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CANIS LATRANS ECOLOGY AND MAMMALS DIVERSITY AT RANCHO EXPERIMENTAL TESEACHI, NAMIQUIPA, CHIHUAHUA, MEXICO

POR:

BIOL. FERNANDO ÁLVAREZ CÓRDOVA

TESIS PRESENTADA COMO REQUISITO PARA OBTENER EL GRADO DE MAESTRO EN CIENCIAS CON ÁREA MAYOR EN RECURSOS NATURALES

Ecología de *Canis latrans* y diversidad de mamíferos del Rancho Experimental Teseachi, Namiquipa, Chihuahua, México. Tesis presentada por el Biólogo Fernando Álvarez Córdova como requisito parcial para obtener el grado de Maestro en Ciencias, ha sido aceptada y aprobada por:

Ph. D. Carlos Ortega Ochoa
Director de la Facultad de Zootecnia y Ecología

D. Ph. Agustín Corral Luna
Secretario de Investigación y Posgrado

Ph. D. Iván Adrián García Galicia
Coordinador Académico

Ph. D. Jesús Abraham Fernández Fernández
Presidente

05-JUNIO-2020
Fecha

Comité:

Ph. D. Jesús Abraham Fernández Fernández
Dra. Angela Andrea Camargo Sanabria
D. Ph. Mieke Titulaer
M. en C. Juan Carlos Ontiveros Chacón

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CURRICULUM VITAE

El autor nació el 29 de diciembre de 1993 en Zapopan, Jalisco, México.

2009 - 2012	Estudios de Educación Media Superior en Preparatoria N.2 de la Universidad Autónoma de Zacatecas (UAZ)
2012 - 2016	Estudios profesionales en la Carrera de Licenciado en Biología, egresado de la Unidad Académica de Ciencias Biológicas de la Universidad Autónoma de Zacatecas (UAZ)
2014 – 2017	Técnico en Atención Médica Prehospitalaria. Protección Civil y Bomberos del Estado de Zacatecas
2016-2018	Miembro de la Asociación Mexicana de Mastozoología A. C.
2018 - 2020	Estudiante de Maestría en Ciencias con Área Mayor en Recursos Naturales y línea en Monitoreo de Recursos Naturales, Facultad de Zootecnia y Ecología, Universidad Autónoma de Chihuahua.

RESUMEN GENERAL

ECOLOGÍA DE *CANIS LATRANS* Y DIVERSIDAD DE MAMÍFEROS DEL RANCHO EXPERIMENTAL TESEACHI, NAMIQUIPA, CHIHUAHUA, MEXICO

POR:

BIÓL. FERNANDO ÁLVAREZ CÓRDOVA

Maestría en Ciencias en Recursos Naturales

Secretaría de Investigación y Posgrado

Facultad de Zootecnia y Ecología

Universidad Autónoma de Chihuahua

Presidente: Ph. D. Jesús Abraham Fernández Fernández

El monitoreo de las poblaciones naturales es importante para generar conocimiento sobre las tendencias de las especies en espacio y tiempo. Además, permite conocer la diversidad y ecología en diferentes ecosistemas. La ecología de *Canis latrans* ha sido estudiada en diferentes partes de la República Mexicana. Sin embargo, para el estado de Chihuahua no existe información sobre índices de abundancia poblacional, hábitat, dieta y su papel en el ecosistema. Específicamente para el Rancho Experimental Teseachi (RET) Namiquipa, Chihuahua, se desconoce la diversidad de mamíferos y ecología del coyote. Tres objetivos fueron establecidos para conocer la diversidad de mamíferos y ecología de *C. latrans* en el RET; (1) identificar la diversidad taxonómica de mamíferos medianos y grandes, a través de tres técnicas de muestreo, (2) estimar y comparar los índices de abundancia, selección de hábitat y dieta de *C. latrans*, (3) identificar endoparásitos de *C. latrans* a través de excretas recolectadas. El

estudio se llevó a cabo de abril de 2018 a marzo de 2019 (dos noches / mes) en bosque de pino-encino (BPE) y pastizal mediano abierto (PMA). Dieciséis especies de mamíferos medianos y grandes se registraron en el área, lo que representa el 12% de la mastofauna del estado. Se encontró mayor índice de abundancia relativa (RAI) de coyote en BPE (0.30) vs PMA (0.23). Sin embargo, no hubo indicios de que los coyotes seleccionen BPE sobre PMA ($\chi 2 = 2.96$, $P > 0.05$). Tres nemátodos del género *Physaloptera* sp. fueron encontrados en las excretas de coyote, reportándose por primera vez para el estado. Este estudio aporta la primera información sobre la ecología del coyote y la diversidad de mamíferos en el área, siendo pionero para posteriores investigaciones.

ABSTRACT

CANIS LATRANS ECOLOGY AND MAMMALS DIVERSITY AT RANCHO EXPERIMENTAL TESEACHI, NAMIQUIPA, CHIHUAHUA, MEXICO

BY:

FERNANDO ÁLVAREZ CÓRDOVA

Monitoring natural populations is important for the generation of knowledge about the trends of the species in space and time. In addition, it provides information on the diversity and ecology in different ecosystems. Coyote ecology has been studied in different parts of Mexican Republic. However, for the state of Chihuahua, there is no information on population trends, habitat, diet, and their role in the ecosystem. Specifically at RET Namiquipa, Chihuahua, the diversity of mammals and ecology of coyote is unknown. Three objectives were established to know the diversity of mammals and the ecology of *C. latrans*; (1) identify the taxonomic diversity of medium and large mammals, (2) estimate and compare the index of abundance, habitat selection and diet of *C. latrans,* and (3) identify endoparasites of *C. latrans* through collected scats. The study was carried out from april 2018 to march 2019 (two nights / month) in pine-oak forest and open medium grassland. Sixteen species of medium and large mammals were recorded, representing 12% of the state's fauna. Higher RAI of coyote was found in POF (0.30) vs OMG (0.23). However, there was no indication that coyotes select for POF over OMG ($\chi 2 = 2.96$, $P > 0.05$). Three nematodes belonging to the genus *Physaloptera* sp. were reported in coyote scats for first time to the state. This study provides the first information on the ecology of the coyote and the diversity of mammals in the area, being a pioneer for further research.

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GENERAL INTRODUCTION

Population monitoring is important for the understanding of population trends of a given species in space and time, and the factors governing these trends. Population monitoring consist of observation, and the periodical record of changes in populations status and tendencies of the organisms in a given territory (López-González *et al*., 2011).

The importance of population monitoring is to understand when, how and why species and ecosystems change in a certain place and time (Chediack, 2009). This can be visualized in two ways; one is on a large scale, where species migrate from one place to another due to abiotic conditions, so they are forced to change their geographical distribution, and on a small scale, where they modify the movement in the geographical space where they live, due to changes in food sources, predation, reproduction, and parental care (Servín, 2000; Marín-Sánchez *et al*., 2015).

There are a variety of techniques for monitoring populations of medium or large mammals, the most frequently used are camera-traps, track prints, scat recollection, capture and recapture, olfactory stations, and radiotelemetry (Hernández *et al.*, 1993; Arévalo, 2001; Zúñiga *et al*., 2004; López-González *et al*., 2011; Gallina-Tessaro y González, 2011). These techniques allow to investigate different ecological aspects of taxonomic groups that are difficult to observe such as carnivores.

Carnivores are an abundant and widespread taxonomic group. However, in particular for coyotes (*Canis latrans* Say, 1823), there are no studies on their

distribution, behavior, abundance, habitat, diet, and the role they play in the ecosystems of Chihuahua, Mexico. Coyotes are important because of the ecological role they play in the ecosystem as a biological controller of different species of wildlife (rodents and lagomorphs). However, the coyote also hunts domestic animals ocasionally or animals of hunting interest that provide economic losses to the livestock sector (Hernández y Laundré, 2014.) This work aims to generate relevant information about the ecology of the coyote in Chihuahua.

Three objectives were established for this project. The first was to generate a taxonomic check list of medium and large mammals through three sampling techniques (cameras traps, scent stations and tracks). The second was to estimate and compare relative abundance index, diet and habitat selection of *C. latrans*, in medium open grassland (OMG) and pine-oak forest (POF), through scent stations. The two vegetation were selected, due to the previous information of the ranch staff and personal observations of the presence of coyotes in both areas. The third goal was to identify if there is any kind of parasite in *C. latrans* scats, in order to enrich the information related to their diet and function as host of endoparasites. All research was carried out at Rancho Experimental Teseachi.

LITERATURE REVIEW

Orden Carnivora

The Order Carnivora comprises a group of species with a cosmopolitan distribution that evolved over 65 million years, showing a series of anatomical modifications for hunting and a meat diet. Carnivores are characterized by a muscular and flexible body, presence of a molar and premolar teeth in the form of a blade, absence of a clavicle for better locomotion added to a digitated posture in canids and felids, and plantigrad in ursids and procyionids (Sánchez, 1972; Wallace *et al*., 2010), and a well developed sense of sight, hearing, and smell.

These characteristics have allowed them evolutionary success and a place in the upper part of the food chain (Wallace *et al*., 2010). Studies on carnivore evolution have divided them into two large groups: Feliformes, comprising species of the families Nandiniidae, Felidae, Herpestidae, Hyaenidae, Viverridae and Eupleridae; and Caniformes including species of the Canidae, Ursidae, Phocidae, Odobenidae, Otariidae, Ailuridae, Mephitidae, Procyonidae and Mustelidae families (Sánchez, 1972; Garrido y Arribas, 2008; Wallace *et al*., 2010).

Evolution of *Canis* Linnaeus, 1758

The Family Canidae belongs to the Order Carnivora. Currently 36 species of canids are recognized worldwide, distributed on all continents but Antarctica. The first taxa of canids originated during the Eocene and were restricted to North America until the end of the Miocene, a period in which they spread to Eurasia through the Bering Strait. Canids arrived to South America 2.4 million years ago in the Pliocene (Hall, 1981; Vaughan y Rodríguez, 1986; Garrido y Arribas, 2008; Wallace *et al*., 2010).

The genus *Canis* groups medium and large modern canids represented today by wolves, coyotes and jackals (Garrido y Arribas, 2008). The oldest known fossil of the coyote *Canis latrans* was found in the Pleistocene in the Cumberland Cave, in the state of Maryland, USA (Bekoff, 1977).

Characteristics of *Canis latrans*

Canis latrans is one of eight species recognized within the genus *Canis*. It is a predator with a high degree of adaptation, distributed in different types of environments such as deserts, bushes, grasslands, pine forests, tropical forests and human-disturbed environments (Bekoff y Gese, 2003). Its distribution ranges from northern Alaska to Panama (Bekoff, 1977). Nineteen subspecies are currently recognized, of which 10 are found in Mexico (Marín-Sánchez *et al*., 2015).

The reproductive success among populations, and the ability to disperse and modify their diet according to available resources, has allowed the coyote to have a high abundance and a wide distribution throughout the American continent. Although it is a carnivorous organism, it easily adapts to changing a environment by turning to an omnivorous diet (Bekoff, 1977; Hall, 1981; Vaughan, 1983).

