



Ecology

Flea diversity and prevalence on arid-adapted rodents in the Oriental Basin, Mexico

Diversidad de pulgas y prevalencia en roedores de zonas áridas en la Cuenca Oriental, México

Roxana Acosta^{a,*}, Jesús A. Fernández^b

^a Museo de Zoología “Alfonso L. Herrera”, Departamento de Biología Evolutiva, Facultad de Ciencias, Universidad Nacional Autónoma de México, Apartado Postal 70-399, 04510 México, D.F., Mexico

^b Departamento de Recursos Naturales, Facultad de Zootecnia y Ecología, Universidad Autónoma de Chihuahua, Periférico Francisco R. Almada Km. 1, 31453 Chihuahua, Chihuahua, Mexico

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Abstract

Inventoring biodiversity is basic for conservation and natural resources management because constant loss of natural areas increases the need for fast biodiversity inventories. Desert flea diversity and associations are not well known in Mexican deserts, especially in the Oriental Basin (OB). Rodents were trapped in the Oriental Basin through June 2007, 2009, and 2010, and July 2008, in 10 localities. A total of 144 rodents belonging to 10 species were trapped, of which 133 were parasitized by 350 fleas belonging to 18 species. *Peromyscus difficilis* had the highest parasite richness with 9 species, followed by *P. maniculatus* with 8. The most abundant fleas in the OB were *Polygenis vazquezi*, *Plusaetis parus*, *Meringis altipecten*, and *Plusaetis mathesoni*. Seven species were found representing new records for 3 states.

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Keywords: Mammals; Mexican arid zones; Parasites; Siphonaptera

Resumen

Tener un inventario de la diversidad biológica es fundamental para la conservación y gestión de los recursos naturales, ya que la pérdida constante de áreas naturales aumenta la necesidad de realizar inventarios rápidos de la biodiversidad. En particular la diversidad de pulgas y sus asociaciones no son muy conocidas en zonas áridas de los desiertos mexicanos, especialmente en la Cuenca Oriental. Por lo anterior, fueron colectados roedores en 10 localidades de la Cuenca Oriental en junio de 2007, 2009, 2010 y julio de 2008. Se recolectó un total de 144 roedores pertenecientes a 10 especies; 133 estaban parasitados por 350 pulgas pertenecientes a 18 especies. *Peromyscus difficilis* tuvo la riqueza más alta de pulgas con 9 especies, seguido por *P. maniculatus* con 8. Las pulgas más abundantes en la Cuenca Oriental fueron *Polygenis vazquezi*, *Plusaetis parus*, *Meringis altipecten* y *Plusaetis mathesoni*. Se encontraron 7 especies que representan nuevos registros para 3 estados.

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Palabras clave: Mamíferos; Zonas áridas mexicanas; Parásitos; Siphonaptera

Introduction

Inventoring biological diversity is a basic scientific activity, essential for good conservation practices and natural resources

management. Financial resources and human efforts dedicated to document biodiversity of a given area ideally promote better conservation activities and policies (Brooks, da Fonseca, & Rodrigues, 2004a, 2004b; Ferrier et al., 2004). Constant loss of natural areas located near cities and drastic changes in land use increase the need for fast biodiversity inventories. An area located in Central Mexico that may vanish in the short term is the Oriental Basin (OB; Hafner & Riddle, 2005).

* Corresponding author.

E-mail address: roxana_a2003@yahoo.com.mx (R. Acosta).

