DOI: https://doi.org/10.29298/rmcf.v10i56.499

Article

Diversidad de mamíferos y aves en bosques de coníferas bajo manejo en el Eje Neovolcánico Transversal

Mammal and bird diversity in coniferous forests under management in the Trans-Mexican Neovolcanic Belt

Gilberto Chávez-León

Resumen

Para certificar sus predios, los silvicultores requieren implementar actividades de monitoreo que, entre otras cosas, muestren la magnitud del impacto de los aprovechamientos sobre la fauna silvestre. Se utilizaron cámaras–trampa distribuidas al azar para valorar la diversidad alfa de dos grupos de vertebrados terrestres en bosques sujetos a manejo en el Eje Neovolcánico Transversal en el estado de Puebla y así establecer una línea base. Los datos se analizaron con números de Hill, un grupo de medidas que incorporan la abundancia relativa y la riqueza de especies; además, consideran el sesgo ocasionado por los individuos presentes dentro de un área pero que no son registrados durante el estudio. El esfuerzo de muestreo fue de 1 800 días-trampa, en los que se captaron imágenes de 13 taxa de mamíferos y siete de aves, lo que corresponde a la riqueza observada, mientras que la riqueza estimada fue de 14 y siete especies efectivas, respectivamente. Los resultados indican que la riqueza y la diversidad de ambos ensambles fue similar en donde se aplican dos métodos de manejo forestal. La excepción fue en el Método de Desarrollo Silvícola, donde el recíproco de la diversidad de Simpson de mamíferos fue 2.5 veces mayor que en el Método Mexicano de Ordenación de Bosques Irregulares. Se recomienda aplicar un diseño experimental riguroso para comparar los efectos de las diferentes prácticas silvícolas.

Palabras clave: Aves, mamíferos, números de *Hill*, probabilidad de detección, riqueza de especies, silvicultura.

Abstract

To certify their forestry properties, foresters need to implement monitoring activities that, among other things, show the magnitude of the impact of timber harvesting on wildlife. To establish a baseline, randomly distributed camera-traps were used to assess the alpha diversity of two groups of terrestrial vertebrates in forests subject to management in the Trans-Mexican Neovolcanic Belt, state of *Puebla*. The data were analyzed with Hill numbers, a group of diversity measures that involves relative abundance and species richness, and consider the bias caused by individuals present within an area but not recorded during the study. The sampling effort was 1 800 trap-days, capturing images of 13 species of mammals and 7 of birds, which corresponds to the observed richness, while the estimated richness was 14 and 7 effective species, respectively. The results indicate that the richness and diversity of both assemblages was similar in two forest management methods. The exception was the Forestry Development Method, where the reciprocal of Simpson's diversity of mammals was 2.5 times higher than in the Mexican Management Method for Irregular Forests It is recommend to apply a rigorous experimental design to compare different management practices.

Key words: Birds, mammals, Hill numbers, detection probability, species richness, forestry.

Fecha de recepción/Reception date: 31 de enero de 2019
Fecha de aceptación/Acceptance date: 20 de mayo de 2019

[1]Centro Nacional de Investigación Disciplinaria en Conservación y Mejoramiento de Ecosistemas Forestales, INIFAP. México.
*Autor por correspondencia: chavez.gilberto@inifap.gob.mx

Introduction

In order to certify their lands at the Mexican Forest Certification System (SCFM, for its acronym in Spanish), foresters have to carry out monitoring activities that, among other things, indicate the magnitude of the impact of exploitation upon fauna and flora and identify changes in the ecosystem (Conafor, 2018). In addition, they must integrate best practices of biodiversity conservation in forest management (Barrón, 2016). Although mammals and birds play important roles in forests, such as seed dispersal, regulation of herbivore and pest populations, pollination and carbon sequestration, among others (Valdez, 2014), there is little information on their conditions where forestry is applied (Lindenmayer and Franklin, 2002; Jardel, 2015).

Technological advances in infrared sensors and digital photography facilitate the use of camera-traps (CT) as a non-invasive and economical tool for the reliable and standardized detection of medium and large-sized wildlife (Meek *at al*., 2014; Burton *et al.,* 2015; Rowcliffe, 2017). The sampling effort is the main factor that indicates the number of species that can be registered with this technique, so it is necessary to increase it to detect the most elusive or rare (Tobler *et al.,* 2008).

To reliably assess animal populations, it is necessary to consider the sources of error, particularly the problem of incomplete determination: when individuals present within an area are not observed (Burton *et al.,* 2015). The study subjects are mobile organisms and, therefore, their detection is imperfect at two spatial scales: on the one hand, those that pass through the small sensitive cone of the camera may not be captured; likewise, those who use a larger area than a CT network covers may not enter that area. Therefore, the decisive factors are its body size, activity area and abundance (Lindstedt *et al.,* 1986; Tobler *et al.,* 2008, Vázquez *et al.,* 2013).

To quantify specific diversity, Hill numbers (or effective number of species) are increasingly used because they represent a statistically robust alternative to traditional indexes and the complexity of the composition of a community cannot be expressed as a single number (Chao. *et al.,* 2014). The objective of this study was to establish a baseline of the diversity of terrestrial vertebrates in productive forests through autonomous digital devices (TC) that serve as a reference for future work to determine the impact of forest exploitation.

Materials and Methods

Study area

The study was conducted in forest lands subject to sustainable management practices that have SCFM certification, integrated into two Regional Associations of Foresters (ARS) of the state of *Puebla*: *Iztaccíhuatl-Popocatépetl, S. C. (Sierra Nevada)* and *Chignahuapan - Zacatlán, A. C. (Sierra Norte de Puebla)*, both in the Trans-Mexican Neovolcanic Belt. The vegetation that predominates is mixed forest (coniferous and broad-leaved), both in primary and secondary stages, in which irregular and regular forestry systems are applied. Climate is similar in both regions: subhumid temperate predominates and in the highest areas it is semi-cold subhumid (Asmarf, 2015; SyCAF, 2016).

Puebla has a richness of 161 species of mammals (Martínez *et al*., 2011) and 595 of birds (Jiménez *et al.,* 2011). In the *Sierra Norte* there are 125 mammals, 87 of which live in the mixed forest; mostly, they are rodents (32) and bats (31), the rest (24) are medium and large sized taxa (Peralta and Martínez, 2013). Of the birds, 35 were found in lands where silvicultural treatments are applied (López-Becerra and Barrón-Sevilla, 2018). In the *Iztaccíhuatl-Popocatépetl* National Park, 48 mammals and 161 birds have been consigned (Conanp, 2013).