It has been hypothesized that its wide distribution and population increase is due to the elimination of the grey wolf (*Canis lupus*) in large portions of the original distribution of the coyote, since both canids were distributed sympatrically and competed for food. In addition to *C. lupus* was known to prey on *C. latrans* (Hall, 1981; Vaughan y Rodríguez, 1986).

Canis latrans is a medium-sized organism, with a length varying from 1 to 1.35 meters (m), with a weight ranging between 7 and 20 kilograms (kg). It can live up to 14.5 years in the wild and is generally monogamous. Females have a gestation period of 63 days with a litter of 6 to 8 offspring. Fur will depend on the region where it is found; coyotes from wooded areas have dark, thick and abundant fur, compared to populations of arid areas where pelage is short, light and less abundant (Bekoff, 1977; Marín- Sánchez *et al*., 2015).

The coyote is an important regulator of mammal populations like rodents and lagomorphs. In addition, they disperse the seeds consumed from their herbivorous diet, fulfilling a relevant role in the regeneration of pine-oak forests (Servín y Huxley, 1993, 1995). Therefore, any variation in the size of its population has an effect on the communities of predators and prey.

Various studies concerning abundance, home range, and diet of *C. latrans* have been carried out on the American continent. In Mexico, several authors have investigated its abundance (Monroy-Vilchis y Velázquez, 2003), home ranges (Hernández, 1990; Hernández *et al*., 1993; Servín y Huxley, 1993 y 1992; Huxley y Servín, 1995; Carreón, 1998), and its biology using techniques such as radiotelemetry (Servín y Huxley, 1993, 1995; Servín, 2000; Hidalgo-Mihart *et al*., 2001 y 2004). Based on these studies, it is estimated that Its home range fluctuates from 3 km² to 67 km², depending on sex and life stage (Hernández, 1990; Hernández *et al*., 1993; Huxley y Servín, 1995; Hidalgo-Mihart *et al*., 2004).

However, several researchers have proposed that scent stations are a simple, low-cost, and effective technique for detecting changes in seasonal and annual trends in carnivore abundance (Linhart y Knowlton,1975; Roughton y

Sweeny, 1982; Conner *et al*.,1983; Gallina-Tessaro y González, 2011). This technique consists of a circle 1 meter in diameter, where the vegetation is removed. sand or fine soil is placed creating a layer on the ground, and a bait (egg, chicken, coyote urine) is placed on it.

In these stations the visits are recorded through the tracks of the organisms that visited them (Linhart y Knowlton, 1975). It is a technique standardized by Linhart y Knowlton (1975), improved by Roughton y Sweeny (1982), validated through comparison with other techniques by Conner *et al*. (1983). And used by different researcher (Sargeant *et al.,* 2003; Monroy-Vilchis y Velázquez, 2002; Ponce *et al*., 2005).

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CHAPTER I. MEDIUM AND LARGE MAMMALS (MAMMALIA) OF RANCHO EXPERIMENTAL TESEACHI IN NAMIQUIPA, CHIHUAHUA, MÉXICO

RESUMEN

MAMÍFEROS MEDIANOS Y GRANDES (MAMMALIA) DEL RANCHO EXPERIMENTAL TESEACHI EN NAMIQUIPA, CHIHUAHUA, MEXICO

POR:

BIÓL. FERNANDO ÁLVAREZ CÓRDOVA

Maestría en Ciencias en Recursos Naturales

Secretaría de Investigación y Posgrado

Facultad de Zootecnia y Ecología

Universidad Autónoma de Chihuahua

Presidente: Ph. D. Jesús Abraham Fernández Fernández

El orden Mammalia es uno de los taxones terrestres más notables del mundo. Documentar su diversidad permite a los manejadores de tierras, agencias gubernamentales e instituciones académicas desarrollar planes de manejo y conservación. El objetivo de este estudio fue identificar la diversidad taxonómica de los mamíferos presentes en el Rancho Experimental Teseachi en hábitats de bosque de pino-encino y pastizal mediano abierto, ubicados al noroeste de Chihuahua. Se realizaron muestreos mensuales con transectos lineales de cinco km en las dos coberturas de vegetación, donde se colocaron cámaras trampa, estaciones olfativas y se buscaron rastros. Se registraron dieciséis especies de mamíferos medianos y grandes en el área, lo cual representa el 12% de la diversidad del estado. La mayor diversidad se encontró en bosque de pino-encino. La implementación de tres técnicas diferentes de muestreo, permitió la documentación de la diversidad de mamíferos en el área.

ABSTRACT

MEDIUM AND LARGE MAMMALS (MAMMALIA) OF RANCHO EXPERIMENTAL TESEACHI IN NAMIQUIPA, CHIHUAHUA, MÉXICO

BY:

FERNANDO ÁLVAREZ CÓRDOVA

The order Mammalia is one of the most remarkable land taxa in the world. Documenting its diversity allows land managers, government agencies and academic institutions to develop management and conservation plans. The objective of this study was to identify the taxonomic diversity of mammals present in Rancho Experimental Teseachi in pine-oak forest and open medium grassland habitats, located in northwestern Chihuahua. Monthly samplings were made with lineal transects of five kilometers in two vegetation coverts where camera-traps and scent-stations were placed and tracks were searched. Sixteen species of medium and large mammals were recorded in the area, representing 12% of the state's diversity. The greatest diversity was found in pine-oak forest. The implementation of three different sampling techniques allowed the records of mammal diversity in the area.

INTRODUCTION

Mammals, probably are the most outstanding terrestrial taxa, they have external and internal characteristics that set them apart from other groups. They are characterized by a high metabolic rate, an ability to increase their metabolism through periods of activity, and to maintain their constant temperature, among other characteristics (Sánchez-Córdero, 2014; Wallace *et al.,* 2010). Medium and large mammals are essential components of the biodiversity of an area, contributing decisively to ecosystem functioning through pollination, seed dispersal and the elimination of old and sick individuals (Sánchez-Córdero *et al.,* 2014).

Medium and large mammals are a charismatic group defined as any mammal whose weight is more than 500 g (Ceballos *et al.,* 2002; Hoffmann *et al.,* 2010). This group of mammals has been studied with a wide array of techniques, the most common and used in biodiversity studies are camera-traps, search of tracks, traces and scats, capture and recapture, olfactory stations and radiotelemetry (Arévalo, 2001; Zúñiga *et al.,* 2004; López-González *et al.,* 2011; Gallina-Tessaro y Lopez-González, 2011).

These techniques allows to collect data in order to investigate different ecological aspects of low density, nocturnal, and difficult to observe groups such as carnivores but also to document diversity in different ecosystems allowing wildlife managers to generate conservation and management plans. For the Mexican Republic, 564 species of mammals have been registered, representing 10.4% of the world total diversity (Anderson, 1972; Ramírez-Pulido *et al.,* 2005;

López-González y García-Mendoza, 2012). Chihuahua is the largest state in the Mexican Republic with an approximate area of 247, 460 km^2 (INEGI, 2005).

In Chihuahua, 133 species of mammals have been found distributed in four large ecological regions as the quebradas, sierra, valleys and arid lands (Lopéz-González y García-Mendoza, 2012). According to López-González y García-Mendoza (2012), Chihuahua harbors 32 species of medium and large mammals, representing almost 25% percent of the total mammalian fauna of the state.

However, the local mammal fauna of the Rancho Experimental Teseachi is not documented. The objective was to identify the taxonomic diversity of medium and large mammals in the study area through the implementation of different sampling techniques. The information generated might be use by local authorities and Rancho Experimental Teseachi managers to carry out conservation and management plans.

MATERIALS AND METHODS

Study Area

The main goal of the Rancho Experimental Teseachi is teaching, research and transfer of technology in animal science and natural resources. It is located 210 km northwestern direction from the capital of the state of Chihuahua (28° 53' 44'N, 107° 27' 22'W, 2,250 masl; Figure 1), among the municipalities of Bachiniva, Namiquipa and Guerrero (Espinoza y Quintana, 2013; Álvarez-Córdova *et al.,* 2019).

This site has an approximate area of 12,300 ha. The landscape is shaped by low hills and high mountain ranges displaying a mixture of open medium grasslands, arboreal pasture grasses, oak chaparral, pine-oak forest and temperate forest (COTECOCA, 1978, Álvarez-Córdova *et al.,* 2019).

Data Collection and Identification of Mammals

Three sampling techniques were used to record medium and large mammals: 1) Fixed scent stations (SS; Table 1) (1.00 m in diameter, baited with chicken and sardine) separated by 500 m between each one, covering a five km transect in open medium grassland and pine-oak forest, 2) randomly-set camera traps (CT; Table 1) were placed in different sites (Moultrie A-30) with a separation of 500 m between each one and at an average height of 45 cm, and 3) search and collection of tracks in both area (T) (Arévalo, 2001; Zúñiga *et al.,* 2004; López-González *et al.,* 2011; Gallina-Tessaro y Lopez-González, 2011).

Fieldwork was carried out from April 2018 to March 2019. Each SS were activated during the afternoon and checked the next day (two nights / month).

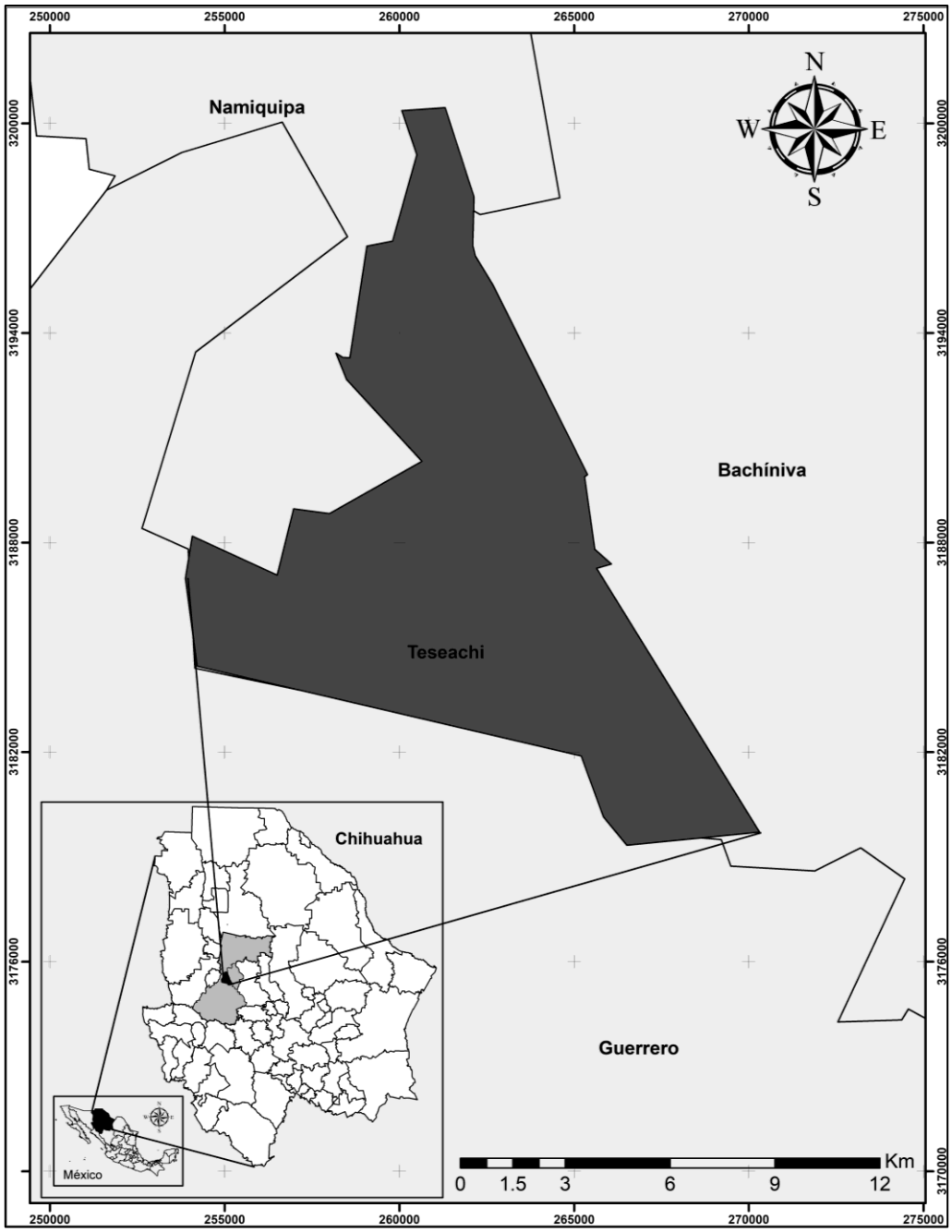


Figure 1. Geographic location of the Rancho Experimental Teseachi, Namiquipa, Chihuahua, México.