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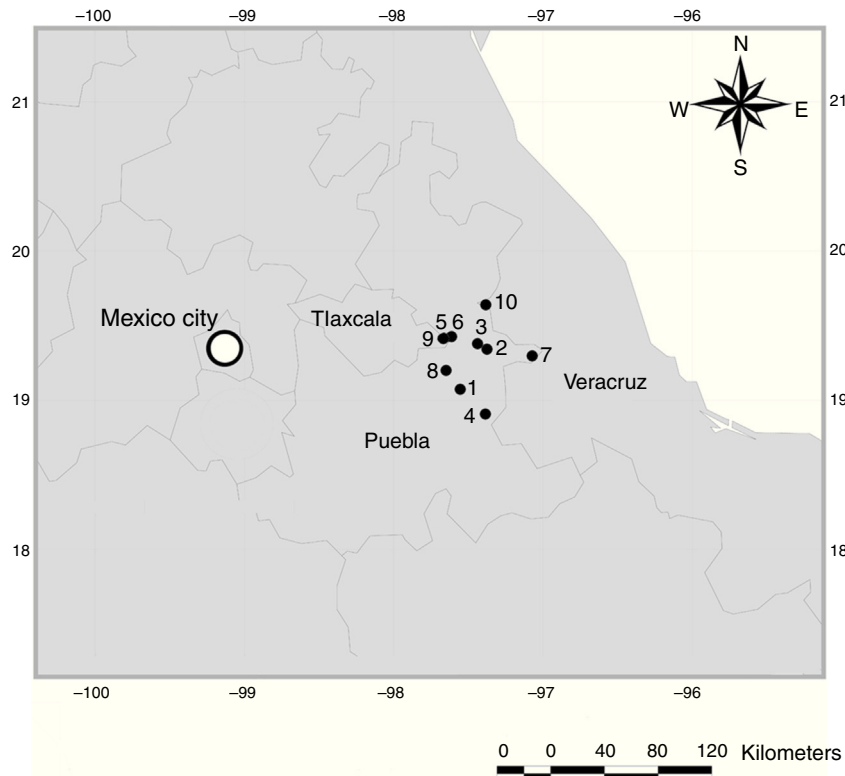


Figure 1. Map of localities in the Oriental Basin in Central Mexico. 1, Chalchicomula de Serna, 3 km S Cd. Serdán entronque Cd. Serdán – Esperanza, Dirección Santa Catarina; 2, Guadalupe Victoria, 2 km W Guadalupe Victoria; 3, Guadalupe Victoria, 9.6 km W Guadalupe Victoria; 4, La Esperanza, 2 km W La Esperanza; 5, Oriental, 1 km S Oriental; 6, Oriental, 1.5 km S Oriental; 7, Quimixtlan, 10 km NE Huaxcaleca; 8, San Salvador El Seco, 1 km S Coyotepec; 9, El Carmen Tequexquitla, 2.5 km El Carmen; 10, Perote, 3 km S El Frijol Colorado.

This region is considered a relict of the Chihuahuan desert and its southern-most extension (Shreve, 1942; Fig. 1). The vegetation is characterized by alkaline grass and thorn scrub in the dry valleys, and coniferous forest in the surrounding mountains (Valdéz & Ceballos, 1997). The OB area has been isolated at least since Pleistocene times, and several endemic mammals can be found here: *Cratogeomys fulvescens* Merriam, 1895 (Hafner et al., 2005), *Peromyscus bullatus* Osgood, 1904 (González-Ruíz & Álvarez-Castañeda, 2005), *Neotoma nelsoni* Goldman, 1905 (Fernández, 2012; González-Ruíz, Ramírez-Pulido, & Genoways, 2006), and *Xerospermophilus spilosoma perotensis* (Bennett, 1833) (Best and Ceballos, 1995; Fernández, 2012).

Interspecific interactions such as parasitism are considered an important part of biodiversity (Wilson, 1992). Some of the most common mammal parasites are fleas (Insecta: Siphonaptera). Siphonapterans are characterized by the lack of wings, and a buccal apparatus adapted for biting and sucking blood. Their body is small (1–9 mm) and laterally compressed, with strong legs and big coxae (Barrera, 1953; Rothschild, 1975).

