twelve cameras). This reserve spans 1,124.37 km² of public, ejido, and private lands, with elevations ranging from 300 to 2,080 meters above sea level (CONANP, 2003; Galina-Tessaro *et al.*, 2019).

The Sierra la Laguna, often described as a continental island, stands out as a unique ecological region due to its distinct tropical ecosystem assemblage. It hosts the driest tropical deciduous forest in Mexico and the only pine-oak forest in Baja California Sur, which are surrounded by lower-elevation xerophytic scrublands (León de la Luz *et al.*, 1999; González-Abraham *et al.*, 2010). This isolated ecosystem supports a high level of biodiversity and endemism, making it a critical site for conservation efforts (Arriaga *et al.*, 2000).

The reserve experiences a highly seasonal climate, with 70-80% of its annual precipitation occurring between July and October (CONANP, 2003). Human presence within the reserve is sparse, with approximately 500 residents spread across about 100 small ranches, typically located at elevations of 300–700 meters above sea level. These settlements are often situated near natural water sources, which are vital for both human and ecological sustainability in the region (Pío-León and Ortega-Rubio, 2020).

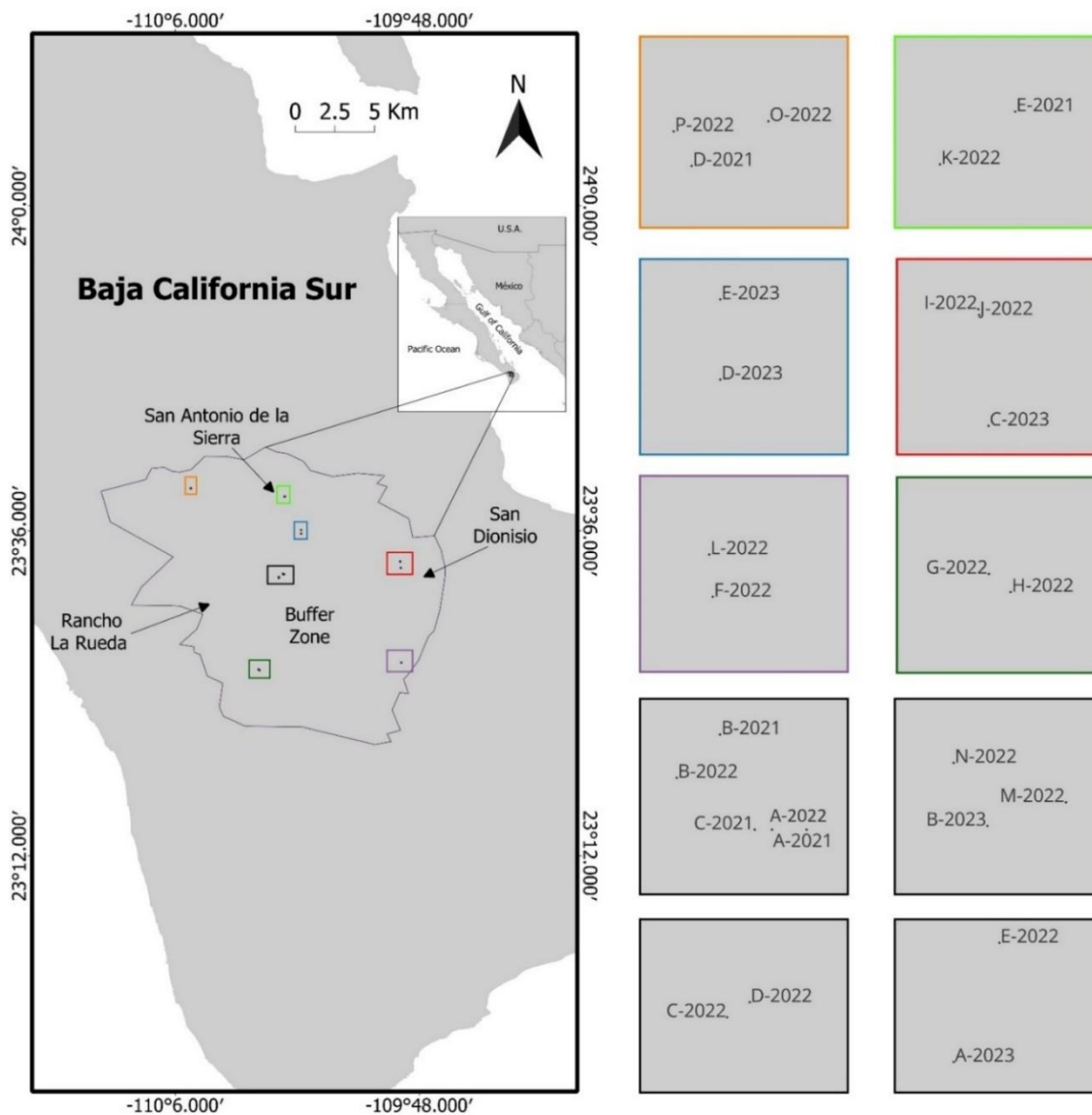


Figure 1. Study area. Locations of camera-trap sites in the Sierra la Laguna Biosphere Reserve are indicated with black dots and with the camera ID number, which includes the year on which the cameras were deployed. The reserve's limit is the solid line. Inset: depicts location of the reserve in the Baja California Peninsula, Mexico.