Table 1. Geographic coordinates and elevation of camera traps placed at Rancho Experimental Teseachi, Namiquipa, Chihuahua, Mexico

Camera trap	Geographic Coordinates	Elevation (m.a.s.l.)
Cam-01	N 28°46´32.6´´	2,191
	W 107°27´33.4´´	
Cam-02	N 28°46´42.8´´	2,170
	W 107°27´45.9	
Cam-03	N 28°47´01.2´´	2,138
	W 107°28´12.5´´	
Cam-04	N 28°47´18.8´´	2,121
	W 107°28´36.6´´	
Cam-05	N 28°47´30.9´´	2,124
	W 107°28´49.9´´	
Cam-06	N 28°27´39.9´´	2,110
	W 107°29´01.3´´	
Cam-07	N 28°47´49.5´´	2,107
	W 107°29´02.1´´	
Cam-08	N 28°52'49.3"	1,876
	W 107°27'08.5"	

The CT were left active for three days (day and night), and the tracks were search and collected at the time of setting the scent stations and checking the trap cameras. Mammals registered by the three techniques were taxonomically identified following Aranda (2015).

Once the records were obtained, a database was created and a curve of species accumulation was plotted (EstimateS 9.10). Also alpha and beta diversity were measured. The curves were created in order to recognize the sampling effort during the study and to know if more species in the area could exist (Gallina-Tessaro and Lopez-González, 2011; Jiménez-Valverde y Hortal, 2003).

RESULTS AND DISCUSSION

A total of 16 species of medium and large mammals were recorded between the two vegetation covers for the Rancho Experimental Teseachi (50% of medium and large mammals reported for Chihuahua by López-González and García-Mendoza [2014]; Table 2). Not a single species is endemic or listed in the threatened species lists of the IUCN or the Norma Oficial Mexicana of the Mexican Government.

The vegetation cover presenting the greatest number of species was pine-oak forest with the totality of the 16 species registered in the study (α = 16; Table 2). In open medium grassland cover only nine species were recorded (*Canis latrans, Urocyon cinereoargenteus, Lynx rufus, Odocoileus virginianus, Conepatus leuconotus, Sylvilagus* cf. f*loridanus, Lepus californicus, Otospermophilus* cf. *variegatus* and *Pecari tajacu* (α=9; Table 2, Figure 2, Figure 3). A replacement rate of seven species was found between both ecosystems (β=7), which was only found in pine-oak forest (diversity beta).

López-González and García-Mendoza (2014) divided the state in four ecological regions (quebradas, sierras, valleys and arid). Four of the species found in this study can be found in all the areas; eight species in three; and four species in two areas (Table 2).

The species with the highest number of records in scent stations in our study was *C. latrans* (n = 109), followed by *U. cinereoargenteus* (n = 80) and *P. tajacu* (n = 16). On the other hand, species such as *N. narica*, *P. lotor*, *U.*

Table 2. Taxonomic list of the medium and large mammals recorded at Rancho Experimental Teseachi, Namiquipa, Chihuahua, Mexico

Taxa	Record method	NOM-059	IUCN	Endemism	Ecological regions
Order Lagomorpha					
Family Leporidae					
Black-tailed jackrabbit					
Lepus californicus (Gray, 1837)	SS, T	NP	LC	NE	S, V, A
Eastern cotontail					
Sylvilagus cf. f*loridanus* (Allen, 1890)	SS, CT	NP	LC	NE	S, V, A
Order Rodentia					
Family Sciuridae					
Rock squirrel					
Otospermophilus cf. *variegatus* (Erxleben, 1777)	SS, CT	NP	LC	NE	Q, S, V, A

Order Carnivora					
Family Felidae					
Bobcat					
Lynx rufus (Schreber, 1777)	SS, CT, T	NP	LC	NE	Q, S, V
Cougar					
Puma concolor (Linnaeus, 1771)	SS, CT, T	NP	LC	NE	S, V, A
Family Canidae					
Coyote					
Canis latrans (Say, 1823)	SS, CT, T	NP	LC	NE	S, V, A
Gray fox					
Urocyon cinereoargenteus (Schreber, 1775)	SS, CT, T	NP	LC	NE	Q, S, V, A
Family Ursidae					
Black bear					
Ursus americanus (Pallas, 1780)	T	NP	LC	NE	S, V
Family Mephitidae					

American hog-nosed skunk *Conepatus leuconotus* (Lichtenstein, 1832)	SS, CT, T	NP	LC	NE	S, V
Hooded skunk *Mephitis macroura* (Lichtenstein, 1832)	SS, CT, T	NP	LC	NE	Q, S, V, A
Striped skunk *Mephitis mephitis* (Schreber, 1776)	SS, CT, T	NP	LC	NE	S, V, A
Western spotted skunk *Spilogale gracilis* (Merriam, 1890)	SS, CT, T	NP	LC	NE	Q, S, A
Family Procyonidae					
White-nosed coati *Nasua narica* (Linnaeus, 1766)	SS, CT	NP	LC	NE	Q, S
Raccoon *Procyon lotor* (Linnaeus, 1758)	T	NP	LC	NE	Q, S, V

Order Artiodactyla					
Family Tayassuidae					
Collared peccari					
Pecari tajacu (Linnaeus, 1758)	SS, CT, T	NP	LC	NE	Q, S
White-tailed deer					
Odocoileus virginianus	SS, CT, T	NP	LC	NE	Q, S, V, A
(Zimmermann, 1780)					

Taxonomic arrangement follows taxonomic proposal by Ramírez-Pulido *et al.* (2014) except for *Pecari tajacu* (*Collared peccary*), which follows Wilson and Reeder (2005). Record method: Scent station = SS, Camera trap = CT, Tracks = T. Categories of national protection level according to the NOM-ECOL 059-2010 (SEMARNAT, 2010): No protection = NP. Categories of global protection level according to the International Union for Conservation of Nature (IUCN, 2015): Least Concern = LC. Endemism was defined following Ceballos *et al.* (2005): No endemic = NE. Ecological regions classification follows López-González and García-Mendoza (2014): Quebradas = Q, Sierra = S, Valleys = V, Arid = A.

Figure 2. A. *Lepus californicus,* Black-tailed jackrabbit. B. *Sylvilagus floridanus*, Eastern cottontail. C. *Otospermophilus variegatus*, Rock squirrel. D. *Lynx rufus*, Bobcat. E. *Puma concolor*, Cougar. F. *Canis latrans*, Coyote. G. *Urocyon cinereoargentatus*, Gray fox. H. *Ursus americanus*, Black bear.

Figure 3. A. *Conepatus leuconotus*, Hog-nosed skunk. B. *Mephitis macroura*, Hooded skunk. C. *Mephitis mephitis*, Stripped skunk. D. *Spilogale gracilis*, Western spotted skunk. E. *Procyon lotor*, Raccon. F. *Nasua nasua*, White-nosed coati. G. *Pecari tajacu*, Collared peccary. H. *Odocoileus virginianus*, White-tailed deer.

americanus and *S. gracilis*, were recorded as unique events during sampling (Graph 1). The species accumulation graphs showed a curve tending towards an asymptote for OMG, however, the opposite is for POF, where the curve continues to increase, suggesting that other species may still be recorded in the area (Graph 2).

In the pine-oak forest, a track of what possibly belongs to *Herpailurus yagouaroundi* was found. However, due to the lack of enough evidence or information about this species in the state and because it was only a single record, the record was discarded until full evidence is compiled.

Annotated List

Records lack sex/age information because all pictures were compiled from camera traps; the acronym UACH-CF = Universidad Autónoma de Chihuahua, Colección de Fotografías; all geographic coordinates and elevation are on Table 1; all recorded species are not endemic to Mexico or Chihuahua.