Fleas are bird and mammal parasites. However, bird fleas represent only 5% of the known flea diversity. Most of the flea species have been found in mammals, and 70% of all fleas have been collected in rodents (Traub, Rothschild, & Haddow, 1983). Usually, when their host dies, fleas leave the body and look for a new host. Many flea species are apparently host specific, whereas

others lack a close relationship with a specific host and are able to parasitize several mammal species (Barrera, 1953; Whitaker & Morales-Malacara, 2005).

Parasite conservation may not be a popular topic, but preserving and studying parasite diversity and interactions represent many benefits. Christe, Michaux, and Morand (2006) point out that parasites must be preserved not only for being part of biodiversity, but also for actively modeling community structure and keeping diversity, for being good indicators of ecosystem health by accumulating heavy metals in their tissues, for their use in biomedicine, and because their DNA may provide a biological record of evolutionary dynamics between parasites and hosts.

In Mexico, 163 flea species have been recorded (Salceda-Sánchez & Hastriter, 2006), and recent work raised the number to 172 (Acosta, 2014). However, flea species diversity in Mexico is probably higher, because many large areas like desert regions lack extensive flea inventories and show only scattered records (Gutiérrez-Velázquez, Acosta, & Ortiz, 2006; Ponce & Lorente, 1996; Salceda-Sánchez & Hastriter, 2006).

Arid land studies on Mexican fleas are not abundant, but some of them have documented new species, generated regional checklists, distributional records, taxonomic revisions, and explored co-distributional aspects (Table 1). Only 2 recent publications exist for the study area: Acosta, Fernández, Lorente, and Jimenez (2008) presented data for 6 and 5 flea species in El Carmen Tequexquitla (Tlaxcala) and La Esperanza (Puebla),

Table 1
Author, year, and main topic of bibliographic references regarding arid land studies on Mexican fleas.

Author	Year	Topic
Traub and Hoff	1951	Description of <i>Meringis altipecten</i>
Holland	1965	Description of <i>Anomiopsyllus durangoensis</i>
Ayala et al.	1998	First catalog of fleas in Colección del Museo de Zoología (MZFC) with records in some states with desertic zones
Acosta	2003	Distribution of mammals and 40 taxa of fleas in Querétaro
Hastriter	2004	Revision of <i>Jellisonia</i> and records in Durango and Guanajuato
Acosta	2005	Relationship of host–parasite in Querétaro
Fernández and Acosta	2005	First flea records on <i>Dipodomys nelsoni</i> in Durango
Acosta, Fernández, and Falcón-Ordaz	2006	Report eight fleas species in Durango and Querétaro
Salceda-Sánchez and Hastriter	2006	List of Mexican fleas species, including states with desert regions
Acosta et al.	2008	Second catalog of fleas at the Colección del Museo de Zoología (MZFC) with records of states with desert zones

respectively; and Falcón-Ordaz, Acosta, Fernández, and Lira-Guerrero (2012) documented ecto- and endo-parasites of 5 rodent species in the OB.

The objective of this work was to increase the existing inventory of fleas and rodents in the OB. Based on the specimens collected, mean abundance and prevalence of fleas species were calculated; likewise, their associations with rodent species were

analyzed. Furthermore, habitat and host preferences, and host and parasite diversity, were also discussed.

Materials and methods

The OB is an arid or semi-arid region located among the southeastern mountains of the Trans-Mexico Volcanic Axis (TMVA; Fig. 1), between 19°42'00" and 18°57'00" N, 98°02'24" and 97°09'00" W. The OB is shared among the states of Puebla, Tlaxcala, and Veracruz, and is a relatively small area (5,000 km² approximately) characterized by grassland, alkaline grassland, thorn scrub and corn fields (Valdéz & Ceballos, 1997).

Rodent sampling was carried out during June 2007, 2009, and 2010, and during July 2008, in 10 localities (Fig. 1; Table 2). Rodents were taken with collecting permits FAUT-0002 and FAUT-0219 granted to F. A. Cervantes and J. J. Morrone, respectively. Mammal specimens were housed at Colección Nacional de Mamíferos (CNMA), Instituto de Biología, Universidad Nacional Autónoma de México (UNAM), and at the Museum of Natural Science (LSUMZ), Louisiana State University. The collected fleas were housed at Colección de Siphonaptera “Alfonso L. Herrera”, Museo de Zoología (MZFC), Facultad de Ciencias, UNAM.