Table I. Distance matrix for camera traps in the Sierra La Laguna Biosphere Reserve, Baja California Sur, Mexico. Values in meters, colors represent different camera groups, and bold numbers indicate the minimum distance between groups or independent cameras. The Camera ID includes the year of deployment.

| Camera ID | A-2021 | | | | | B-2021 | | | | | C-2021 | | | | | D-2021 | | | | | E-2021 | | | | |
|-----------|--------|-----------|-----------|-----------|-----------|-----------|--------|------------|--------|-----------|--------------|-----------|--------|---------------|--------|-----------|--|--|--|--|------------|--|--|--|--|
| A-2021 | | | | | | 14 | | | | | 2 | | | | | 16947 | | | | | 11252 | | | | |
| B-2021 | | | | | | | | | | | 13 | | | | | 16354 | | | | | 11003 | | | | |
| C-2021 | | | | | | | | | | | | | | | | 16366 | | | | | 11016 | | | | |
| D-2021 | | | | | | | | | | | | | | | | | | | | | 11866 | | | | |
| E-2021 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Camera ID | A-2022 | B-2022 | C-2022 | D-2022 | E-2022 | F-2022 | G-2022 | H-2022 | I-2022 | J-2022 | K-2022 | L-2022 | M-2022 | N-2022 | O-2022 | P-2022 | | | | | | | | | |
| A-2022 | | 18 | 31 | 32 | 47 | 19313 | 12852 | 12942 | 15381 | 15381 | 10972 | 19309 | 780 | 688 | 16364 | 16384 | | | | | | | | | |
| B-2022 | | | 44 | 47 | 61 | 19341 | 12856 | 12946 | 15396 | 15395 | 10966 | 19325 | 791 | 697 | 16349 | 16369 | | | | | | | | | |
| C-2022 | | | | 4 | 42 | 19295 | 12860 | 12950 | 15353 | 15352 | 10968 | 19288 | 756 | 666 | 16382 | 16402 | | | | | | | | | |
| D-2022 | | | | | 44 | 19294 | 12862 | 12955 | 15350 | 15349 | 10965 | 19287 | 752 | 662 | 16382 | 16402 | | | | | | | | | |
| E-2022 | | | | | | 19273 | 12818 | 12909 | 15363 | 15362 | 11010 | 19265 | 782 | 695 | 16410 | 16430 | | | | | | | | | |
| F-2022 | | | | | | | 17975 | 17856 | 13807 | 13763 | 26958 | 11 | 19023 | 19181 | 35532 | 35553 | | | | | | | | | |
| G-2022 | | | | | | | | 175 | 23095 | 23096 | 23757 | 17967 | 13385 | 13395 | 26152 | 26098 | | | | | | | | | |
| H-2022 | | | | | | | | | 23072 | 23049 | 23885 | 17857 | 13450 | 13487 | 26257 | 26269 | | | | | | | | | |
| I-2022 | | | | | | | | | | 44 | 16977 | 13797 | 14668 | 14804 | 13794 | 28105 | | | | | | | | | |
| J-2022 | | | | | | | | | | | 17005 | 13753 | 14658 | 14800 | 28094 | 28125 | | | | | | | | | |
| K-2022 | | | | | | | | | | | | 26949 | 10561 | 10503 | 11791 | 11825 | | | | | | | | | |
| L-2022 | | | | | | | | | | | | | 19016 | 19171 | 35522 | 35547 | | | | | | | | | |
| M-2022 | | | | | | | | | | | | | | 162.43 | 16550 | 16571 | | | | | | | | | |
| N-2022 | | | | | | | | | | | | | | | 16404 | 16424 | | | | | | | | | |
| O-2022 | | | | | | | | | | | | | | | | 36 | | | | | | | | | |
| P-2022 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Camera ID | A-2023 | | | | | B-2023 | | | | | C-2023 | | | | | D-2023 | | | | | E-2023 | | | | |
| A-2023 | | | | | | 768 | | | | | 15388 | | | | | 6685 | | | | | 7142 | | | | |
| B-2023 | | | | | | | | | | | 14761 | | | | | 5996 | | | | | 6460 | | | | |
| C-2023 | | | | | | | | | | | | | | | | 13340 | | | | | 13505 | | | | |
| D-2023 | | | | | | | | | | | | | | | | | | | | | 498 | | | | |
| E-2023 | | | | | | | | | | | | | | | | | | | | | N/A | | | | |

Camera traps were deployed either in groups of two to five or individually at georeferenced sites each year. Within a group, cameras were spaced an average of 70 meters apart, while the minimum distance between different groups or independent cameras was 662 meters (Table I). Cameras placed near each other in different years were not considered part of the same group (Tables II and III).

Sites were selected based on reports from local ranchers indicating high mammal abundance and included natural trails, water springs, and creeks. The distribution of camera traps was designed to maximize spatial coverage across the reserve (Fig. 1).