Order Lagomorpha

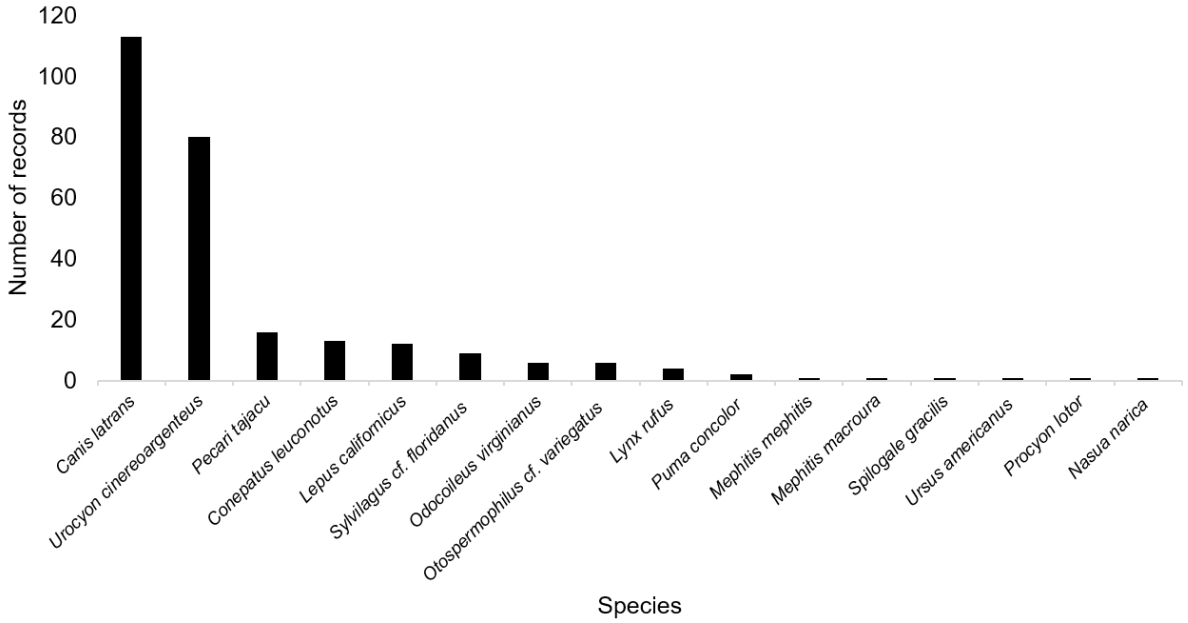
Family Leporidae

***Lepus californicus* (Gray, 1837)**

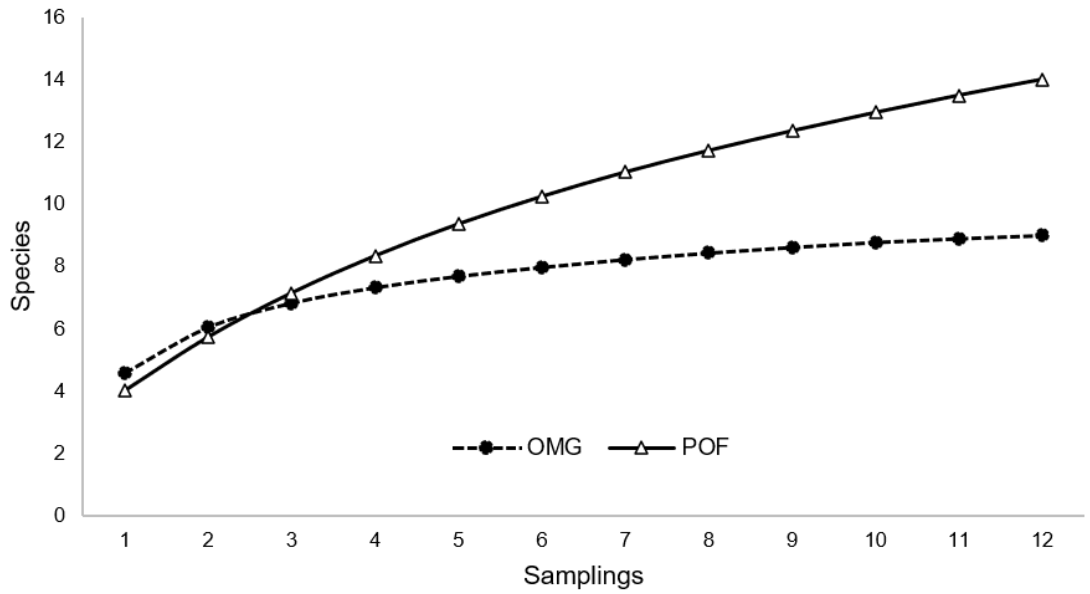
Black-tailed jackrabbit. Figure 2A.

Material examined. 12 records (tracks) in the SS. MEXICO, State of Chihuahua, Municipality of Namiquipa; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Sierras, Valleys and Arid; UACH-CF-XXX.

Identification. The second largest member of the genus in Chihuahua and the only species inhabiting the highlands of the Sierra Madre Occidental.



Graph 1. Number of records for medium and large mammals at Rancho Experimental Teseachi, Namiquipa, Chihuahua, México.



Graph 2. Species accumulation curves OMG vs POF for medium and large mammals at Rancho Experimental Teseachi, Namiquipa, Chihuahua, México.

Large black-tipped ears and hind feet distinguished it easily from *S. floridanus* in the area. It has a black line in the middle of the back reaching the tail, its sides are light brown mixed with gray hairs (Best, 1996).

Distribution. Central and western United States of America (USA); in Mexico, in the Baja California Peninsula, the Sonoran and Chihuahuan Deserts to Tamaulipas in eastern Mexico, through the Mexican Plateau to northern Tlaxcala in the Transmexican Volcanic Belt (TMVB) in central Mexico (Best, 1996).

Remarks. One of the two species of the genus *Lepus* of the region (López-González y García-Mendoza, 2014). *Lepus californicus* is frequently seen at night in the open areas of the ranch.

***Sylvilagus* cf. *floridanus* (Allen, 1890)**

Eastern cottontail. Figure 2B.

Material examined. 9 records (tracks) in the SS; 263 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa, 263 pictures, Cam 1 (23), Cam 2 (62), Cam 3 (9), Cam 4 (79), Cam 5 (2), Cam 6 (19), Cam 7 (51), Cam 8 (13); May, Jun., Aug., Oct., Nov. 2018, Jan., Mar. 2019; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Sierras, Valleys and Arid; UACH-CF-XXX.

Identification. The largest member of the genus in Chihuahua and the only species inhabiting the highlands of the Sierra Madre Occidental. A large, heavy-bodied rabbit, with a gray-brown coat, and a conspicuous white tail. The belly hair is white (Chapman *et al*., 1980).

Distribution. From southern Canada, through central, eastern USA and the Mexican highlands (pine, pine-oak forests) to Central America, and southern South America (Venezuela and Colombia; Chapman *et al*., 1980).

Remarks. In Chihuahua only two species of the genus *Sylvilagus* have been recorded (López-González y García-Mendoza, 2014) The eastern cottontail rabbit and the desert cottontail rabbit; the former inhabits forested areas (pine and pine-oak forests), and the second one inhabits grassland and desert areas.

Order Rodentia

Family Sciuridae

***Otospermophilus* cf. *variegatus* (Erxleben, 1777)**

Rock squirrel. Figure 2C.

Material examined. 6 records (tracks) in the SS; 228 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa, 228 pictures, Cam 2 (8 pictures), Cam 4 (27), Cam 7 (119), Cam 8 (74); June, July, Aug., Oct., Dec. 2018, Jan., Aug. 2019; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Quebradas, Sierras, Valleys and Arid; UACH-CF-XXX.

Identification. The only member of the genus in Chihuahua. A medium sized squirrel, with a mottled grayish brown coat and well-marked light-colored ring around their eyes. *O. variegatus* have long, hairy tails (Oaks *et al*., 1987).

Distribution. Central, southwestern USA, through most of northern and central Mexico to the TMVB (Oaks *et al*., 1987).

Remarks. Ten sciurids have been recorded in Chihuahua (López-González y García-Mendoza, 2014) but six of them are present in the Sierra

Madre Occidental. *Otospermophilus variegatus* is frequently seen near rocky habitat.

Order Carnivora

Family Felidae

***Lynx rufus* (Schreber, 1777)**

Bobcat. Figure 2D.

Material examined. 4 records (tracks) in the SS; 17 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa, 17 pictures, Cam 1 (6 pictures), Cam 3 (3), Cam 4 (8); coordinates; altitude/elevation m a.s.l.; 16 Jan. 1998; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Quebradas, Sierras, and Valleys; UACH-CF-XXX.

Identification. The only member of its genus in Mexico. A medium-sized cat with a short tail and red or gray on the dorsal part of its body, underparts are white with black spots. Ears with pointed tufts, and hair on sides of head is long (Lariviere y Walton, 1997).

Distribution. Southern Canada, the USA, through most of northern and central Mexico to the TMVB (Lariviere y Walton, 1997).

Remarks. Bobcat is a common felid inhabiting most of the state (López-González y García-Mendoza, 2014), even urban or semi-urban areas, however, in the sierra because of its habits, is rarely seen.

***Puma concolor* (Linnaeus, 1771)**

Cougar or mountain lion. Figure 2E.

Material examined. 2 records (tracks) in the SS; 1 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa, 1 picture, Cam 4 (1

pictures); Oct. 2019; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Quebradas, Sierras, and Valleys; UACH-CF-XXX.

Identification. The only extant member of its genus. A big cat with a long-tail, without spots. Head and ears small and rounded. The dorsal color shows an array of shades of brown, the underparts are white (Currier, 1983).

Distribution. Central, southwestern Canada, central, north-western USA, through most of Mexico to southern South America (Currier, 1983).

Remarks. The second largest felid in Mexico, only the jaguar (*Panthera onca*) is bigger. Based on current records for Chihuahua (López-González and García-Mendoza, 2014), both species are not sympatric because jaguar records are restricted to the Quebradas.

Family Canidae

***Canis latrans* (Say, 1823)**

Coyote. Figure 2F.

Material examined. 109 records (tracks) in the SS; 206 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa, 206 pictures, Cam 1 (15 pictures), Cam 2 (41), Cam 3 (88), Cam 4 (48), Cam 5 (2), Cam 6 (2), Cam 7 (10); Apr., May, June, Aug., Dec., 2018, Jan., 2019; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Sierras, Valleys and Arid; UACH-CF-XXX.

Identification. The only member of its genus in the study area. Dog-like body. Fur color ranges from gray-brown to yellow-brown on top, and white fur in the ventral region. It has a long, narrow snout with triangular ears on top of its head and a long bushy tail (Bekoff, 1977).

Distribution. Canada, USA, Mexico to Panamá (Bekoff, 1977).

Remarks. Four canids have been recorded in Chihuahua (Genera *Canis*, *Urocyon*, and *Vulpes*; López-González and García-Mendoza, 2014). The two members of the genus *Canis* (*C. latrans* and *C. lupus*) used to be sympatric in some parts of the state, however, *C. lupus* went extinct in the wild in Chihuahua allowing coyotes to expand its distribution.

***Urocyon cinereoargentatus* (Schreber, 1775)**

Gray fox. Figure 2G.

Material examined. 80 records (tracks) in the SS; 1,783 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa, 1,783 pictures, Cam 1 (224 pictures), Cam 2 (417), Cam 3 (37), Cam 4 (188), Cam 5 (69), Cam 6 (90), Cam 7 (253), Cam 8 (505); May, June, Aug., Sept., Oct. 2018; Jan., Feb., Mar. 2019; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Quebradas, Sierras, Valleys and Arid; UACH-CF-XXX.

Identification. The only member of its genus in Mexico. Smaller than a coyote, with peppery gray on dorsal surface, with red-brown on its sides, chest and the back of head. Legs and feet are also orange color. It has a long bushy tail a pointed muzzle and ears (Fritzell y Haroldson, 1982).

Distribution. Southern Canada, most of the USA, through Mexico to northern South America (Fritzell y Haroldson, 1982).

Remarks. Gray fox is the canid with the widest distribution in Chihuahua (López-González y García-Mendoza, 2014). It was the most frequently seen medium or large mammal in the Rancho Experimental Teseachi.

Family Ursidae

***Ursus americanus* (Pallas, 1780)**

Black bear. Figure 2H.

Material examined. 1 record (scats). MEXICO, State of Chihuahua, Municipality of Namiquipa, coordinates; altitude/elevation m a.s.l.; 16 Jan. 1998; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Sierras, and Valleys; UACH-CF-XXX.

Identification. The only extant member of its genus in Mexico. A medium-sized bear with black or brown color, and fur long and coarse (Lariviere, 2001).

Distribution. Canada, USA and Mexico through the pine, pine-oak forests of the Sierra Madre Occidental and Sierra Madre Oriental (Lariviere, 2001).

Remarks. Now extinct in most of northern Mexico. Only surviving in small patches of pine forests in the Sierra Madre Occidental and Sierra Madre Oriental of Mexico (Scheick y McCown, 2014). In the ranch, it was recorded only by one scat.

Family Mephitidae

***Conepatus leuconotus* (Lichtenstein, 1832)**

Hog-nosed skunk. Figure 3A.