Field methods

The methods used were based on the guidelines of the National Biodiversity Monitoring System (García and Schmidt, 2016) and those of the Tropical Ecology Monitoring and Evaluation Network (TEAM Network, 2011). Its objective is to register changes in terrestrial vertebrate communities based on richness and diversity indicators through the use of camera-traps in permanent monitoring stations distributed with a systematic design.

Design of phototraps

30 stations were established with minimum spacings of 2 km (Figure 1, Table 1), in which a camera-trap was placed (Cuddeback; https://www.cuddeback.com/), fixed in a tree from 20 to 40 cm of normal diameter, 30-40 cm from the ground and their geographical coordinates were recorded. They were installed between July 5 and August 16, 2016 inside wooded areas (canopy coverage> 50 %). Herbaceous vegetation was cleared in front of the CT up to a distance of 10 m. There were randomly arranged 21 devices with black flash (model E3) and nine with white flash (model C1), with a range of 15 m and a firing speed of 0.25 s. They operated autonomously for 60 consecutive days, reviewing them every 10 days. They were programmed to simultaneously take videos of 20 s and still photos with a 20 MP definition in 15 s firing periods (Chávez-León, 2017).

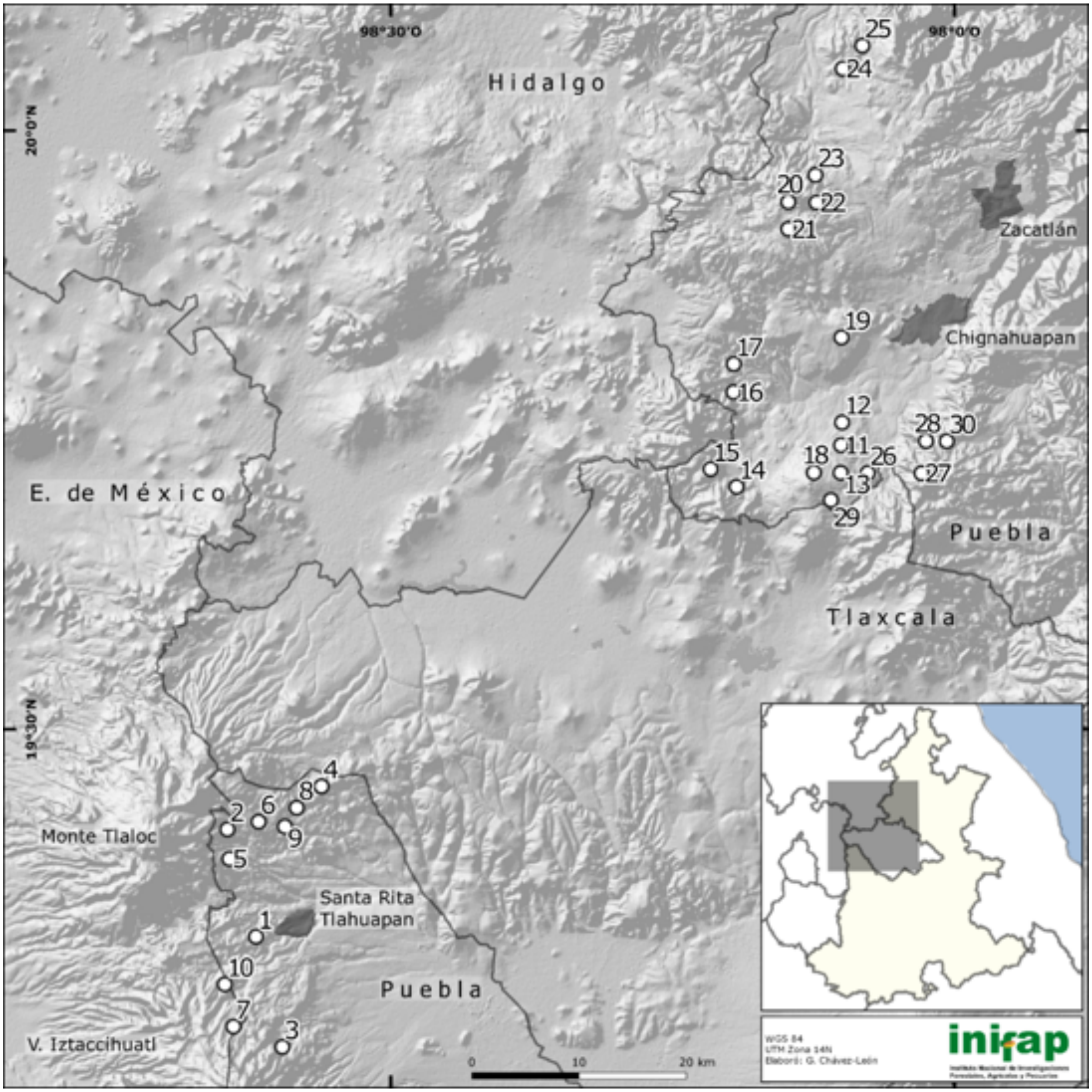

Figure 1. Geographic distribution of 30 phototrapping stations (white circles) in the state of *Puebla,* Mexico.

Table 1. Location of camera-traps in forest lands of two Regional Associations of Foresters of the state of *Puebla*, Mexico.

Num.	ARS *Ejidos*/Private property	Latitude	Longitude	Altitude (masl)	Forestry Method[1]	Forestry Practice
	ARS Iztaccíhuatl-Popocatépetl					
1	*Santa Rita Tlahuapan*	19°19'34.6"	98°37'10.5"	2951	MMOBI	Selective cutting
2	*Santiago Coltzingo*	19°24'58.1"	98°38'41.7"	3215	MMOBI	Selective cutting
3	*San Andrés Hueyacatitla*	19°14'01.9"	98°35'46.3"	3185	MMOBI	Selective cutting
4	*San Francisco La Unión*	19°27'07.8"	98°33'41.1"	3053	Conservación	Conservation
5	*Ignacio M. Altamirano*	19°23'29.5"	98°38'35.3"	3153	MMOBI	Selective cutting
6	*San Juan Cuauhtémoc*	19°25'21.2"	98°37'01.9"	3030	MMOBI	Selective cutting
7	*El Poblanito*	19°14'38.3"	98°39'24.3"	3549	MMOBI	Selective cutting
8	*Santiago Coltzingo*	19°26'03.3"	98°35'00.3"	2801	MMOBI	Selective cutting
9	*Juárez Coronaco*	19°25'06.7"	98°35'38.1"	2871	MMOBI	Selective cutting
10	*Santa Rita Tlahuapan*	19°17'11.0"	98°38'50"	3246	Conservación	Conservation
	ARS Chignahuapan-Zacatlán					
11	*Villa Cuauhtémoc*	19° 44' 15.0"	98° 06' 02.4"	2759	MDS	First thinning
12	*Villa Cuauhtémoc*	19° 45' 23.2"	98° 05' 59.0"	2527	MDS	Release cutting
13	*Villa Cuauhtémoc*	19° 42' 51.9"	98° 06' 03.8"	2856	MDS	Thinning
14	*Rinconada*	19° 42' 09.7"	9°8 11' 35.8"	2870	MDS	Thinning
15	*Rinconada*	19° 43' 02.8"	98° 12' 59.0"	3040	MDS	Thinning
16	*San Luís del Valle*	19° 46' 54.5"	98° 11' 46.0"	2625	MDS	Third thinning
17	*San Luís del Valle*	19° 48' 18.8"	98° 11' 44.9"	2615	MDS	Third thinning
18	*Acolihuia*	19° 42' 52.3"	98° 07' 29.1"	2922	MDS	Third thinning
19	*Chignahuapan*	19° 49' 38.6"	90° 06' 01.0"	2677	MDS	Thinning
20	*Cruz Colorada*	19° 56' 25.8"	98° 08' 50.8"	2934	MDS	Thinning
21	*Cruz Colorada*	19° 55' 04.6"	98° 08' 51.1"	2934	MDS	Thinning