Table II. Deployment timeline of camera traps in the Sierra La Laguna Biosphere Reserve, Baja California Sur, Mexico. Colors indicate camera groups as defined in Table I. Cameras without color were independent. The Camera ID includes the year of deployment.

| Camera ID | 2021 | | | | | | 2022 | | | | | | 2023 | | | | | | | | | | | | | | | | | |
|-----------|------|---|---|---|---|---|------|---|---|---|---|---|------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N |
| A-2021 | ■ | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A-2022 | | | | | | | | | ■ | ■ | | | | | | | | | | | | | | | | | | | | |
| A-2023 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B-2021 | ■ | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B-2022 | | | | | | | | | | | ■ | ■ | ■ | | | | | | | | | | | | | | | | | |
| B-2023 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C-2021 | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C-2022 | | | | | | | | | | | ■ | ■ | ■ | | | | | | | | | | | | | | | | | |
| C-2023 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| D-2021 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| D-2022 | | | | | | | | | | ■ | ■ | ■ | | | | | | | | | | | | | | | | | | |
| D-2023 | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | | |
| E-2021 | | | | | | | | | | | ■ | ■ | ■ | | | | | | | | | | | | | | | | | |
| E-2022 | | | | | | | | | | | ■ | ■ | ■ | | | | | | | | | | | | | | | | | |
| E-2023 | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | |
| F-2022 | | | | | | | | | | | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | |
| G-2022 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| H-2022 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| I-2022 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| J-2022 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| K-2022 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| L-2022 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M-2022 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N-2022 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| O-2022 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P-2022 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

The distance of the cameras to the nearest ranch varied from 533–7,239 m ($\mu = 4,020$ m) and their elevation ranged from 300–1,802 m ($\mu = 1,400$ m). Cameras were attached to trees 40–50 cm above the ground and each camera was deployed from 35–117 ($\mu = 60$) consecutive days between June 2021 and December 2023. Since more than one camera could have been active during the same dates (Table III), there was a total of 1,563 camera operation days spanning over 682 sampling dates distributed along fifteen months in the dry season and ten months in the rainy season. A mammal species was considered detected at site during a given date if at least one photograph was obtained on that date and was considered undetected otherwise. Detected mammals were identified based on specialized literature (Ceballos, 2014) as well as in the authors’ knowledge and confirmed with species lists from relevant publications (Arnaud *et al.*, 2012; CONANP, 2003; Galina-Tessaro *et al.*, 2019). Detection data were used to calculate species richness over time, determine the number of detected species by site, and quantify the number of detections for all species by camera and overall, which was then compared to existing reports.

Table III. Features of the camera-trap sites in the Sierra la Laguna Biosphere Reserve, Baja California Sur, Mexico. P.O. = pine-oak forest; D. = deciduous forest.

| Latitude | Longitud | Camera ID | Vegetation | Elevation (m) | Dist. Ranch (m) | No. Operational days |
|------------|--------------|-----------|------------|---------------|-----------------|----------------------|
| 23.543140° | -109.972790° | A-2021 | P.O. | 1,787 | 6,461.4 | 49 |
| 23.543140° | -109.972750° | A-2022 | P.O. | 1,787 | 6,464.6 | 49 |
| 23.541811° | -109.972883° | A-2023 | P.O. | 1,789 | 6,365.3 | 57 |
| 23.543250° | -109.972850° | B-2021 | P.O. | 1,787 | 6,463.9 | 50 |
| 23.543200° | -109.972900° | B-2022 | P.O. | 1,787 | 6,456.5 | 50 |
| 23.546322° | -109.967162° | B-2023 | P.O. | 1,787 | 7,132.1 | 56 |
| 23.543140° | -109.972810° | C-2021 | P.O. | 1,787 | 6,459.7 | 69 |
| 23.543161° | -109.972472° | C-2022 | P.O. | 1,787 | 6,488.6 | 50 |
| 23.554273° | -109.822830° | C-2023 | D. | 449 | 533.4 | 65 |
| 23.652209° | -110.080995° | D-2021 | D. | 668 | 1,003.8 | 78 |
| 23.543180° | -109.972443° | D-2022 | P.O. | 1,787 | 6,492.3 | 66 |
| 23.596527° | -109.945192° | D-2023 | P.O. | 1,702 | 3,469.5 | 53 |
| 23.642360° | -109.965184° | E-2021 | D. | 1,004 | 1,375.6 | 111 |
| 23.542783° | -109.972510° | E-2022 | P.O. | 1,788 | 6,460.2 | 66 |
| 23.601014° | -109.945192° | E-2023 | P.O. | 1,698 | 3,361.2 | 92 |
| 23.437744° | -109.822085° | F-2022 | D. | 300 | 1,910.8 | 96 |
| 23.429397° | -109.997696° | G-2022 | D. | 761 | 2,460.5 | 35 |
| 23.428340° | -109.996431° | H-2022 | D. | 754 | 2,618.4 | 35 |
| 23.562400° | -109.823550° | I-2022 | D. | 643 | 1,418.6 | 37 |
| 23.562000° | -109.823500° | J-2022 | D. | 602 | 1,374.4 | 37 |
| 23.641992° | -109.965709° | K-2022 | D. | 1,001 | 1,430.1 | 67 |
| 23.437841° | -109.822093° | L-2022 | D. | 1,787 | 1,920.8 | 49 |
| 23.546639° | -109.966113° | M-2022 | P.O. | 1,802 | 7,238.9 | 42 |
| 23.547165° | -109.967610° | N-2022 | P.O. | 1,786 | 7,152.2 | 44 |
| 23.652365° | -110.080727° | O-2022 | D. | 1,787 | 1,002.3 | 117 |
| 23.652330° | -110.081057° | P-2022 | D. | 1,787 | 1,018.4 | 43 |

Given that all detected species are long-lived, non-migratory, and do not hibernate (Nowak, 1999), that camera traps were not evenly deployed across years (Table II), and that no significant ecosystem disturbances (e.g., wildfires) occurred during the sampling period, we did not divide our data by year. Instead, we analyzed the relationship between species richness and the number of detections per site, as well as how these community variables relate to environmental factors such as vegetation type (pine-oak vs. tropical deciduous forest), season (rainy vs. dry), altitude (m) and distance to the nearest ranch (m). Species richness and mammal detection data were not normally distributed (Shapiro-Wilk's test, $p < 0.05$) and nonparametric statistical tests were therefore applied. Species richness and number of detections were compared between vegetation types (pine-oak vs. deciduous forest) and seasons (rainy vs. dry) with a Mann-Whitney U test and correlations among all continuous variables were determined through the Spearman's Rank Correlation Coefficient.