Material examined. 13 record (tracks) in the SS; 25 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa, 25 pictures, Cam 5 (3 pictures), Cam 7 (6), Cam 8 (16); Oct. 2018, Jan. 2019; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Sierras, and Valleys; UACH-CF-XXX.

Identification. The largest skunk in Chihuahua and the only member of its genus. Body is black with a white band along the dorsal region, and a pig-like nose (Dragoo y Sheffield, 2009).

Distribution. Southwestern USA through most of Mexico (not distributed in the Peninsula of Baja California) to northern Nicaragua (Dragoo y Sheffield, 2009).

Remarks. Four skunks have been recorded in Chihuahua and in the ranch (López-González y García-Mendoza, 2014), easily recognized by its pig-like nose.

***Mephitis macroura* (Lichtenstein, 1832)**

Hooded skunk. Figure 3B.

Material examined. 1 record (tracks) in the SS; 24 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa, 24 pictures; Cam 2 (3 pictures), Cam 4 (9), Cam 5 (3), Cam 7 (6), Cam 8 (3); Sep. 2018; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Quebradas, Sierras, Valleys and Arid; UACH-CF-XXX.

Identification. Very similar to *M. mephitis*, however, it differs in having a longer and softer fur with a hood-kind region of longer hair on the dorsal part of the neck (Hwang y Leriviere, 2001).

Distribution. Southwestern USA through most of Mexico (not distributed in the Peninsula of Baja California) to northern Nicaragua (Hwang y Leriviere, 2001).

Remarks. One of the two skunks of the genus *Mephitis* recorded in Chihuahua (López-González y García-Mendoza, 2014). Distributed along all the ecoregions of the state.

***Mephitis mephitis* (Schreber, 1776)**

Striped skunk. Figure 3C.

Material examined. 1 record (tracks) in the SS; 18 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa, 18 pictures, Cam 2 (3 pictures), Cam 7 (4), Cam 8 (11); Oct., Dec. 2018; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Sierras, Valleys y Arid; UACH-CF-XXX.

Identification. It can be distinguished from other skunks in the area by a conspicuous white stripe running from head to tail. The stripe starts with a white hair spot in the head and divides into two thinner stripes down the dorsal region (Wade-Smith y Verts, 1982).

Distribution. Canada, most of USA and northern Mexico (Wade-Smith y Verts, 1982).

Remarks. The striped skunk is widely distributed in the state (López-González y García-Mendoza, 2014), lacking only in Quebradas where only the hooded skunk can be found.

***Spilogale gracilis* (Merriam, 1890)**

Western spotted skunk. Figure 3D.

Material examined. 1 record (tracks) in the SS; 6 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa, 6 pictures, Cam 4; 11 Jan. 2019; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Quebradas, Sierras, and Arid; UACH-CF-XXX.

Identification. The only member of its genus in Chihuahua. It has a black dorsal region with extensive white markings, and a dorsal pair of white stripes beginning in the ears (Verts *et al*., 2001).

Distribution. Southwestern Canada, western USA to Mexico (Peninsula of Baja California, through northern Mexico to the TMVB (Verts *et al*., 2001).

Remarks. The smallest of the skunks of Chihuahua (López-González y García-Mendoza, 2014) with records for three of the four ecoregions of the state, however, in the ranch it is the skunk with the lowest number of records.

Family Procyonidae

***Nasua narica* (Linnaeus, 1766)**

White-nosed coati. Figure 3E.

Material examined. 1 record (tracks) in the SS; 4 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa, 4 pictures; Cam 4 (4 pictures), 31 Mar. 2019; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Quebradas, and Sierras; UACH-CF-XXX.

Identification. The only member of its genus in Chihuahua. The face has a black mask with white markings around the eyes, and a distinctive long and pointed snout; the tail is ringed, long and hold upright while walking (Gompper, 1995).

Distribution. Marginal in southwestern USA, distributed through most of Mexico (not distributed in the dry Mexican Plateau) to Central America and South America (Colombia; Gompper, 1995).

Remarks. Only recorded in one sampling point. Usually moving in groups preferring harsh terrain like small and medium gorges and forests (Gompper, 1995).

***Procyon lotor* (Linnaeus, 1758)**

Raccoon. Figure 3F.

Material examined. 1 record (tracks) in the SS; 1 skull. MEXICO, State of Chihuahua, Municipality of Namiquipa, 1 track; 28 48" 33.7' N, 107 28" 02.99' W; 2,068 masl.; 30 Mar. 2019; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Quebradas, Sierras, and Valleys; UACH-CF-XXX.

Identification. The only member of its genus in Chihuahua. It has a distinctive black mask with large black spots around each eye. Thick body with a furry, ringed tail (Lotze y Anderson, 1979).

Distribution. Through most of Canada, the USA and Mexico to Costa Rica and Panama (Lotze y Anderson, 1979).

Remarks. Usually close to water currents (Lotze and Anderson, 1979) where it catches amphibians and invertebrates.

Order Artiodactyla

Family Tayassuidae

***Pecari tajacu* (Linnaeus, 1758)**

Collared peccary. Figure 3G.

Material examined. 16 records (tracks) in the SS; 65 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa 65 pictures: Cam 1 (13 pictures), Cam 2 (5), Cam 4 (13), Cam 7 (12), Cam 8 (22); Aug. and Oct.

2018; Jan. 2019, Jan. 2019; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Quebradas, and Sierras; UACH-CF-XXX.

Identification. The only member of the genus in Chihuahua. Pig-like appearance. Coarse fur with a conspicuous white collar above, rest of the body blackish gray (Schmidly and Bradley, 2016).

Distribution. Southwestern USA, most of Mexico (not distributed in the Peninsula of Baja California and the Mexican Plateau), through most of South America (not distributed in the western slope of the Andes; Schmidly and Bradley, 2016).

Remarks. The only pig that can be found in this part of the state. In the northern parts of Chihuahua it can be found too the javelina of European boar (*Sus scrofa*).

***Odocoileus virginianus* (Zimmermann, 1780)**

White-tailed deer. Figure 3H.

Material examined. 6 records (tracks) in the SS; 152 records (pictures) in CT. MEXICO, State of Chihuahua, Municipality of Namiquipa, 152 pictures: Cam 1 (7 pictures), Cam 4 (21), Cam 5 (3), Cam 6 (26), Cam 7 (36), Cam 8 (59); Aug. and Oct. 2018; Jan. 2019; coll. F. Álvarez-Córdova; recorded habitats in Chihuahua are Quebradas, Sierras, Valleys and Arid; UACH-CF-XXX.

Identification. The second largest member of the genus in Chihuahua and the only species inhabiting the highlands of the Sierra Madre Occidental. Dorsal color varies from shades of brown to gray. White fur patches can be found in the nose, around the eyes and beneath the tail (Smith, 1991).

Distribution. Canada, the USA and most of Mexico (not distributed in the Peninsula of Baja California) to northern South America (Smith, 1991).

Remarks. Two deer species have been recorded in Chihuahua (López-González and García-Mendoza, 2014). The white-tailed deer inhabits most of the forested areas of the state and only marginally the arid regions where its replaced by the largest member of the genus, the mule deer (*Odocoileus haemonius*).

The species recorded in this study represent 12% of the diversity reported for Chihuahua in an area of 4.85% of the state. All species recorded in this work have been already recorded for the state by different authors. The species accumulation curves show differences in mammalian diversity between the two types of vegetation, being higher in POF (α = 16) than in OMG (α = 9).

Between both ecosystems there is a β diversity = 7, this difference in mammals can be due to the fact that organisms such as *Puma concolor*, *Mephitis mephitis*, *Mephitis macroura*, *Spilogale gracilis*, *Procyon lotor*, *Nasua narica* and *Ursus americanus* have been reported for forest areas, this ecosystem provides them with food, shelter and protection (Anderson, 1972; Ramírez-Pulido *et al.,* 2005; López-González and García-Mendoza, 2012).

All the species in this study (n = 16) are reported by the IUCN (2019) as learn concern (LC), this means that their populations do not have any problems that require immediate attention for their conservation. The same applies for NOM-059 (2010), which is the endangered species list developed by the Mexican government, there is no mention of any category for the 16 species reported.

All the categories of protection for the species recorded agree with López-González and García-Mendoza (2012). On the other hand, none of the species

reported are endemic to the Mexico, all species have wider distribution in North America or Central America (Ceballos *et al.,* 2005).

All the sampling techniques have advantages and disavantages, however, if they are implementing mixing them, it is possible to generate trustful inventories. The mammal information generated for this project will be the baseline for the establishment of better management and conservation plans for the Rancho Experimental Teseachi, Chihuahua, Mexico.

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CHAPTER II. ABUNDANCE, HABITAT SELECTION AND DIET OF THE COYOTE, *CANIS LATRANS* (SAY, 1823) IN TWO TYPES OF VEGETATION IN NORTHERN MÉXICO

RESUMEN

ABUNDANCIA, SELECCIÓN DE HABITAT Y DIETA DEL COYOTE, *CANIS LATRANS* (SAY, 1823) EN DOS TIPOS DE VEGETACIÓN EN EL NORTE DE MÉXICO

POR:

BIÓL. FERNANDO ÁLVAREZ CÓRDOVA

Maestría en Ciencias en Recursos Naturales

Secretaría de Investigación y Posgrado

Facultad de Zootecnia y Ecología

Universidad Autónoma de Chihuahua

Presidente: Ph. D. Jesús Abraham Fernández Fernández

El coyote (*Canis latrans*) es un depredador con un alto grado de adaptación a diferentes ecosistemas. El objetivo de este estudio fue estimar la abundancia relativa, la selección del hábitat y la dieta de *C. latrans*, en dos tipos de vegetación ubicados en el noroeste de Chihuahua: bosque de pino-encino (BPE) y pastizal mediano abierto (PMA). Desde abril de 2018 hasta marzo de 2019, se colocaron diez estaciones olfativas fijas (EO) y ocho trampas de cámaras aleatorias (CT) en cada tipo de vegetación, con una separación de 500 m lineales entre estaciones, durante 12 muestreos (uno por mes). Un total de 420 SS y 288 días CT. Se encontró un indice de abundancia relativa mayor en bosque pino-encino (0.30) a comparación del pastizal mediano abierto (0.23). La selección del hábitat (Chi²) mostró un χ^2 más bajo (2.96 <3.85), entre BPE y PMA, lo que sugiere que la abundancia y el tipo de vegetación son independientes (P

> 0.05). Los items alimenticios detectados en 34 excrementos recolectados fueron 55.88% de mamíferos, 35.29% de frutas y 8.82% de artrópodos. Este estudio genera por primera vez información relevante respecto a las poblaciónes de *C. latrans* en el estado de Chihuaua.