22	*Peñuelas Pueblo Nuevo*	19° 56’ 24.1”	98° 07’ 20.7”	2858	MDS	Thinning
23	*Peñuelas Pueblo Nuevo*	19° 57’ 46.6”	98° 07’ 24.3”	2612	Conservación	Conservation
24	*Rancho Nuevo Nanacamila*	20° 03’ 06.1”	98° 05’ 57.3”	2433	MDS	First thinning
25	*Rancho Nuevo Nanacamila*	20° 04’ 15.2”	98° 04’ 54.2”	2404	MDS	Second thinning
26	*San Antonio Macahuacales*	19° 42’ 51.3”	98° 04’ 37.4”	2721	MDS	Regeneation cutting
27	*Fracción III, ex Hacienda de Atlamaxac*	19° 42’ 50.5”	98° 01’ 45.5”	3121	MMOBI	Selective cutting
28	*Fracción I, ex Hacienda de Atlamaxac*	19° 44’ 27.1”	98° 01’ 31.0”	2945	Conservación	Conservation
29	*San Antonio Macahuacales*	19° 41’ 29.7”	98° 06’ 34.8”	2947	MDS	Second thinning
30	*El Manantial*	19° 44’ 26.6”	98° 00’ 25.0”	2895	SICODESI	Regeneration cutting

[1]MMOBI = Mexican Management Method for Irregular Forests (nine stations); MDS = Forestry Development Method (16 stations); SICODESI = Silvicultural Conservation and Development System (one station); Conservation = Areas dedicated to conservation, are included here because they are part of the property management program (four seasons).

Taxonomic determination

The photos and their associated videos were reviewed by date and time of the shot. The marks, scars and relative size were observed to avoid a double counting of the same individual. In the absence of distinctive features, an individual was considered as the same animal if it appeared in several consecutive images recorded by the same camera during the same day (24 h), which was compared with simultaneous videos to see if an additional subject appeared. The determination of mammals was based on the descriptions, taxonomic keys and distribution maps of Hall (1981), Villa and Cervantes (2003) and Ceballos and Oliva (2005); the nomenclature of Ramírez *et al*. (2014) and the Spanish names of Ceballos and Oliva (2005) and Villa and Cervantes (2003). For the birds the works of Howell and Webb (1995), Van Perlo (2006) and Dunn and Alderfer (2011) were used; the taxonomy is from Chesser *et al.* (2018) and the common names of

Escalante *et al.* (2014). The species at risk and endemics included in the official Mexican standard NOM-059-SEMARNAT-2010 (Semarnat, 2010) are indicated.

Analysis of data

The set of sites was analyzed (30) and also the two management methods that are predominant in the study area were compared: the Mexican Management Method for Irregular Forests (MMOBI, with 9 stations) and the Forestry Development Method (MDS), with 16. To match the number of samples, nine of the latter were randomly selected. The least used processes in the region were the System of Conservation and Silvicultural Development (SICODESI, for its acronym in Spanish) and areas dedicated to conservation, which are only included in the total analysis.

The relative abundance index by species (RAI) was determined with the formula:

$$IAR = C/EM * 1000\, night\ traps$$

Where:

C = Captures or photographed independent events

EM = Sampling effort and 1000 trap-days as standard unit (Chávez *et al*., 2013; Hernández *et al*., 2015)

The problem of incomplete detection produces biases in the analysis of richness and diversity, which is why it was corrected with nonparametric estimators, that consider the proportion of species that are not discovered: the number of observed ones plus those present, but not detected (Burton *et al.,* 2015).

Estimators of wildlife diversity

Richness. Species richness is the basic measure of diversity of a biological assembly, represented by the amount of taxa that occur at a specific time point. A basic concept of information theory is that the abundant elements (which are more likely to be recorded) provide almost no details about those that were not found, while the rare ones (which may not be located or which are few) contain almost all the information about those not found. From three estimators the corrected bias (Chao1-bc), the coverage based on abundance (ACE) and the Jacknife, the first two improve their deviation and precision as the sample size increases, which is the reason to use them in this study (Chao and Chiu, 2016).

Diversity. Hill numbers are expressed in units of "effective number of species" or "effective species": the number of equally abundant taxa that would be needed to give the same value of a measure of diversity. If two assemblies have an identical richness, it will be greater the one which has equal abundances among all its members, while it will be smaller in that dominated by one or a few (Chao *et al.,* 2014).

Effective numbers were calculated with three orders of diversity ^{q}D: ^{0}D, ^{1}D and ^{2}D, in which the parameter q determines its sensitivity to relative abundances (Chao and Jost, 2015).

For the q = 0 (species richness, which does not consider the number of individuals) order, the nonparametric ACE estimator (Abundance-based coverage estimator) was used; for q = 1 (exponential of Shannon entropy, weights the taxa in proportion to their frequency), a correction of the subsampling bias was used when there is a fraction of missing species (Bias-corrected Shannon diversity estimator); and for that of q = 2 (inverse of the Simpson index, gives more weight to the dominant species and discounts the rare ones) the MVUE (Minimum Variance Unbiased Estimator) was used. The estimators have as a measure of inventory completeness the coverage of the sample, which represents the fraction of the total abundances (Moreno *et al.,* 2011; Chao and Jost, 2012) as a measure of completeness of the inventories.

The Hill numbers and their confidence intervals (CI) were computed with the SpadeR program (Chao *et al*., 2015). As an alternative to the traditional method of test of significance to judge differences between two point estimates, the overlap between the associated CIs was examined, which is possible when lists or charts of CI are presented, although knowledge of their limitations must be known. When the 95 % CIs did not overlap, it was considered a significant difference at a level of 5 % between the expected differences (Schenker and Gentleman, 2001).