Results y discussion

A total of twelve mammal species were detected after 546 sampling days (Figs. 2 and 5). The most frequently observed native species was the mule deer (*Odocoileus hemionus*), with 142 detections, followed by coyotes (*Canis latrans*, 82 detections) and raccoons (*Procyon lotor*, 78 detections). Other native species included the grey fox (*Urocyon cinereoargenteus*, 54 detections), bobcat (*Lynx rufus*, 27 detections), skunk (*Spilogale gracilis*, 14 detections), desert mouse (*Peromyscus eva*, 3 detections), and ringtail (*Bassariscus astutus*, 1 detection). None of these species is considered endangered or protected by national legislation. Additionally, four introduced ungulate species were recorded: cows (*Bos taurus*, 70 detections), pigs (*Sus scrofa*, 65 detections), horses (*Equus caballus*, 13 detections), and donkeys (*Equus asinus*, 3 detections) (Fig. 3). The mean number of detections for all species was 46 ± 41.6 SD, with a highly variable number of species and detections among cameras (Fig. 4).

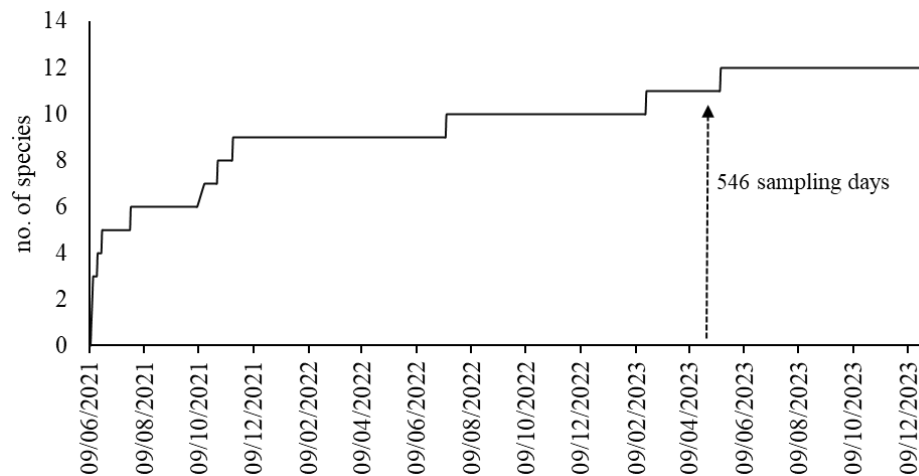


Figure 2. Accumulated mammal species richness over time in the Sierra la Laguna Biosphere Reserve, Baja California Sur, Mexico.

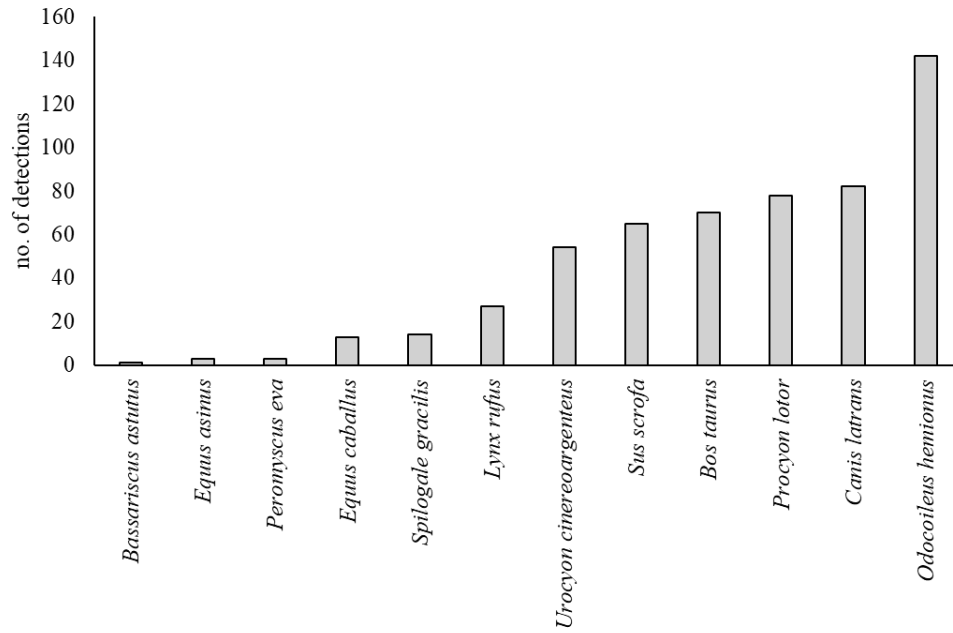


Figure 3. Number of detections per mammal species detected by camera-traps from June 2021 to December 2023 in the Sierra la Laguna Biosphere Reserve, Baja California Sur, Mexico.