Rodents were trapped using standard methods approved by the American Society of Mammalogists (Kelt, Hafner, & The American Society of Mammalogists' ad hoc Committee for guidelines on handling rodents in the field, 2010; Sikes, Gannon, & the Animal Care and Use Committee of the American Society of Mammalogists, 2011). Sherman traps were baited with oatmeal, and captured rodents were identified in the field or at the laboratory using taxonomic keys (Hall, 1981).

Table 2
States, sampling localities, vegetation, elevation, and geographic coordinates of sampling areas in the Oriental Basin (OB), Mexico.

State	Localities	Vegetation	Altitude	Geographic coordinates
Puebla	Chalchicomula de Serna, 3 km S Cd. Serdán junction	Desert scrub	8,320 ft	19°00'32.5" N, 97°33'21.3" W
	Cd. Serdán – Esperanza, direction Santa Catarina	Crop/farming – sandy soil	7,893 ft	19°16'49.7" N, 97°22'41.4" W
	Guadalupe Victoria, 2 km W Guadalupe Victoria.	Crop/farming – sandy soil	7,874 ft	19°18'56.8" N, 97°25'58.4" W
	Guadalupe Victoria, 9.6 km W Guadalupe Victoria.	Crop/farming – sandy soil	7,874 ft	19°18'56.8" N, 97°25'58.4" W
	La Esperanza, 2 km W La Esperanza	Crop/farming – Agave fields	8,349 ft	18°50'31.0" N, 97°23'09.1" W
	Oriental, 1 km S Oriental	Desert scrub	7,742 ft	19°21'10" N, 97°38'07.8" W
	Oriental, 1.5 km S Oriental.	Desert scrub	7,742 ft	19°21'10" N, 97°38'07.8" W
Tlaxcala	Quimixtlan, 10 km NE Huaxcaleca.			19°13'59" N, 94°4'46" W
	San Salvador El Seco, 1 km S Coyotepec	Desert scrub	7,988 ft	19°00'32.5" N, 97°33'21.3" W
Tlaxcala	El Carmen Tequexquitla, 2.5 km El Carmen.	Desert scrub	7,801 ft	19°21'00.4" N, 97°39'54.5" W
Veracruz	Perote, 3 km S El Frijol Colorado	Crop/farming	7,988 ft	19°34'20.4" N, 97°23'00.7" W

Table 3

Fleas from rodent species in the OB, Mexico (Nt = number of total individuals, Ni = number of infested individuals, MA = abundance, P = prevalence %).