Results and Discussion

The effort of phototraping was 1 800 trap days, in which 172 records of 20 taxa were obtained (tables 2 and 3). The greatest number were mammals (65 %), with the highest total proportion of incidences (74 %), of which slightly more than half (53 %) were medium and large (> 1 000 g). The third part consisted of birds (35 %), with a quarter of the organisms detected (26 %), most of which (71 %) are small (<100 g).

Table 2. Mammals and birds captured by camera-traps in forest management lands of *Puebla*, Mexico.

	Scientific name	Common name	Relative Abundance Index	Mass[3] (g)
Mammals				
1	*Mustela frenata* Lichtenstein, 1831	Long-tailed weasel	0.56	85 a 340
2	*Sciurus aureogaster* F. Cuvier, 1829	Red-bellied squirrel	10.56	350 a 690
3	*Sciurus oculatus* Peters, 1863	Peters's squirrel	8.89	550 a 750
4	*Didelphis marsupialis* Linnaeus, 1758	Common opossum	0.56	565 a 1610
5	*Bassariscus astutus* (Lichtenstein, 1830)	Ringtail	6.11	870 a 1100
6	*Sylvilagus floridanus* (J.A. Allen, 1890)	Eastern cottontail	11.11	900 a 1800
7	*Sylvilagus cunicularius* (Waterhouse, 1848)	Mexican cottontail	3.89	1008 a 2300
8	*Didelphis virginiana* Kerr, 1792	Virginia opossum	10.56	1100 a 2800
9	*Dasypus nomemcinctus* Linnaeus, 1758	Nine-banded armadillo	1.11	1000 a 10 000
10	*Nasua narica* (Linnaeus, 1766)	White-nosed coati	0.56	4000 a 6000
11	*Lynx rufus* (Schreber, 1777)	Bobcat	1.11	5700 a 31 000
12	*Canis latrans* Say, 1822	Coyote	14.44	8000 a 16 000
13	*Odocoileus virginianus* (Zimmermann, 1780)	White-tailed deer	1.11	27 000 a 135 000
Birds				
1	*Junco phaeonotus* Wagler, 1831	Yellow-eyed junco	6.67	16 a 23
2	*Catharus occidentalis* Sclater, 1859	Russet nightingale-thrush	3.89	22 a 32
3	*Pipilo maculatus* Swainson, 1827	Spotted Towhee	3.33	33 a 49
4	*Turdus migratorius* Linnaeus, 1766	American Robin	7.78	74 a 84
5	*Toxostoma ocellatum* (Sclater, 1862)	Ocellated trasher	1.11	77 a 89
6	*Cyanocitta stelleri* (Gmelin, 1788)	Steller's Jay	1.67	100 a 140
7	*Colaptes auratus* (Linnaeus, 1758)	Yellow-shafted flicker	0.56	129 a 154

List ordered by body size (mass). [1]Mammals = Ramírez *et al*., 2014; Birds = Chesser *et al*, 2018; [2]Mammals = Ceballos and Oliva, 2005; Birds = Escalante *et al*., 2014. [3]Mammals = Ceballos and Oliva, 2005; Birds = Rodewald, 2015; Schulenberg, 2019; these data are measurement ranges in all the geographic distribution area of each species, since there is no accurate information for the study area.

Table 3. Number of records of mammals and birds per camera-trap in forest management lands of *Puebla*, Mexico.

	Camera																														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total**
Mammals																															
Didelphis marsupialis	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Didelphis virginiana	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	5	0	0	1	0	2	0	0	2	2	3	1	0	0	0	19
Dasypus nomemcinctus	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Sylvilagus cunicularius	0	0	0	0	0	0	2	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	7
Sylvilagus floridanus	1	0	0	0	0	0	3	0	0	0	0	1	1	0	0	1	0	0	3	4	1	1	1	2	0	0	1	0	0	0	20
Sciurus aureogaster	0	0	1	2	0	0	0	0	0	0	0	1	1	0	0	1	0	0	3	4	1	1	1	2	0	0	1	0	0	0	19
Sciurus oculatus	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	3	4	1	1	1	2	0	0	1	0	0	0	16
Lynx rufus	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Canis latrans	3	4	0	0	1	0	11	0	5	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	26
Mustela frenata	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bassariscus astutus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	2	0	1	2	0	2	2	11
Nasua narica	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Odocoileus virginianus	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Total	4	5	2	6	1	0	17	0	5	1	0	7	4	2	0	10	0	0	10	12	6	3	4	10	2	6	6	0	2	2	127
Birds																															
Colaptes auratus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Cyanocitta stelleri	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3
Catharus occidentalis	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	7
Turdus migratorius	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0	4	0	0	0	0	2	0	0	1	3	0	0	0	14
Toxostoma ocellatum	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Pipilo maculatus	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	6
Junco phaeonotus	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	4	2	0	0	1	0	0	1	0	0	2	0	0	0	0	12
Total	0	0	0	0	0	0	2	0	0	0	1	10	2	1	1	7	2	4	0	2	0	1	3	0	0	4	3	2	0	0	45

In this study, 13 (54.2 %) of the 24 mammalian taxa of medium and large size consigned for the coniferous forests of the *Sierra Norte de Puebla* by Peralta and Martínez (2013) were found. In that region, Silverio and Ramírez (2014) documented with camera-traps six species (46.1 %) in a protected mesophilic forest and four (30.8 %) in a disturbed property by livestock out of a total of 13 possible, based on interviews with the local population. In two protected natural areas of *Yucatán* with *Petén* vegetation, Hernández *et al.* (2015) captured 16 species of mammals, equivalent to 50 % and 61.5 % of the 32 and 26 registered there. This indicates that phototraping reveals an average proportion (± 50 %) of all the species present in a site or region, mainly those difficult to observe.

Although there is no history of the use of phototraping to investigate the effect of forestry upon birds, in this study seven taxa were detected. The main methods for their study are the visual and auditory record, as well as their capture with mist-nets. With these techniques, López-Becerra and Barrón-Sevilla (2018) recorded 35 species in ranches where silvicultural treatments (thinning, release, regeneration and selection) were applied in *Chignahuapan* municipality, *Puebla*. In *Michoacán*, Aguilar (2006) detected 49 resident birds in stands subject to forest management, with greater diversity in conserved forests and third thinning cuts, that is, in sites with high and intermediate structural complexity of the vegetation; in the treatment of regeneration cuts (“father trees”), of greater intensity of management, the diversity of birds was very low.