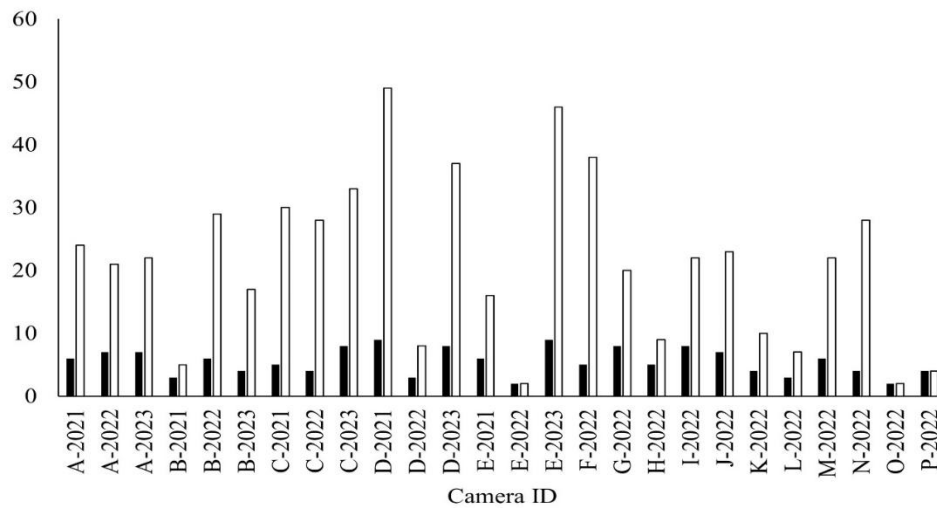


Figure 4. Black columns = number of mammal species by camera; White columns = number of detections by camera from June 2021 to December 2023 in the Sierra la Laguna Biosphere Reserve, Baja California Sur, Mexico.



Figure 5. Cropped pictures taken from camera trap photographs in the Sierra la Laguna Biosphere Reserve, Baja California Sur, Mexico. A = *Canis latrans*; B = *Urocyon cinereoargenteus*; C = *Lynx rufus*; D = *Odocoileus hemionus*; E = *Bassariscus astutus*; F = *Bos taurus*; G = *Equus asinus*; H = *Procyon lotor*; I = *Equus caballus*; J = *Spilogale gracilis*; K = *Sus scrofa*; L = *Peromyscus eva*.

The Sierra la Laguna Biosphere Reserve is home to forty-two species of native mammals (Arnaud *et al.*, 2012) and six species of introduced ungulates (Galina-Tessaro *et al.*, 2019). In our study, however, we detected only eight native species and four introduced ungulates. In the case of native mammals this discrepancy likely arises from the limitations of camera traps, which are generally less effective at detecting small mammals such as rodents, shrews, and gophers —particularly those with subterranean or arboreal habits— unless the cameras are specifically positioned and modified for that purpose (Littlewood *et al.*, 2021). Notably, in this study, the least detected native species, *B. astutus* (arboreal) and *P. eva* (small rodent), were the last to be photographed by our cameras after 504 and 546 sampling dates, respectively.

Although camera-traps have been effective in detecting bats at lowland water bodies (40–60 m.a.s.l.) in Baja California Sur (Mesa-Zavala *et al.*, 2012), our cameras failed to detect any bat species. In part because of the position of the cameras and because of the known limitations of conventional camera traps, which often lack the speed or sensitivity required to capture images of fast-moving bats (Rydell *et al.*, 2022).

Neither of the two lagomorph species previously reported in the reserve, *Sylvilagus audubonii* and *Lepus californicus* (Arnaud *et al.*, 2012), were detected by our cameras. *S. audubonii* typically inhabits riparian areas in arid regions (Champan and Ceballos, 1990), while *L. californicus* is more common in cactus deserts and overgrazed grasslands (Best, 1996), in the reserve these species have only been reported at xerophytic scrublands under 400 m.a.s.l. (CONANP, 2003). Remarkably, these habitats were not included in our study, explaining the lack of detections in our camera traps.

Taxidea taxus has also been reported in the reserve (Arnaud *et al.*, 2012) and it is known to occupy a wide variety of habitats (Proulx *et al.*, 2016), including pine-oak forests in the Baja California Peninsula (Ruiz-Campos *et al.*, 2002). However, our cameras did not detect this species, likely due to its semi-fossorial and elusive behaviors (Ceballos, 2014) and that it prefers low elevation areas within the reserve (CONANP, 2003).

Despite local reports and anecdotal evidence from ranchers suggesting the presence of cougars (*Puma concolor*), no concrete evidence of this species was captured by the camera traps during the study period. The absence of cougar detections aligns with the challenges of documenting this elusive carnivore (Arnaud *et al.*, 2012), which may require targeted monitoring efforts to determine whether cougars persist in unsampled habitats or if the species is now absent from the reserve.

Our cameras further confirmed the presence of cows, pigs, horses, and donkeys among the introduced ungulates previously reported in the reserve. In contrast, goats (*Capra hircus*) and sheep (*Ovis aries*) were not detected, supporting the notion that these species are not feral in the reserve due to local ranching practices, where goats and sheep are released to graze near ranches during the day and returned to the ranch by evening (Galina-Tessaro *et al.*, 2019).