ABSTRACT

ABUNDANCE, HABITAT SELECTION AND DIET OF THE COYOTE, *CANIS LATRANS* (SAY, 1823) IN TWO TYPES OF VEGETATION IN NORTHERN MÉXICO

BY:

BIÓL. FERNANDO ÁLVAREZ CÓRDOVA

The coyote (*Canis latrans*) is a widespread predator with a high degree of adaptation to different ecosystems. The objective of this study was to estimate the relative abundance, habitat selection, and diet of *C. latrans*, in two types of vegetation located in northwestern Chihuahua: pine-oak forest (POF) and open medium grassland (OMG). From april 2018 to march 2019, ten fixed scent stations (SS) and eight random cameras traps (CT) were placed in each vegetation type, with a linear separation of 500 linear meters between stations, during 12 samplings (one per month), totaling 420 SS and 288 CT days. A higher relative abundance index was found in pine-oak forest (0.30) compared to the open medium grassland (0.23). The habitat selection (Chi^2) showed a lower χ^2 (2.96 <3.85), between POF and OMG, suggesting that abundance and type of vegetation are independent ($P > 0.05$). The food items detected in 34 scats collected were 55.88 % belong to mammals, 35.29 % to fruits and 8.82 % to arthropods. This study generates for first time relevant information regarding the populations of *C. latrans* in the state of Chihuaua.

INTRODUCTION

The Coyote (*Canis latrans*) is a predator that is considered to have a high degree of ecological plasticity; consequently, it can be found in different types of ecosystems including sub-urban and urban human settlements. Its geographical distribution ranges from North America to northern Panamá (Bekoff *et al*., 2003; Marín-Sánchez *et al.*, 2015; Méndez-Carvajal y Moreno, 2014; Hody *et al*., 2019). The coyote's reproductive success and its ability to disperse, has allowed it to have high population numbers and a wide distribution (Carreón, 1998; Garrido y Arribas, 2008; Hernández y Laundré, 2014; Méndez-Carvajal y Moreno, 2014).

The home range of the coyote may comprise 3 km^2 to 67 km^2 and its extension varies according to the characteristics of the specimen and the stage of life in which it is found (Hernández, 1990; Hernández *et al*., 1993; Servín and Huxley, 1995; Hidalgo-Mihart *et al*., 2001). It has been hypothesized that its wide distribution and population abundance in North America is due to the elimination of the Gray wolf (*Canis lupus*), since both canids are sympatric species competing for resources. Additionally, it has been documented that *C. lupus* preyed on *C. latrans* (Hall, 1981; Vaughan y Rodríguez, 1986).

Although the coyote is a carnivore, the modification of its diet for the different environments in which it is found has allowed it to be an omnivorous mammal. All these characteristics together, have led it to be a successful predator (Bekoff, 1977; Hall, 1981; Vaughan y Rodríguez, 1986). The coyote is considered an important regulator of populations of small mammals such as rodents and lagomorphs. Additionally, they disperse consumed seeds from their herbivorous diet, fulfilling a relevant role in the regeneration of pine-oak forests. Therefore,

the erradication of coyote populations would have a drastic effect on animal and plant communities and on ecosystems as a whole (Servín y Huxley, 1993; 1995).

Although the coyote is considered an abundant and widely distributed species in Mexico, there are no studies on its abundance, distribution, role they play in a given habitat, or diet in any ecosystem in Chihuahua, northern Mexico. Therefore, the objective was to estimate and compare relative abundance, habitat selection, and diet of the coyote (*Canis latrans*) in two types of vegetation (open medium grassland and pine-oak forest) in northern Mexico, through indirect methods such as scent stations, cameras trap and scats. The information generated might be use by local authorities and Rancho Experimental Teseachi managers to carry out conservation plans.

MATERIALS AND METHODS

Study Area

The study was conducted at the Rancho Experimental Teseachi, located in central-western Chihuahua. The ranch is owned by the Universidad Autonoma de Chihuahua, and has as its main objective teaching, research, and transfer of technology in animal science and natural resources (Espinoza y Quintana, 2013; Álvarez-Córdova *et al*., 2019). It encompasses approximately 12,300 ha and is located between the municipalities of Namiquipa, Bachiniva, and Guerrero (28 ° 53 ’44’ N, 107 ° 27 ’22’ W) at 2,250 masl (Figure 4).

The landscape is shaped by hills and high mountain ranges displaying a mixture of arboreal pasture grasses, oak chaparral, temperate forest, open medium grasslands, and pine-oak forest (COTECOCA, 1978; Álvarez-Córdova *et al*., 2019). For this study, the pine-oak forest (POF) and open medium grassland (OMG) vegetation were selected, due to the previous information of the ranch staff and personal observations of the presence of coyotes in both areas.

Methods

From April 2018 to March 2019, fixed scent stations (SS) of 1.00 meter in diameter, baited with chicken and sardine, and camera traps (CT) were placed along a five km transect with a separation of 500 m (Figure 4) in each type of vegetation (POF and OMG). All SS-CTs were activated during the afternoon and checked the next day (two nights / month). Camera traps were placed in order to have a photographic record of the species at the study area. Traces and scats found at SS were identified as belonging to *C. latrans* following Aranda (2012).

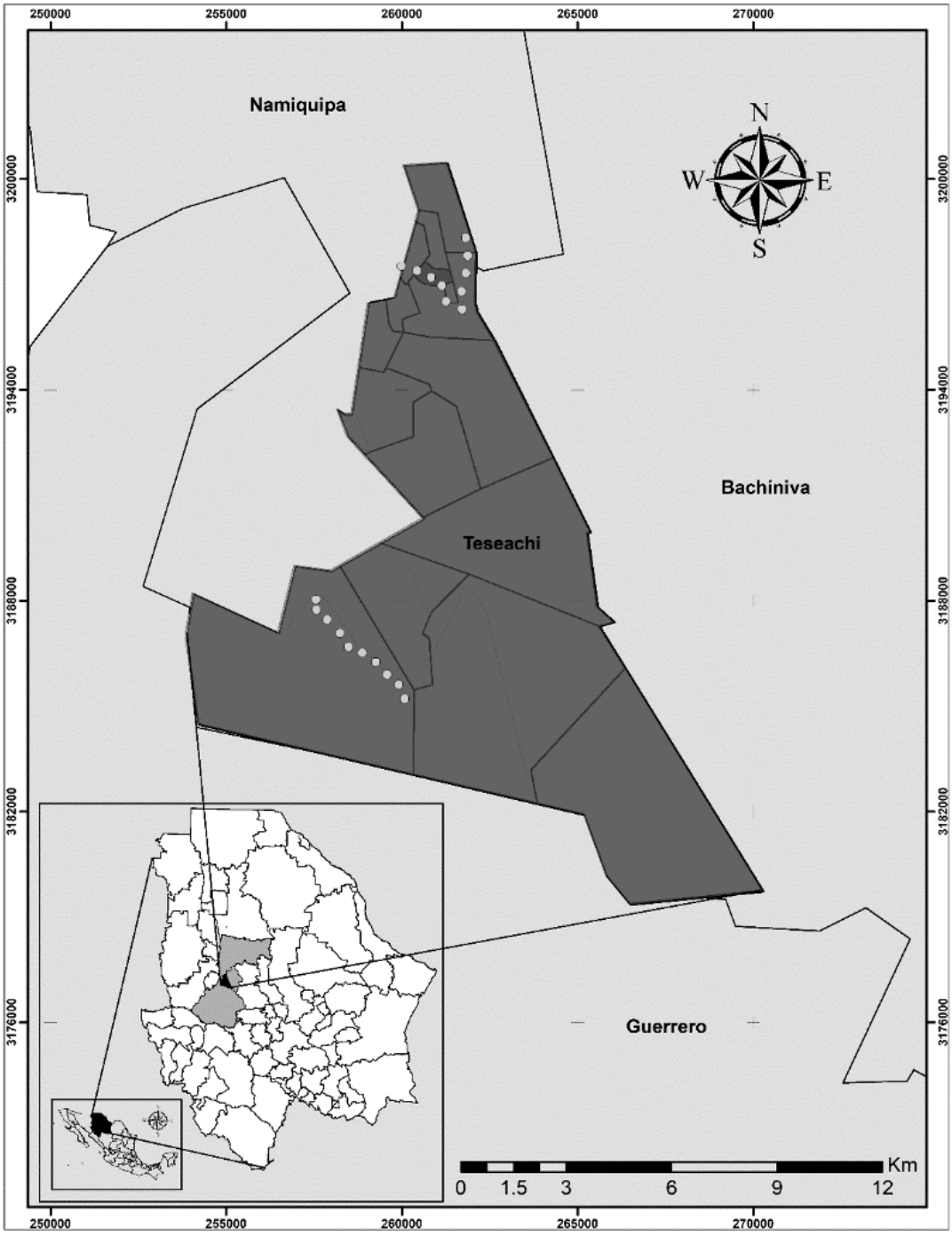


Figure 4. Geographic location of the Rancho Experimental Teseachi, Namiquipa, Chihuahua, Mexico. Gray circles indicate sampling sites.

Each collected scat was georeferenced through a Global Positioning System (GPS), measurements (width and length) were taken with a measuring tape, and they were subsequently stored individually in airtight bags (Álvarez-Córdova *et al.,* 2019). Once in the laboratory they were cleaned following Arnaud (1993) and Álvarez-Córdova *et al.* (2019). Following the field guidelines of Álvarez-Castañeda *et al*. (2015) the organisms within the scats were identified.

Data Analysis

To estimate the relative abundance index, a database was generated with the records of visits of *C. latrans* to the SS was used. Each visit was defined as the presence of at least one trace of coyotes or other species. To calculate the relative abundance index (RAI), the formula proposed by Linhart and Knowlton (1975) was used: number of visits of the species / number of active olfactory stations (Roughton y Sweeny, 1982; Conner *et al*., 1983; Carreón, 1998).

To compare patterns of habitat selection between types of vegetation (POF and OMG), a Chi square test was performed (χ^2). All records obtained from *C. latrans* at scent stations were used. It was taken as a null hypothesis (H0) to test the hypothesis that relative abundance of *C. latrans* was independent on the type of vegetation ($\alpha = 0.05$). A double entry contingency table was developed, in which the observed frequencies (OF) corresponded to the scent stations that were positive during the study in the two types of vegetation, and expected frequencies (EF) for OMG and POF were calculated according to the chi-square formula. To achieve this, the information collected was divided between records of *C. latrans* present and absent in scent stations in both types of vegetation.