The less abundant species (IAR) were the Bobcat, the White-tailed deer, the White-nosed coati, the Nine-banded armadillo, the Virginia opossum, the Yellow-shafted flicker and the Ocellated trasher. The Nine-banded armadillo was photographed only in an area dedicated to conservation, but the other animals were captured in stands intervened with MMOBI or MDS. Among the most frequent were the Coyote, the Eastern cottontail, the Red-bellied squirrels and the Peters´s squirrels, the Common opossum, the Yellow-eyed junco and the American Robin (tables 2 and 3). Although the two opossums are similar, they are distinguished because the northern one has white cheeks and the length of the dark portion of the base of the tail reaches from half to three quarters; the southerner has cheeks of cream to yellow tone and the dark zone of the tail is smaller than the middle part (McManus, 1974; Ceballos and Oliva, 2005). The two squirrels are different because Peters's back has a dark olive brown color without bright spots, which contrasts with the gray on the sides, while on the other, the back is pale gray to dark grayish brown with dorsal patches and the belly brown-reddish (Koprowski *et al*., 2017). Although the color of its coat is similar, the Mexican cottontail is larger than the Eastern cottontail; the back of the ears of the first has thin gray hair, with the outer edge and edges dark, but not as intense as in the second (Chapman *et al*., 1980; Cervantes *et al*., 1992). The images in which these characteristics were not clearly distinguished were discarded. Although the CTs photographed very small animals, such as mice (Rodentia: Cricetidae) and shrews (Soricomorpha: Soricidae), it was not possible to determine their taxonomic or individual identity, so they were excluded from the analysis.

Of this assemblage, the only species at risk, and, in addition, endemic to Mexico, is the Peters´s squirrel, in the category of subject to special protection (Pr) according to NOM-059 (Semarnat, 2010). Another mammal and two birds also have a restricted distribution to the Mexican territory: the Mexican cottontail, the Russet nightingale-thrush and the Ocellated trasher, although they are not at risk.

In addition, in 20 stations images of 33 people were captured, mainly mushroom pickers and hunters; as well as 60 dogs, a herd of 15 cattle and three horses with rider. This indicates a constant human and domestic animal activity in the area, with a possible negative effect on wildlife, such as illegal hunting, predation by dogs, the alteration of their habitual behavior and the deterioration of their habitat (Bötsch *et al*., 2018; Buxton *et al*., 2018).

Richness of species

The 13 species of mammals and seven of birds correspond to the total of the observed richness. In the nine randomly selected sites where the MMOBI or the MDS is applied, almost the same number of mammalian *taxa* was found in both, but more birds in MDS (Table 4). This difference may be the result of the fact that, where the MMOBI is used, the herbaceous and shrub layers are denser due to the forestry practices, but the MDS generally eliminates them, which increases the probability of being captured by the automatic devices.

It is also related to their habitat preferences, since, with the exception of the Steller´s Jay, most are ecotones and open space species. That is to say, it is possible that the generalists are favored to the detriment of the specialists of the interior of the forest by the diminution of the density of the vegetation. Another discrepancy was the number of *taxa* that were found only in properties where one of the two methods is applied: in MMOBI three mammals (White-nosed coati, White-tailed deer and Bobcat) were detected that were not found in MDS; in this, two mammals (Long-tailed weasel and Common opossum) and three unique birds (Russet nightingale-thrush, Ocellated trasher and Spotted Towhee) were captured, although the Yellow-shafted flicker was registered in one of the sites that were excluded at random from the analysis (Table 4).

Table 4. Number of species and records captured by camera-traps in forest management lands of *Puebla*, Mexico.

	Stations	Mammals		Birds	
		Species (records)	**Unique species**	**Species (records)**	**Unique species**
Total	30	13 (127)	-	7 (45)	-
MMOBI[1]	9	10 (40)	3	3 (3)	0
MDS[2]	9	9 (38)	2	6 (26)	3

[1]MMOBI = Mexican Management Method for Irregular Forests; [2]MDS = Forestry Development Method.

Of the non-parametric estimators of richness, ACE and Chao1-bc, the second had smaller standard values and errors, although the confidence intervals (CI) for the two overlapped in the comparisons, implying that there is no significant difference between the mammals richness observed and expected (Table 5). No differences were found in the case of MDS for birds, although in MMOBI the number of taxa was not enough to perform the calculations (Table 6). Sample coverage, an objective measure of inventory sufficiency (Chao and Jost, 2012; Chao and Chiu, 2016), was high under the conditions analyzed; that is, the camera-traps captured between 88 and 98 % of the mammals in the study area and between 98 and 100 % of the birds that use the ground (tables 5 and 6).

Table 5. Observed and expected richness of species calculated with non-parametric estimators in forest management lands of *Puebla,* Mexico.

	n[1]	S_{obs}[2]	**Chao1-bc**[3] **(IC 95%)**[4]	**ACE**[5] **(IC 95%)**	***C***[6]
Total	127	13	13.7 (13.1-21.4)	17.3 (13.7-37.8)	0.976
MMOBI[7]	40	10	12.4 (10.4-26.6)	17.1 (11.4-45.8)	0.875
MDS[8]	38	9	10.5 (9.1-23.7)	11.2 (9.3-23.7)	0.921

[1]n = Number of individuals; [2]*S*obs = Observed richness; [3]Chao1-bc = Expected richness; [4]IC = Confidence interval at 95 %, upper and lower limits; [5]ACE = Estimator of coverage based on abundance; [6]*C* = Sample coverage; [7]MMOBI = Mexican Management Method for Irregular Forests; [8]MDS = Forestry Development Method.

Table 6. Observed and expected richness of bird species calculated with non-parametric estimators in forest management lands of *Puebla,* Mexico.

	n[1]	S_{obs}[2]	**Chao1-bc**[3] **(IC 95%)**[4]	**ACE**[5] **(IC 95%)**	***C***[6]
Total	45	7	7.0 (7.0-8.9)	7.5 (7-13.6)	0.978
MMOBI[7]	2	2	-	-	-
MDS[8]	26	6	6.0 (6.0-.7.4)	6 (6-7.4)	1.000

[1]n = Number of individuals; [2]*S*obs = Observed richness; [3]Chao1-bc = Expected richness; [4]IC = Confidence interval at 95 %, upper and lower limits; [5]ACE = Estimator of coverage based on abundance; [6]*C* = Sample coverage; [7]MMOBI = Mexican Management Method for Irregular Forests; [8]MDS = Forestry Development Method.