Comparing our detection results with those of previous camera-trap studies in the Sierra la Laguna Biosphere Reserve (Arnaud *et al.*, 2012; Galina-Tessaro *et al.*, 2019) presents some challenges due to sampling characteristics and data management. For example, as reported by (Arnaud *et al.*, 2012), cows accounted for 43.8% of all photographic records, while in our study, they represented only 12.7% of all mammal detections. This same comparison for deer and ringtails shows similar percentages between the two studies (< 0.3% difference, Table II). For all other species, the detection percentages in our study were higher than the photographic record percentages reported by (Arnaud *et al.*, 2012; Table II). It is important to highlight that photographic records and detections are not equivalent measures. Photographic records reflect the number of photos captured for each species

and could even include pictures of the same individuals in the same day, whereas in our study detections consolidate multiple photos of the same species taken on the same date into a single detection event (*i.e.* one day).

Table II. Comparison of mammal photographic records previously reported by (Arnaud *et al.*, 2012) and mammal detections from this study.

| Common name-species | Arnaud <i>et al.</i> , 2012: % of photographic records (Jan.-Feb. 2010; 25 cameras). | | This study: % of total detections; (Jun. 2021-Dec. 2023; 26 cameras). |
|--------------------------------------|--|---|---|
| Cows- <i>B. primigenious</i> | 43.8 | > | 12.7 |
| Mule deer- <i>O. hemionus</i> | 25.3 | ~ | 25.7 |
| Coyote- <i>C. latrans</i> | 13.5 | < | 14.8 |
| Pigs- <i>S. scrofa</i> | 6.7 | < | 11.8 |
| Gray Fox- <i>U. cinereoargenteus</i> | 5.6 | < | 9.8 |
| Bobcat- <i>L. rufus</i> | 2.8 | < | 4.9 |
| Raccoon- <i>P. lotor</i> | 1.1 | < | 14.1 |
| Ringtail- <i>B. astutus</i> | .5 | ~ | 0.18 |
| Skunk- <i>S. gracilis</i> | .5 | < | 2.5 |
| Donkey- <i>E. asinus</i> | 0 | < | 0.5 |
| Desert mouse- <i>P. eva</i> | 0 | < | 0.5 |
| Horse- <i>E. caballus</i> | 0 | < | 2.3 |

When comparing our results with those of (Galina-Tessaro *et al.*, 2019) the percentage of cameras capturing images of cows, pigs, and mule deer was higher in our study. Although our sampling period was longer than that of Galina-Tessaro *et al.* (2019) (Table III), we did not find a significant correlation between detections and the number of operational camera days ($p > 0.05$; Table IV). This suggests that the presence of these ungulate species is becoming more ubiquitous in the reserve (Table III).

Table III: Comparison of percentage of cameras with mammal detections in the Sierra la Laguna Biosphere Reserve.

| Common name-species | (Galina-Tessaro <i>et al.</i> , 2019); (Feb. 2010–Aug. 2011; 25 cameras) | | This Study; (Jun. 2021–Dec. 2023; 26 cameras). |
|-------------------------------|--|---|--|
| Mule deer- <i>O. hemionus</i> | 84.5% | < | 88.5% |
| Cows- <i>B. primigenious</i> | 75.6% | < | 80.7% |
| Pigs- <i>S. scrofa</i> | 34.3% | < | 65.0% |

Although these comparisons may suggest that introduced ungulate species are not impacting native mammal populations, it is important to recognize that the sampling design was not intended to assess such effects. Targeted studies are needed to analyze species interactions; for instance,

introduced ungulates may negatively affect native mule deer, or there may be predator-prey dynamics, such as coyotes preying on deer.

Each camera detected between two and nine mammal species ($\mu = 5.5 \pm 2.1$ SD), with individual cameras recording as few as two detections and as many as forty-nine detections ($\mu = 21.2 \pm 12.8$ SD; Fig. 4). There was a strong positive correlation between the number of species detected by each camera and the number of detections per camera ($p < 0.001$; Table IV). Positive correlations between species richness and abundance have been similarly documented in various communities, including rodents, lizards, and birds, across different habitats including forests, grasslands, and mesquite-oak savannas (Bock *et al.*, 2007; Pautasso and Gaston, 2005). Since the detection of certain vertebrate species is often positively correlated with their abundance (McCarthy *et al.*, 2013), our findings suggest that mammalian species richness surveys in the Sierra la Laguna Biosphere Reserve could also serve as a proxy for species abundance, highlighting the importance of using species richness as an indicator of conservation value in protected areas.

We found a negative correlation between both, species richness and the number of detections with altitude ($p < 0.05$). Although altitude and the distance to the nearest ranch were strongly correlated ($p < 0.001$), the distance to ranches itself does not appear to directly influence species richness or the number of detections ($p > 0.05$) (Table IV).