Species of rodents	Nt	Ni	Species of fleas	Nt	MA	P %
<i>Heteromys irroratus</i>	17	15	<i>Echidnophaga gallinacea</i>	2	0.117	5.8
			<i>Polygenis vazquezi</i>	68	4	76.4
			<i>Plusaetis parus</i>	1	0.058	5.8
<i>Dipodomys phillipsii</i>	12	10	<i>Meringis altipecten</i>	41	2.41	83.3
			<i>Anomiopsyllus perotensis</i>	2	1.166	8.3
			<i>Plusaetis parus</i>	1	0.083	8.3
			<i>Polygenis vazquezi</i>	1	0.014	1.4
<i>Peromyscus difficilis</i>	68	68	<i>Anomiopsyllus sinuatus</i>	3	0.0441	2.94
			<i>Anomiopsyllus perotensis</i>	1	0.014	1.4
			<i>Strepsylla villai</i>	7	0.1029	8.8
			<i>Jellisonia (Jellisonia) breviloba barrerai</i>	1	0.014	1.4
			<i>Jellisonia (Jellisonia) breviloba breviloba</i>	2	0.0294	1.4
			<i>Pleochaetis mundus</i>	6	0.088	7.35
			<i>Plusaetis mathesoni</i>	34	0.5	29.5
			<i>Plusaetis parus</i>	95	1.397	67.6
			<i>Meringis altipecten</i>	8	0.4210	21.05
			<i>Jellisonia (Jellisonia) breviloba breviloba</i>	3	0.157	10.5
			<i>Jellisonia (Jellisonia) breviloba barrerai</i>	1	0.0526	5.26
<i>Peromyscus maniculatus</i>	19	16	<i>Jellisonia (Jellisonia) hayesi</i>	1	0.0526	5.26
			<i>Pleochaetis mundus</i>	20	1.526	42.10
			<i>Plusaetis apollinaris</i>	1	0.0526	5.26
			<i>Plusaetis mathesoni</i>	1	0.0526	5.26
			<i>Plusaetis parus</i>	2	0.105	5.26
			<i>Kohlsia whartoni</i>	2	1	100
			<i>Plusaetis parus</i>	1	0.5	50
			<i>Ctenophthalmus micropus</i>	3	1.5	50
			<i>Jellisonia (Pleochaetoides) wisemani</i>	1	0.5	50
			<i>Pleochaetis mundus</i>	1	0.5	50
<i>Peromyscus levipes</i>	2	2	<i>Plusaetis apollinaris</i>	2	1	100
			<i>Plusaetis parus</i>	1	0.5	50
			<i>Plusaetis parus</i>	3	1.5	50
			<i>Jellisonia (Pleochaetoides) wisemani</i>	1	0.5	50
<i>Peromyscus furvus</i>	2	2	<i>Pleochaetis mundus</i>	1	0.5	50
			<i>Plusaetis apollinaris</i>	2	1	100
			<i>Plusaetis parus</i>	7		
<i>Peromyscus sp.</i>	7	7	<i>Plusaetis mathesoni</i>	13	1.857	28.5
			<i>Plusaetis parus</i>	6	0.857	57.14
			<i>Plusaetis parus</i>	3	1.5	100
<i>Reithrodontomys megalotis</i>	7	5	<i>Plusaetis parus</i>	3	1.5	100
<i>Reithrodontomys fulvescens</i>	2	2	<i>Opisocrostis hirsuta</i>	1	1	100
<i>Xerospermophilus perotensis</i>	1	1	<i>Meringis altipecten</i>	2	2	100
<i>Cratogeomys fulvescens</i>	1	1	<i>Dactylopsylla megasona</i>	3	3	100

Fleas were collected by brushing every rodent with a toothbrush, and they were subsequently placed in vials filled with 80% ethanol. Siphonapterans were mounted on slides following Smit (1957). Fleas were determined to species level using taxonomic keys by Acosta and Morrone (2003), Barnes, Tipton, and Wildie (1977), Hastriter (2004), Hopkins and Rothschild (1956, 1962, 1966), Linardi and Guimarães (2000), Stark (1958), Traub (1950), and Traub et al. (1983). For each host species the following indices and parameters were calculated: flea species richness (S = number of species), mean abundance (MA = total number of individuals of a parasite species on a host/total number of species, including infested and non-infested species), and prevalence ($[P = \text{number of infested animals with 1 or more individuals of a parasite species/total number of examined mammals for that parasite species}] * 100$). The Shannon–Wiener diversity index ($H = -\sum [p_i \ln p_i]$) was also calculated for hosts and parasites (Begon, Harper, & Townsend, 1988; Bush, Lafferty, Lotz, & Shostak, 1997).

Results

A total of 144 rodents belonging to 10 species ($H = 1.450$), 4 families (Muridae, Heteromyidae, Sciuridae and Geomyidae), and 6 genera were recorded, of which 133 were parasitized by 350 fleas belonging to $S = 18$ species ($H = 1.860$), 11 genera, and 4 families (Pulicidae, Rhopalopsyllidae, Ctenophthalmidae, and Ceratophyllidae).