Diversity

The Hill number of order q = 1 is easier to understand and interpret than Shannon's traditional index or entropy, which is not a measure of biological diversity and whose units are amounts of information (bytes), unlike its exponential, which are the number of expected or effective species with equal abundances (Chao and Jost, 2012). As in the analysis of the specific richness, the CIs of the estimators overlapped in the ^{0}D and ^{1}D comparisons, which suggests absence of significant difference between the observed and expected diversity of mammals in both management methods. The ^{2}D CIs (inverse of the Simpson index) did not overlap, so their expected diversity in the MDS was 2.5 times higher than in the MMOBI (Table 7). In all three orders of bird diversity, no significant differences were found (Table 8).

Table 7. Observed and expected diversity of mammal species calculated with non-parametric estimators in forest management lands of *Puebla,* Mexico

Setting	Shannon's entropy (IC 95%)[1]	Observed diversity[2]			Expected diversity[2]		
		^{0}D	^{1}D	^{2}D	^{0}D	^{1}D	^{2}D
Total	2.19 (2.04-2.33)	13 (10.55-15.45)	8.39 (7.26-9.53)	7.20 (6.23-8.18)	14.49 (5.39-23.59)	8.90 (7.60-10.20)	7.58 (6.50-8.66)
MMOBI[3]	1.67 (1.16-2.18)	10 (7.02-12.98)	4.38 (2.44-6.32)	2.59 (1.40-3.78)	14.06 (0.96-27.16)	5.30 (2.71-7.89)	2.70 (1.35-4.05)
MDS[4]	2.09 (1.72-2.47)	9 (6.54-11.46)	6.81 (5.20-8.42)	5.92 (4.54-7.29)	13.38 (4.82-21.94)	8.11 (5.70-10.53)	6.82 (5.00-8.65)

[1]IC = Confidence interval at 95 %, upper and lower limits; [2]Estimated and expected diversity (effective species) = ^{0}D (richness of species), ^{1}D (exponential of Shannon´s entropy), ^{2}D (Simpson's index reverse); [3]MMOBI = Mexican Management Method for Irregular Forests; [4]MDS = Forestry Development Method.

Table 8. Observed and expected diversity of bird species calculated with non-parametric estimators in forest management lands of *Puebla,* Mexico.

Setting	Shannon's entropy (IC 95%)[1]	Observed diversity[2]			Expected diversity[2]		
		^0D	^1D	^2D	^0D	^1D	^2D
Total	1.76 (1.52-1.99)	7 (5.44-8.56)	5.35 (4.21-6.50)	4.61 (3.48-5.75)	7.49 (4.36-10.62)	5.79 (4.49-7.09)	5.02 (3.65-6.40)
MMOBI[3]	-	-	-	-	-	-	-
MDS[4]	1.76 (1.53-2.00)	6 (5.00-7.00)	5.27 (4.29-6.25)	4.76 (3.66-5.86)	6.00 (4.39-7.63)	5.83 (4.71-6.96)	5.60 (4.08-7.12)

[1]IC = Confidence interval at 95 %, upper and lower limits; [2]Estimated and expected diversity (effective species) = ^0D (richness of species), ^1D (exponential of Shannon´s entropy), ^2D (Simpson's index reverse); [3]MMOBI = Mexican Management Method for Irregular Forests; [4]MDS = Forestry Development Method.

The main advantage of the use of camera-traps is that they are a reliable source that certifies the presence of the species in a specific place and time (Cadman and González, 2014). They are a non-invasive method of collecting data that cause minimal disturbance to the target species. They provide georeferenced photographic evidence that serves as an objective record of the visual characteristics of the animal that allow its identification even at the level of individuals. They can be left in the field for several weeks and, therefore, are ideal for the study of rare or elusive animals, such as Bobcat, and nocturnal or crepuscular, such as the Ringtail, which avoid humans or are difficult to study.

As well as there are advantages in the use of these devices, it is important to consider their limitations. Although the results show that the sample coverage (C) of mammals and birds was close to 100 %, which indicates that the inventory was complete, it is restricted to the type of identifiable organisms that the capacity of the cameras allows to capture, as the medium and large ones that are located in their detection cone. The probability of photographing small animals (mice and shrews), as well as those of arboreal habits, like the majority of the birds of the canopy and the Flying squirrel, *Glaucomys volans* (Linnaeus, 1758), although there is a record of their presence in the zone of study (Bueno *et al.,* 2015), is minimal. For this, it is necessary to use complementary methods, such as observation by point-counts, search for signs and tracks and capture with mechanical traps (Chávez-León, 2017). If the study focuses on a particular species, such as the Flying squirrel, the CTs would be placed in the places they frequent, such as branches of trees and with different settings.

The few studies carried out in Mexico on this subject do not clarify the contribution of sustainable forest management to the conservation of the diversity of wildlife. The results presented here indicate that the mammalian richness was similar between the two methods, although the inverse of the Simpson index (which gives more weight to the dominant species) in MDS was double that in MMOBI. Therefore, it could be said that the MDS possibly benefits the generalist species.

Other investigations present divergent conclusions. López-Becerra and Barrón-Sevilla, (2018), for example, with other methods recorded the greatest richness and diversity of birds in MDS, and concluded that the species can be conserved because the greater variety of treatments favors the heterogeneity of habitats compared to MMOBI. In contrast, Aguilar (2006) indicated that the more complex the structure of the vegetation (abundance and height of trees, shrubs and herbaceous) will increase the diversity of the avifauna, as in a mature forest without forestry intervention or in third thinning or selection. This suggests that the effect of forest management on fauna is very variable and specific for each site, functional group and species, intensity of treatment and other factors.

Conclusions

A reliable and standardized detection of mammals and some birds was accomplished through camera-traps, which generated a baseline for properties where two forest management methods are applied, since this is the first time these devices have been used in this region.

A representative measure was obtained of the diversity of two groups of terrestrial vertebrates and of human use in properties subject to silvicultural practices, considering the limitations of phototraping.

Although the observed and estimated diversity were not significantly different, it is necessary to plan this type of studies with an experimental design with sufficient repetitions (silvicultural or forestry treatments) and control (undisturbed forest), which would improve the estimates in similar environments in a context of forest management, for which the local and landscape scales should be considered.

Acknowledgements

This study was funded by the *Comisión Nacional Forestal* through the *Programa Nacional Forestal 2016* and the *Fideicomiso INIFAP 2017*. The chairmen boards of the *ARS* of *Iztaccíhuatl-Popocatépetl, S. C.* and of *Chignahuapan-Zacatlán, A. C*. allowed the entrance and provided the facilities to perform field work in their properties. The chairmen of *Forestería y Medio Ambiente, S. de R.L. de C.V (Forma)*, J. L. García Martínez (dead), and *Asesores en Manejo de Recursos Forestales, S.C.* (Asmarf), M. Morales Martínez, provided technical, material and logistic support. The technicians from *Forma*: I. Damián Santiago and M. Martínez Otero; and from Asmarf: L. Martínez Cuamayt, J. A. Luna Hernández, D. Guerrero Mote and D. Rodríguez Fernández carried out field work under the surveillance of the author. Three anonymous reviewers contributed with observations to improve the manuscript.