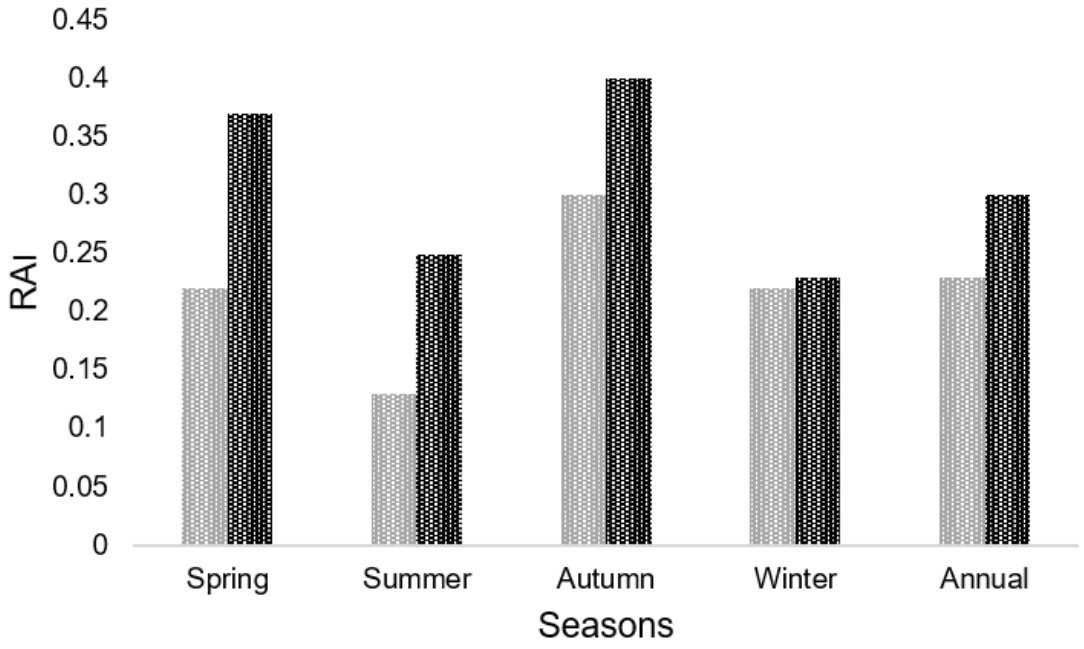
The results were also analyzed seasonally between both types of vegetation with a chi-square test per season (χ^2). To describe the diet of the coyote, the food items in each scat were separated, and a percentage of frequency was calculated for each item (Linhart y Knowlton, 1975; Roughton and Sweeny, 1982; Conner *et al*., 1983; Carreón, 1998; Monroy-Vilchis y Velázquez, 2002).

RESULTS AND DISCUSSION

In total, we obtained 113 coyote visits in a total of 420 SS placed during an annual period, 67 visits for POF and 46 for OMG. Also, more than 2,000 photographic records of different mammals were obtained in both areas, of which 206 photos were from *C. latrans*. The annual RAI in POF was 0.30 and in OMG was 0.23 (Graph 3). Differences in the RAI were found among seasons in both POF and OMG, indicating a higher RAI for coyotes during Spring and Autumn.

However, although there are differences between stations, the pattern remains, that is, regardless of the season, the RAI is always greater in POF than in OMG. The biggest seasonal differences were found in POF, where coyotes were more abundant in Spring (0.37) and Autumn (0.40) compared to summer and winter. In OMG the highest RAI was found in Autumn (0.30) (Graph 3).

For habitat selection, the double entry contingency table (χ^2) showed that of 420 scent stations (200 SS for OMG and 220 SS for POF) set during sampling, in 113 SS the presence of *C. latrans* were registered, corresponding to frequencies observed of 46 /113 and 67/113 for OMG and POF, respectively (Table 3). However, we did not find a significant difference between POF and OMG ($\chi^2 = 2.96$, $P > 0.05$). In the same way, we did not find significant differences (All $P > 0.05$) between seasons, Spring ($\chi^2 = 3.26$), Summer ($\chi^2 = 2.63$), Autumn ($\chi^2 = 0.87$) and Winter ($\chi^2 = 0.89$). Therefore, the results suggest that coyote abundance and type of vegetation are independent variables across seasons.



Graph 3. Relative abundance index (RAI) of Coyote (*Canis latrans*) seasonally and annually during 2018-2019 at Rancho Experimental Teseachi, Namiquipa, Chihuahua, Mexico. Open medium grassland (gray bars) and pine-oak forest (black bars).

Table 3. Double entry contingency table (χ^2) (OF: observed frequencies, EF: expected frequencies) for Coyotes (*Canis latrans*) at Rancho Experimental Teseachi, Namiquipa, Chihuahua, Mexico

Vegetation	Present	Absent	Total
OMG[a]	OF=46	OF=154	200
	EF=53.8	EF=146.2	
POF[b]	OF=67	OF=153	220
	EF=59.2	EF=160.8	
Total	113	307	420

[a]Open medium grassland
[b]Pine oak-forest.

A total of 34 scats were collected, four in OMG and 30 for POF [2.0 to 3.1 (2.4) ± 0.33 mm width x 13.0 to 15.0 (13.3) ± 0.87 mm length]. Annually, 55.88% of the food items recovered from the scats belong to mammals, 35.29% to plants and 8.82% to insects (Orthoptera: Acrididae). For Spring season, 16 scats were collected, in which 68.8% of the food items recovered belonged to mammals and 31.2% to plants. During Summer, seven scats were collected, with 71.4% of the remains corresponding to mammals and 28.6% to insects. In Autumn, only five scats were recovered where 40% of the items belonged to mammals, 40% to plants and 20% to insects. Finally, in Winter six scats were found and 16.7% of the items recovered were mammals and 83.3% plants (Table 4).

The mammalian species identified corresponded to Cotton rats (*Sigmodon* sp.), Woodrats (*Neotoma* sp.), and Cottontail rabbits (*Sylvilagus* sp). The plants recovered corresponded to fruits of Manzanita (genus *Arctostaphylos*), and the insects were Grasshoppers of the family Acrididae (Table 4). The four scats collected in OMG corresponded only to plants.

There are several studies documenting the relative abundance of *C. latrans* through scent stations (Linhart y Knowlton, 1975; Roughton y Sweeny, 1982; Conner *et al*., 1983). Nevertheless, for the Mexican Republic there are only a few studies where scent stations were used to determine the relative abundance of this carnivore (Carreón, 1998; Monroy-Vilchis y Velázquez, 2002; Ponce *et al*., 2005). This is the first study for the state of Chihuahua.

Throughout the sampling period, the POF showed the greatest abundance of C. latrans. This may be because the POF provides them with shelter from climatic situations and a greater variety of fruits and insects.

Table 4. Annual and seasonal variation in the diet of Coyotes (*Canis latrans*) at Rancho Experimental Teseachi, Namiquipa, Chihuahua, Mexico

Season	Mammals	Plants	Ortoptera	Scats
Spring	68.7%	31.2%	0%	16
Summer	71.4%	0%	28.6%	7
Autumn	40.0%	40.0%	20.0%	5
Winter	16.7%	83.3%	0%	6
Annual	55.9%	35.3%	8.8%	34

Differences in the RAI between POF and OMG were found and this results is similar to those presented by Monroy-Vilchis y Velázquez (2002), where the authors found the highest RAI of *C. latrans* in pine and mixed forests. However, our results do not match Ponce *et al*. (2005), where they found less coyote abundance in forests, maybe because of the complexity of capturing prey, and competition with other predators (mountain lions [*Puma concolor*] and black bears [*Ursus americanus*]).

Several authors have recognized POF and OMG as important ecosystems for mammals using them for protection and food (Servín y Huxley, 1991; Hidalgo-Mihart *et al.,* 2001, Randa y Yunger, 2004). The two seasons with the highest RAI were Spring and Autumn in both ecosystems, coinciding with an increase in rainfall, resulting in an abundance of potential prey (small mammals), and other food items like fruits (Randa y Yunger, 2004).

Although the RAI was different between POF and OMG, the habitat selection analysis did not show statistically significant differences in annual abundance of coyotes between the two vegetation types as if to affirm that the coyote prefers a particular type of vegetation. Nevertheless, the season that presented the greatest variation was Spring, while Autumn showed less variation.

Different authors reported that potential prey and vegetation defines *C. latrans* presence in different ecosystems (Bekoff, 1977; Hall, 1981; Vaughan y Rodríguez, 1983; Bekoff y Gese, 2003; Randa y Yunger, 2004; Ponce *et al*., 2005).

In the annual diet, mammals were the main food with 55.88%, and then plants (35.29%). Diet preferences coincide with the ecosystem role these canid

plays as a biological control of rodent populations and seed disperser in different ecosystems in which it is distributed (Servín y Huxley, 1991; Grajales-Tam *et al*., 2003; Cruz-Espinoza *et al*., 2008; Arias-Del Razo *et al*., 2011; Grajales-Tam y González-Romero, 2014; Poessel *et al*., 2017).

Differences in diet were found between seasons, that can be explain by the variation in food availability among seasons (Randa y Yunger, 2004; Ponce *et al*., 2005). The small rodents and lagomophs consumed by *C. latrans* were found throughout the four seasons (Servín y Huxley, 1991); nevertheless, fruits were found in Spring, Autumn and Winter; and Orthopteran insects only appeared in Summer and Autumn, corresponding to the rainy season when there is an increase in the population of Acrididae (Rivera, 2006).

Coyotes need the greatest energy intake for reproduction in Winter, so that pups will be born in Spring coinciding with the yearly food peak (Roughton y Sweeny, 1982; Servín y Huxley, 1991; Bekoff y Gese, 2003; Randa y Yunger, 2004; Ponce *et al*., 2005; Hernández y Laundré, 2014).

In addition, in the collected scats there were specimens of a genus of nematode (*Physaloptera* sp.) not reported before for the state of Chihuahua, Mexico (Álvarez-Córdova *et al*., 2019). The presence of this nematode in scats of coyote agrees with the feeding habits of this canid, because this nematode is parasite of intermediate hosts like lagomorphs and rodents (Álvarez-Córdova *et al*., 2019).

This study is the first to be carried out systematically in order to generate information about the ecology of *Canis latrans* specifically about the abundance trends of this carnivore in two types of vegetation in an annual period for central-

western Chihuahua populations. In addition, it is corroborated that coyote rather than a selective carnivore is an opportunistic carnivore in its diet, so it fulfills its function as a biological control of different species.

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CHAPTER lll. FIRST RECORD OF THE GENUS *PHYSALOPTERA* SP. (NEMATA: PHYSALOPTERIDAE) IN SCATS FROM COYOTE, *CANIS LATRANS* IN CHIHUAHUA, MÉXICO

POR

Fernando Álvarez-Córdova[1], Jesús A. Fernández[1], Elizabeth A. Martínez-Salazar[2] and Rogelio Rosas-Valdez[2]

[1]Departamento de Recursos Naturales, Facultad de Zootecnia y Ecología, Universidad Autónoma de Chihuahua.
[2]Laboratorio de Colecciones Biológicas y Sistemática Molecular, Unidad Académica de Ciencias Biológicas, Universidad Autónoma de Zacatecas.

Álvarez-Córdova, F., J. A. Fernández, E. A. Martínez-Salazar and R. Rosas-Valdez. 2019. First record of the genus *Physaloptera* sp. (Nemata: Physalopteridae) in scats from coyote, *Canis latrans* in Chihuahua, Mexico. Therya 10:183-185.

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First record of the genus *Physaloptera* sp. (Nemata: Physalopteridae) in scats from coyote, *Canis latrans* in Chihuahua, México

Fernando Álvarez-Córdova[1*], Jesús A. Fernández[1], Elizabeth A. Martínez-Salazar[2] and Rogelio Rosas-Valdez[2]

[1] Departamento de Recursos Naturales, Facultad de Zootecnia y Ecología, Universidad Autónoma de Chihuahua. Periférico Francisco R. Almada Km. 1, CP. 31453, Chihuahua. Chihuahua, México. Email: biofer.alva@gmail.com (FAC), jaff1789@gmail.com (JAF).

[2] Laboratorio de Colecciones Biológicas y Sistemática Molecular, Unidad Académica de Ciencias Biológicas, Universidad Autónoma de Zacatecas. Campus II, Av. Preparatorio s/n Col. Agronómica, CP. 98066, Zacatecas. Zacatecas, México. Email: rogrosas.uaz@gmail.com (RRV), eamsuaz@gmail.com (EAMS).