Table IV. Summary result of Spearman Rank of correlations between response and predictor variables available in this study (n = 26).

| | S | RHO | P |
|--|--------|-------|--------|
| Sp. richness - no. of detections | 868.8 | 0.70 | <0.001 |
| Altitude - distance to nearest ranch | 1118.7 | 0.61 | <0.001 |
| Sp. richness - altitude | 4332.5 | -0.48 | 0.01 |
| No. of detections - altitude | 4119.0 | -0.40 | 0.04 |
| Sp. richness - distance to nearest ranch | 4749.6 | -0.28 | 0.16 |
| No. of detections - no. of camera operation days | 2476.2 | 0.15 | 0.45 |
| Sp. richness - no. of camera operation days | 3301.7 | -0.12 | 0.53 |
| No. of detections - distance to nearest ranch | 2983.1 | -0.02 | 0.92 |

Moreover, species richness and detections were similar between pine-oak forest and tropical deciduous forest areas as well as between the dry and rainy seasons (Mann Whitney U: $p > 0.4$; Table V). These results suggest that factors related to altitude (e.g. temperature and precipitation), rather than proximity to human activities (e.g. ranches), vegetation type or season, may be driving the observed patterns of species presence and detection. As altitude increases, both the number of different species and the frequency of species detections tend to decrease in the Sierra la Laguna

Biosphere Reserve, this is consistent with the known trend in elevational species richness on which richness decreases with increasing elevation (McCain and Grytnes, 2010; Rahbek, 1995), even when most of our camera sites traps were placed at elevations above 1,600 m.a.s.l. (61.5%), only 15.4% between 700–1600 m.a.s.l. and 19.2% under 700 m.a.s.l.

Table V. Comparison of mean species richness and number of detections for mammals in the Sierra la Laguna Biosphere Reserve.

| | Sp. richness | No. of detections. |
|-------------------------------------|----------------|--------------------|
| Vegetation type | | |
| Pine-oak (n = 14 cameras) | 5.28 ± 1.97 SD | 22.78 ± 11.62 SD |
| Tropical deciduous (n = 12 cameras) | 5.75 ± 2.16 SD | 19.41 ± 13.93 SD |
| Mann-Whitney U test | $p = 0.5$ | $p = 0.4$ |
| Season | | |
| Dry (n = 15 months) | 6.07 ± 1.75 SD | 21.28 ± 11.90 SD |
| Rainy (n = 10 months) | 5.66 ± 2.26 SD | 22.88 ± 16.59 SD |
| Mann-Whitney U test | $p = 0.7$ | $p = 1.0$ |

Conclusions

In summary, camera traps have proven to be an effective, non-invasive tool for monitoring mid- to large-sized mammals in the Sierra la Laguna Biosphere Reserve, providing valuable indicators such as species richness and detection trends that contribute to assessing the conservation status of these species. To maximize the efficiency of both the cameras and the efforts of the reserve's staff, it is recommended to deploy camera traps simultaneously and systematically along an elevation gradient, encompassing vegetation types that were not included in this study, such as xerophytic scrublands, riparian zones, and natural grasslands. This approach would enable a more comprehensive understanding of the altitudinal effects on mammal diversity and abundance while increasing the likelihood of detecting species not yet recorded, such as *Taxidea taxus*, *Sylvilagus audubonii*, and *Lepus californicus*.

This study enhances our understanding of the mammal community within the reserve. The results indicate that both native and introduced species are prevalent, and their presence may even be increasing. This suggests that introduced ungulates have not significantly impacted native ungulate species like *Odocoileus hemionus* or potential predators like *Canis latrans*, and that the reserve's

management has been effective in conserving mid- to large-sized mammals. However, the ongoing presence of introduced species remains a poorly understood pressure, with important implications for the management and conservation of the reserve's ecosystems. Continued research is necessary to fully understand and mitigate these pressures to ensure the long-term health of the reserve's biodiversity.

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References

- Arnaud, G. 1992. *Efectos potenciales del coyote en las practicas cinegéticas, ganadera y agrícola*. pp. 251–261. En: Ortega-Rubio, A (Ed.). *Uso y Manejo de los Recursos Naturales en la Sierra de la Laguna, Baja California Sur*. Centro de Investigaciones Biológicas de Baja California Sur. La Paz, México. 367 p.
- Arnaud, G., S. Álvarez-Cárdenas, y P. Cortés-Calva. 2012. *Mamíferos de la reserva de la biosfera Sierra de la Laguna*. pp. 145–161. En: Lagunas-Vázquez, M., L.F. Beltrán-Morales y A. Ortega-Rubio (Eds.). *Evaluación de la Reserva de la Biosfera Sierra La Laguna, Baja California Sur: Avances y Retos*. Centro de Investigaciones Biológicas del Noroeste S.C. La Paz, México. 412 p.
- Arriaga, L., J.M. Espinoza, C. Aguilar, E. Martínez, L. Gómez y E. Loa. 2000. *Regiones terrestres prioritarias de México*. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). México.