Conflict of interest

The author declares no conflict of interests.

Contribution by author

Gilberto Chávez-León: planning, development and supervision of the research study; structure, taxonomic determination, interpretation of results, design, drafting and review of the manuscript.

References

Aguilar G., I. 2006. Efectos de técnicas de manejo forestal sobre la estructura y comunidad de aves en un bosque templado. Tesis de Maestría. Centro de Investigación en Ecosistemas, Universidad Nacional Autónoma de México. México, D.F., México. 67 p.

Asesores en Manejo de Recursos Forestales (Asmarf). 2015. Estudio de cuenca de abasto para la región Chignahuapan-Zacatlán, Puebla. Conafor, Zapopan, Jalisco, México. 217 p. http://www.conafor.gob.mx (10 de diciembre de 2018).

Barrón S., J. A. 2016. Manual de mejores prácticas de manejo forestal para la conservación de la biodiversidad en la región centro de México. Programa de las Naciones Unidas para el Desarrollo y Comisión Nacional Forestal. Zapopan, Jal., México. 55 p.

Bötsch, Y., Z. Tablado, D. Scherl, M. Kéry, R. F. Graf and L. Jenni. 2018. Effect of recreational trails on forest birds: human presence matters. Frontiers in Ecology and Evolution 6(175): 1-10. doi: 10.3389/fevo.2018.00175.

Bueno C., A., N. Gil F., U. Velázquez C., C. Olivera Á. y A. G. Colodner Ch. 2015. Nuevos registros de la ardilla voladora (*Glaucomys volans*) en Puebla: implicaciones de su presencia en áreas de aprovechamiento forestal. Acta Zoológica Mexicana 31(2): 337-340. doi: 10.21829/azm.2015.312997.

Burton, A. C., E. Neilson, D. Moreira, A. Ladle, R. Steenweg, J. T. Fisher, E. Bayne and S. Boutin. 2015. Wildlife camera trapping: a review and recommendations for linking surveys to ecological processes. Journal of Applied Ecology 52: 675–685. doi: 10.1111/1365-2664.12432.

Buxton, R. T., P. E. Lendrum, K. R. Crooks and G. Wittemyer. 2018. Pairing camera traps and acoustic recorders to monitor the ecological impact of human disturbance. Global Ecology and Conservation 16: 1-9. doi: 10.1016/j.gecco.2018.e00493.

Cadman, M. and A. González T. (eds.). 2014. Publishing camera trap data, a best practice guide. Global Biodiversity Information Facility. http://www.gbif.org/orc/?doc_id=6045 (29 de enero de 2019).

Ceballos, G. y G. Oliva. 2005. Los mamíferos silvestres de México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad - Fondo de Cultura Económica. México, D. F., México. 986 p.

Cervantes, F. A., C. Lorenzo, J. Vargas and T. Holmes. 1992. *Sylvilagus cunicularius*. Mammmalian Species 412:1-4.

Chao, A. and L. Jost. 2012. Coverage-based rarefaction and extrapolation: standardizing samples by completeness rather than size. Ecology 93: 2533-2547.

Chao, A. and L. Jost. 2015. Estimating diversity and entropy profiles via discovery rates of new species. Methods in Ecology and Evolution 6: 873-882. doi: 10.1111/2041-210X.12349.

Chao, A., N. J. Gotelli, T. C. Hsieh, E. L. Sander, K. H. Ma, R. K. Colwell and A. M. Ellison. 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. Ecological Monographs 84(1): 45-67. doi: 10.1890/13-0133.1.

Chao, A., K. H. Ma, T. C. Hsieh, and C. H. Chiu. 2015. Online Program SpadeR (Species-richness Prediction and Diversity Estimation in R). Program and User's Guide. http://chao.stat.nthu.edu.tw/wordpress/software_download/ (27 de noviembre de 2018).

Chao, A. and C. H. Chiu. 2016. Species richness: estimation and comparison. Wiley StatsRef: Statistics Reference Online. 1–26. doi: 10.1002/0471667196.ess5051.

Chapman, J. A., J. G. Hockman and M. M. Ojeda C. 1980. *Sylvilagus floridanus*. Mammalian Species 136:1-8.

Chávez, C., A de la Torre, H. Bárcenas, R. A. Medellín, H. Zarza y G. Ceballos. 2013. Manual de fototrampeo para estudio de fauna silvestre. El jaguar en México como estudio de caso. Alianza WWF-Telcel, Universidad Nacional Autónoma de México. México, D. F., México. 103 p.

Chávez-León, G. 2017. Establecimiento y operación de estaciones de monitoreo de fauna silvestre en predios bajo manejo forestal del estado de Puebla. Folleto Técnico Núm. 28. Cenid Comef, INIFAP. Ciudad de México, México. 76 p.

Chesser, R. T., K. J. Burns, C. Cicero, J. L. Dunn, A. W. Kratter, I. J. Lovette, P. C. Rasmussen, J. V. Remsen, Jr., D. F. Stotz, B. M. Winger and K. Winker. 2018. Check-list of North American Birds (online). American Ornithological Society. http://checklist.aou.org/taxa (1 de abril de 2019).

Comisión Nacional de Áreas Naturales Protegidas (Conanp). 2013. Programa de Manejo. Parque Nacional Iztaccíhuatl Popocatépetl. Comisión Nacional de Áreas Naturales Protegidas, Secretaría de Medio Ambiente y Recursos Naturales. México, D.F., México. 185 p.

Comisión Nacional Forestal (Conafor). 2018. Sistema de Certificación Forestal Mexicano (Sceformex). https://www.gob.mx/conafor/acciones-y-programas/certificacion-forestal-59242 (14 de noviembre de 2018).

Dunn, J. and J. Alderfer. 2011. National Geographic field guide to the birds of North America, 6th ed. Washington, DC USA. 574 p.

Escalante, P., A. M. Sada y J. Robles G. 2014. Listado de nombres comunes de las aves de México. 2a ed. UNAM, CIPAMEX. México, D. F., México. 39 p.

García A., N. y M. Schmidt. 2016. Sistema Nacional de Monitoreo de la Biodiversidad. Versión preliminar. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Ciudad de México, México. 206 p.

Hall, E. R. 1981. The mammals of North America. Vol. I, II. John Wiley and Sons. New York, NY USA. 1181 p.