*Corresponding author

The knowledge of the helminth parasites of *Canis latrans* from México is scarce. This study 23 scats of *C. latrans* were collected and examined to identify alimentary items between April and September of 2018, at the rancho experimental Teseachi of the Universidad Autónoma de Chihuahua, in Namiquipa, Chihuahua, México. Three nematode specimens of *Physaloptera* sp. were found and identified by morphology. This endoparasite is reported for the first time in scats of *C. latrans* for the state of Chihuahua.

El conocimiento de los helmintos parásitos de *Canis* latrans de México es escaso. Este estudio 23 excretas de *C. latrans* fueron recolectadas y examinadas para identificar atributos alimenticios entre Abril y Septiembre del 2018 en el rancho experimental Teseachi de la Universidad Autónoma de Chihuahua, en Namiquipa, Chihuahua, México. Tres especímenes de nemátodos de *Physaloptera* sp. fueron encontrados e identificados por su morfología. Se reporta por primera vez este género de endoparásito en excretas de *C. latrans* para el estado de Chihuahua.

Key words: canidae; carnivora; endoparasite; mammals; nematoda; parasitism.

Introduction

Canis latrans is a predator with a high degree of adaptation to different ecosystems, from desert to tropical and temperate environments (Bekoff and Gese 2003). Its distribution extends from Costa Rica to northern Alaska (Bekoff 1977). Their reproductive success, the ability to disperse, and their supreme success at adapting to different environments and resources has allowed coyotes to expand both their range and their diet which is now basically omnivorous. These characteristics have made coyotes one of the most abundant and widely distributed carnivores on the American continent (Bekoff 1977; Hall 1981; Vaughan and Rodríguez 1986).

The omnivore diet of *C. latrans* promotes infections by different endoparasite species such as Platyhelminthes and nematodes in the Nearctic Realm: *Ancylostoma* spp., *Capillaria* spp., *Dirofilaria* spp., *Physaloptera* sp., *Strongyloides* sp., *Toxascaris* spp., *Trichinella* spp., among others nematode parasites reported (Ramalingam and Carbyn 1978; Hernández and Laundré 2014; Luna-Estrada *et al.* 2017). Curiously, up to the present time, there few records of parasites of *Canis latrans* in México, one record the nematode *Strongyloides* sp. parasitizing *C. latrans* from the Zoológico "Manuel Álvarez del Toro", in Chiapas, México (in García-Prieto *et al.* 2012); and one records the nematode *Dirofilaria immitis* near Queretaro City, México (Hernández and Pineda 2012).

Eight records of parasites have been reported from the municipality of Tepehuanes, Durango; five nematodes (*Ancylostoma caninum*, *Physaloptera* sp., *Spirocerca lupi*, *Spirura* sp., and *Didelphonema longispiculata*), one trematode (*Alaria* sp.) and one cestode (*Taenia pisiformis*; Luna-Estrada *et al.* 2017). To the best of our knowledge, there is no information on the endoparasites of *C. latrans* from the state of Chihuahua. The aim of this paper was to present the first record of *Physaloptera* sp. obtained from scats of *C. latrans* in the state of Chihuahua, México.

Materials and Methods

Study area. The main goal of the rancho experimental Teseachi is teaching, research and transfer of technology in animal science and natural resources (Espinoza and Quintana 2003). It is located among the municipalities of Namiquipa, Bachiniva and Guerrero in Chihuahua, México (28° 53' 44" N, -107° 27' 22" W, 2,250 masl). This site has an approximate area of 12,300 hectares, the landscape is shaped by hills and high mountain ranges displaying a mixture of open medium grassland, arboreal pasture grasses, oak chaparral, pine-oak forest, and temperate forest. Comisión Técnico Consultiva de Coeficientes de Agostaderos (COTECOCA 1978).

Data collection and identification of parasites. Linear transects of five kilometers were revised in search of scats. A total of 23 scats of *C. latrans* were collected from April to September of 2018, the scats were identified as belonging to *C. latrans* according to the characteristics detailed by Aranda (2012). Each scat collected was georeferenced through a Global Positioning System (GPS), and measurements (width and length) were taken with a measuring tape, and they were subsequently stored individually in

airtight bags. Once in the laboratory at Facultad de Zootecnia y Ecología, Universidad Autónoma de Chihuahua, they were cleaned using conventional means (Arnaud 1993). The nematodes were collected and stored in glass vials with 70 % ethanol to preserve morphological traits for further identification.

The identification of the nematodes was conducted in the Laboratorio de Colecciones Biológicas y Sistemática Molecular (LCBySM), Unidad Académica de Ciencias Biológicas (UACB), Universidad Autónoma de Zacatecas (UAZ), Zacatecas, Zacatecas, México, using conventional morphological techniques (Lamothe-Argumedo 1997) and identified using specialized literature (Chabaud 1975). Voucher specimen was deposited in the reference collection in the laboratory previously mentioned: Colección de Invertebrados no Artrópodos (CINZ08).

Results

From the 23 scats examined, only one was positive for worms parasites (prevalence of 4.3 %) with three specimens; two females were identified and the other was in high degree of decomposition. Nematodes were identified through the use of morphological characters, and they clearly belong to genus *Physaloptera* sp. (Nemata: Physalopteridae). The two specimens obtained were measured with an average total length of 24 mm. In the optical microscope different structures were observed that allowed the identification at genus level, such as the anal opening, the size and structure of the embryonated eggs [42.11 to 55.47 (50.61) ± 2.95 µm long x 30.00 to 36.70 (32.40) ± 1.75 µm width, n = 20], and cephalic features, such as two large, simple, triangle lateral lips, two pairs of frontal papillae, internal teeth (three in each lip) and presence of a well developed stoma (Figure 1 to 3). Because there were no males collected, it was not possible to identify these nematodes to the species level (Ramalingam and Carbyn 1978; Ortlepp 1922).

Figure 1. Embryonated eggs of Physaloptera sp. Scale bar = 50µm.

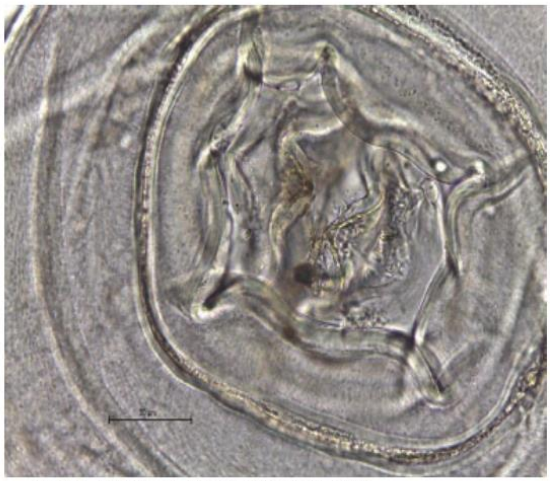

Figure 2. Cephalic end, apical view. Scale bar = 50µm.

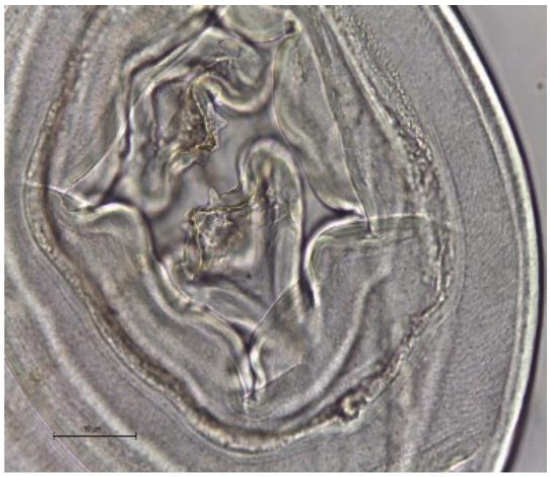

Figure 3. Internal teeth (three in each lip) and buccal cavity. Scale bar = 50µm.

Discussion

For the Mexican Republic there are few records documenting infection of nematodes in *C. latrans* through gastrointestinal dissections, however none with scats review (García-Prieto *et al.* 2012; Hernández and Pineda 2012; Luna-Estrada *et al.* 2017). To our knowledge, for the state of Chihuahua there was no record of *Physaloptera* sp. in *C. latrans*. The presence of *Physaloptera* sp. in Chihuahua agrees with Luna-Estrada *et al.* (2017), they reported the presence of this nematode in *C. latrans* in northern México, in Tepehuanes Durango (at 425 km lineal distance approximately). Nematode species of the genus *Physaloptera* (Nematoda: Physalopteridae) are parasites of mammals, birds and reptiles (Chabaud 1975).

The life cycle of *Physaloptera* spp. is indirect, the coyotes are considered the definitive hosts of the *Physaloptera rara* from North America (Ameel 1955), the infections is

through oral ingestion of the intermediate hosts (*e. g.*, beetles, crickets, cockroaches, earwigs and grasshoppers) or ingestion of paratenic hosts, such as mice that are infected with encysted juvenile or larval *Physaloptera* sp. (Petri 1950; Olsen 1980). The presence of *Physaloptera* sp. in coyote scats agrees with the feeding habits of this canid, because this nematode is parasite of intermediate hosts like lagomorphs and rodents. They are common prey of *C. latrans*, where the parasites complete its life cycle (Luna-Estrada *et al.* 2017).

Parasites are an important part of the natural biota of free-living organisms, playing a role as bioindicators of ecosystem health (Marcogliese 2005), despite this, there is a lack of information on Mexican mammal parasites, so it is necessary to increase the study of helminth fauna in the Mexican Republic. This is the first report of *Physalopera* sp. in scats of *C. latrans* in Chihuahua, Chihuahua, México.

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CONCLUSIONS AND GENERAL RECOMMENDATIONS

A systematic study was conducted for the first time to identify the taxonomic diversity of mammals and the ecology of *C. latrans* at the Rancho Experimental Teseachi, Namiquipa, Chihuahua, Mexico.

Differences in mammalian diversity were found between the two types of vegetation that were studied, the diversity in pine-oak forest being greater than open medium grassland.

There was variation in the relative abundance index of coyote according to the season of the year. The seasonal variation in RAI was greater in pine-oak forest compared to open medium grasland. However, in the statistical test it was not found information to confirm that coyotes select a particular type of these two vegetations.

The most frequent prey of *C. latrans* correspond to the order Rodentia, mainly *Sigmodon* sp. and *Neotoma* sp. individuals. This result is in agreement with the main diet reported in different studies.

The nematode genus *Physaloptera* sp. is reported for the first time in scats of *C. latrans* for the state of Chihuahua, Mexico. The presence of this nematode reinforces the eating habits of this canid, because this nematode is a parasite of intermediate hosts such as lagomorphs and rodents. They are common prey for *C. latrans.*

Sampling is recommended in other areas of the ranch in order to potentially increase the diversity recorded of mammals. In addition, it is recommended to sample small mammals in order to complete the taxonomic list.

It is recommended to continue with the sampling in order to identify *C. latrans* fluctuations as time passes and to determine the important life history events for the biology of the species. Also, it is recommended to carry out samplings in other areas of the ranch to compare trends at different locations.