- Arriaga, L., y A. Ortega. 1988. La Sierra de La Laguna de Baja California Sur. Centro de Investigaciones Biológicas de Baja California Sur, La Paz, México. 237 p.
- Best, T.L. 1996. *Lepus californicus*. Mammalian Species, 530: 1–10.
- Bock, C.E., Z.F. Jones y J.H. Bock. 2007. *Relationships between species richness, evenness, and abundance in a southwestern savanna*. Ecology 88: 1322–1327.
- Ceballos, G. 2014. Mammals of Mexico. John Hopkins University Press. Baltimore, USA. 957 pp.
- Champan, J.A., y G. Ceballos. 1990. *The cottontails*. pp. 95–110. En: Chapman J.A. y J.E.C. Flux (Eds.). Rabbits, hares and pikas: status survey and conservation action plan. International Union for the Conservation of Nature and Natural Resources. Gland, Switzerland. 168 pp.
- CONANP. 2003. Programa de Manejo Reserva de la Biosfera Sierra La Laguna. Comisión Nacional de Áreas Naturales Protegidas. Distrito Federal, México. 209 pp.
- Galina-Tessaro, P., G. Arnaud, A.B. Solis-Cámara, y S. Álvarez-Cárdenas. 2019. *Ungulates in Sierra La Laguna Biosphere Reserve, Baja California Sur, México*. pp.11–41. En: Gallina-Tessaro, S. (Ed.). Ecology and Conservation of Tropical Ungulates in Latin America. Springer Cham. Switzerland.
- Gallina, S., P. Galina-Tessaro y S. Álvarez-Cárdenas. 1991. *Mule deer density and pattern distribution in the pine oak forest at the Sierra La Laguna in Baja California Sur, Mexico*. Ethology Ecology and Evolution 3(1): 27–33.
- González-Abraham, C. E., P.P. Garcillán y E. Ezcurra. 2010. *Ecorregiones de la península de Baja California: Una síntesis*. Boletín de la Sociedad Botánica de México 87: 69–82.
- León de la Luz, J.L., R. Domínguez-Cadena, M. Domínguez-León y R. Coria-Benet. 1999. *Flora of the woodlands of the Sierra de La Laguna, Baja California Sur, Mexico*. pp. 144–151. En: De Lano, F. (Ed.). Biodiversity and the management of the Madrean Archipelago: the Sky Islands of Southwestern U. S. and Northwestern Mexico. Diane, Darby. Pennsylvania, USA.
- Littlewood NA, M.H. Hancock, S. Newey, G. Shackelford y R. Toney. 2021. *Use of a novel camera trapping approach to measure small mammal responses to peatland restoration*. European Journal of Wildlife Research 67(1): 12.
- McCain, C.M., y J.A. Grytnes. 2010. *Elevational gradients in species richness*. En: Encyclopedia of Life Sciences. John Wiley & Sons, Ltd: Chichester. doi: 10.1002/9780470015902.a0022548

- McCarthy, M.A., J.L. Moore, W.K. Morris, K.M. Parris, G.E. Garrard, P.A. Vesk, L. Rumpff, K.M. Giljohann, J.S. Camac, S.S. Bau, T. Friend, B. Harrison y B. Yue. 2013. *The influence of abundance on detectability*. *Oikos* 717–726.
- Mesa-Zavala, E., S. Álvarez-Cárdenas, P. Galina-Tessaro, E. Troyo-Diéguéz, e I. Guerrero-Cárdenas. 2012. *Vertebrados terrestres registrados mediante foto-trampeo en arroyos estacionales y cañadas con agua superficial en un hábitat semiárido de Baja California Sur, México*. *Revista Mexicana de Biodiversidad* 83(1): 235–245.
- Nowak, R.M. 1999. *Walker's mammals of the world*. 6th edition. Johns Hopkins University Press. United Kingdom. 1936 pp.
- Ortega-Rubio, A. 1992. *Uso y manejo de los recursos naturales en la Sierra de la Laguna, Baja California Sur*. Centro de Investigaciones Biológicas Del Noroeste, S.C. La Paz, México. 367 pp.
- Ortega-Rubio, A., y C. Argüelles-Méndez. 1999. *Management plans for natural protected areas in Mexico: La Sierra de la Laguna case study*. *International Journal of Sustainable Development and World Ecology* 6(1): 68–75.
- Pautasso, M., y K.J. Gaston. 2005. *Resources and global avian assemblage structure in forests*. *Ecology Letters* 8: 282–289.
- Pío-León, J.F., y A. Ortega-Rubio. 2020. *Sociocultural and environmental interactions between people and wild edible plants: The case of Sierra la Laguna Biosphere Reserve*. pp 325–335. En: Ortega-Rubio, A. (Ed.). *Socio-ecological studies in natural protected areas: Linking community development and conservation in Mexico*. Springer International Publishing. Germany.
- Proulx, G., A.V. Abramov, I. Adams, A. Jennings, I. Khorozyan, L.M. Rosalino, M. Santos-Reis, G. Veron y E. Do Linh San. 2016. *World distribution and status of badgers – a review*. pp. 31–116. En: Proulx G., y E. Do Linh San (Eds.). *Badgers: systematics, biology, conservation and research techniques*. Alpha Wildlife Publications. Alberta, Canada.
- Rahbek, C. 1995. *The elevational gradient of species richness: a uniform pattern?* *Ecography* 18(2): 200–205.
- Ruiz-Campos, G., R. Martínez-Gallardo, J. Alaníz-García, S. González-Guzmán, y R. Eaton-González. 2002. *Recent records of North American badger, Taxidea taxus, in Baja California, Mexico*. *The Southwestern Naturalist* 47(2): 316–319.

Rydell, J., D. Russo, P. Sewell, E.C.J. Seamark, C.M. Francis, S.L. Fenton y M.B. Fenton. 2022. *Bat selfies: photographic surveys of flying bats*. *Mammalian Biology* 102(3): 793–809.

Woloszyn, B., y D. Woloszyn. 1981. *Algunas observaciones sobre las poblaciones de los pegueños mamíferos de la Sierra la Laguna, Baja California Sur*. pp. 496–502. En: Caballero, M., R.H. Hamre, R. Driscoll, W. Bonner y H. Lund (Eds.). *Inventarios de recursos de tierras áridas. Desarrollo de métodos eficientes en costos*. USDA, Forest Service, General Technical Reports. USA.

Cita

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