Hernández P., E., R. Reyna H., G. Castillo V., M. Sanvicente L. y J. F. Moreira R. 2015. Fototrampeo de mamíferos terrestres de talla mediana y grande asociados a petenes del noroeste de la península de Yucatán, México. Therya 6(3): 559-573. doi: 10.12933/therya-15-290, ISSN 2007-3364.

Howell, S. and S. Webb. 1995. A guide to the birds of Mexico and Northern Central America. Oxford University Press. New York, NY USA. 851 p.

Jardel P., E. J. 2015. Criterios para la conservación de la biodiversidad en los programas de manejo forestal. Comisión Nacional Forestal y Programa de las Naciones Unidas para el Desarrollo. Zapopan, Jal., México. 126 p.

Jiménez M., F. J., M. C. López T., R. Mendoza C., M. A. Pineda M. y O. R. Rojas S. 2011. Aves en Puebla. *In*: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (Conabio). La biodiversidad en Puebla: estudio de estado. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Gobierno del Estado de Puebla, Benemérita Universidad Autónoma de Puebla. México, D. F., México. pp. 159-163.

Koprowski, J. L., A. Nieto M. de O., G. H. Palmer, N. Ramos L. and R. M. Timm. 2017. *Sciurus aureogaster* (Rodentia: Sciuridae). Mammalian Species 49:81-92.

Lindenmayer, D. B. and J. F. Franklin. 2002. Conserving forest biodiversity: a comprehensive multiscaled approach. Island Press. Washington, DC USA. 511 p.

Lindstedt, S. L., B. J. Miller and S. W. Buskirk. 1986. Home range, time, and body size in mammals. Ecology 67: 413-418. doi: 10.2307/1938584.

López-Becerra, J. L. y J. A. Barrón-Sevilla. 2018. Diversidad de aves en un bosque bajo manejo forestal en la Sierra Norte de Puebla, México. Huitzil, Revista Mexicana de Ornitología 19(2):168-179. doi: 10.28947/hrmo.2018.19.2.338.

Martínez V, J., R. M. González M., M. C. López T. y A. G. Colodner C. 2011. Mamíferos. *In*: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (Conabio). La biodiversidad en Puebla: estudio de estado. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Gobierno del Estado de Puebla, Benemérita Universidad Autónoma de Puebla. México, D. F., México. pp. 163-169.

McManus, J. J. 1974. *Didelphis virginiana*. Mammalian Species 40:1-6.

Meek, P. D., G. Ballard, A. Claridge, R. Kays, K. Moseby, T. O'Brien, A. O'Connell, J. Sanderson, D. E. Swann, M. Tobler and S. Townsend. 2014. Recommended guiding principles for reporting on camera trapping research. Biodiversity and Conservation 23(9): 2321–2343. doi: 10.1007/s10531-014-0712-8.

Moreno, C. E., F. Barragán, E. Pineda y N. P. Pavón. 2011. Reanálisis de la diversidad alfa: alternativas para interpretar y comparar información sobre comunidades ecológicas. Revista Mexicana de Biodiversidad 82: 1249-1261.

Peralta M., J. V. y J. Martínez V. 2013. Biodiversidad mastofaunística de la Sierra Norte de Puebla, México. *In*: Sigala R., J. J. (coord.). Memorias del XXI Congreso Nacional de Zoología 2013. Universidad Autónoma de Aguascalientes, 4 al 8 de noviembre de 2013. Aguascalientes, Ags., México. pp. 719-723.

Ramírez P., J., N. González R., A. L. Gardner and J. Arroyo C. 2014. List of recent land mammals of Mexico, 2014. Special Publications, Museum of Texas Tech University. 63: 1-69.

Rodewald, P. (ed.). 2015. The birds of North America. Cornell Laboratory of Ornithology, Ithaca, NY. https://birdsna-org.bnaproxy.birds.cornell.edu (14 de enero de 2019).

Rowcliffe, J. M. 2017. Key frontiers in camera trapping research. Remote Sensing in Ecology and Conservation 3(3): 107–108. doi: 10.1002/rse2.65.

Schenker, N. and J. F. Gentleman. 2001 On judging the significance of differences by examining the overlap between confidence intervals. The American Statistician 55(3): 182-186. doi: 10.1198/000313001317097960.

Schulenberg, T. S. (ed.). 2019. Neotropical birds online. Cornell Lab of Ornithology, Ithaca, NY, USA. https://neotropical.birds.cornell.edu/Species-Account/nb/home (14 de enero de 2019).

Secretaria de Medio Ambiente y Recursos Naturales (Semarnat). 2010. Norma Oficial Mexicana NOM-059-ECOL-2010, Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio - Lista de especies en riesgo. Secretaría de Medio Ambiente y Recursos Naturales. Diario Oficial de la Federación (Segunda Sección). jueves 30 de diciembre de 2010. México, D.F., México. 77 p.

Servicios y Consultoría Ambiental y Forestal (SyCAF). 2016. Estudio de cuenca de abasto – Región Izta Popo. Estados de Puebla y Tlaxcala. Conafor. Zapopan, Jalisco, México. 216 p. www.conafor.gob.mx (10 diciembre de 2018).

Silverio O., L. y O. E. Ramírez B. 2014. Registro de la presencia de mamíferos medianos en dos zonas del municipio de Cuetzalán, en la Sierra Norte de Puebla. Theria 5(3): 855-860. doi: 10.12933/therya-14-16.

TEAM Network. 2011. TEAM Network sampling design guidelines. Tropical Ecology, Assessment and Monitoring Network, Science and Knowledge Division, Conservation International. Arlington, VA USA. 36 p.

Tobler, M. W., S. E. Carrillo-Percategui, R. Leite Pitman, R. Mares and G. Powell. 2008. An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. Animal Conservation 11: 169–78. doi: 10.1111/j.1469-1795.2008.00169.x.

Valdez, R. 2014. Perspectivas del manejo y la conservación de fauna en México. *In*: Valdez, R. y J. A. Ortega S. (eds.). Ecología y Manejo de Fauna Silvestre en México. Biblioteca Básica de Agricultura, Colegio de Postgraduados. Montecillo, Texcoco, Edo. de Méx., México. pp. 21-40.

Van Perlo, B. 2006. Birds of Mexico and Central America. Princeton University Press. Princeton, NJ USA. 336 p.

Vázquez, J., V. Farías, L. Rodríguez M., A. Bautista, G. Palacios R. y M. Martínez G. 2013. Ámbito hogareño del conejo mexicano (*Sylvilagus cunicularius*) en un bosque templado del centro de México. Therya 4(3): 581-595. doi: 10.12933/therya-13-144.

Villa R., B. y F. A. Cervantes. 2003. Los Mamíferos de México. Instituto de Biología, UNAM, y Grupo Editorial Iberoamérica. México, D. F., México. 140 p.