Peromyscus difficilis (J. A. Allen, 1891) had the highest parasite richness of $S = 9$, followed by *P. maniculatus* (Wagner, 1845) with $S = 8$ species. The rodent species with the smallest number of fleas were the fulvous harvest mouse *Reithrodontomys fulvescens* J. A. Allen, 1894 and the Perote ground squirrel *Xerospermophilus pilosoma perotensis* with only 1 species each (Table 1).

The most abundant fleas in the OB were *Polygenis vazquezi* Vargas, 1951, *Plusaetis parus* (Traub, 1950), *Meringis altipecten* Traub and Hoff, 1951, and *Plusaetis mathesoni* (Traub,

1950; Table 3). Differences were found in flea prevalence on rodent species (Table 3). *Meringis altipecten* (83.3%) on Phillips' kangaroo rat *Dipodomys phillipsii* Gray, 1841, *P. vazquezi* on the Mexican spiny pocket mouse *Heteromys irroratus* (Gray, 1868) (76.4%), and *P. parus* (67.6%) on the rock mouse *Peromyscus difficilis*, show the highest rodent-specific prevalence values, above 50% of prevalence (some species have values of 100% but these were not taken into account by the sample size). The total prevalence value for the OB was 92.3%, meaning that most rodent species harbor at least 1 species of flea. The largest overall prevalence values in fleas in the OB were *P. parus* (42.36%), *P. mathesoni* (16.6%), *P. mundus* (Jordan and Rothschild, 1922) (12.5%), and *M. altipecten* (11.8%) (Table 4), besides being shared species in 3 states, on the other hand, smallest prevalence values for fleas were *Opisocrostitis hirsuta* Jordan, 1933, *Dactylopsylla megasona*, *Jellisonia (Jellisonia) hayesi* Traub, 1950, and *Echidnophaga gallinacea* (Westwood, 1875), with a value of 0.69% in each case.

The fleas that were found on most of the hosts were: *Plusaetis parus* on 7 rodent species (Table 3), followed by *P. mundus* on 4 species, *P. mathesoni*, and *M. altipecten* on 3 species, respectively.

In the OB, 7 species were found representing new records for 3 states, Tlaxcala (1 species), Puebla (3), and Veracruz (3; Table 4).

Table 4
Fleas species collected in the Oriental Basin, Central Mexico.

Species of fleas	Tlaxcala	Veracruz	Puebla	P%
Pulicidae				
<i>Echidnophaga gallinacea</i>			X	0.69
Rhopalopsyllidae				
<i>Polygenis vazquezi</i>	X ^a	X	X	9.7
Ctenophthalmidae				
<i>Anomiopsyllus perotensis</i>		X	X ^a	1.38
<i>Anomiopsyllus sinuatus</i>		X ^a	X ^a	1.38
<i>Ctenophthalmus micropus</i>			X	0.69
<i>Meringis altipecten</i>	X	X	X	11.8
<i>Strepsylla villai</i>		X ^a		4.16
Ceratophyllidae				
<i>Dactylopsylla megasona</i>		X ^a		0.69
<i>Jellisonia (Jellisonia) breviloba barrerae</i>	X		X	2.14
<i>Jellisonia (Jellisonia) breviloba breviloba</i>			X	1.38
<i>Jellisonia (Jellisonia) hayesi</i>	X			0.69
<i>Jellisonia (Pleochaetoides) wisemani</i>			X	0.69
<i>Kohlsia whartoni</i>			X	1.38
<i>Opisocrostitis hirsuta</i>			X ^a	0.69
<i>Plusaetis parus</i>	X	X	X	42.36
<i>Plusaetis mathesoni</i>	X	X	X	16.6
<i>Plusaetis apollinaris</i>	X		X	2.14
<i>Pleochaetis mundus</i>	X	X	X	12.5
Total				92.3

P = prevalence %.

^a New record in the state.

Discussion

This is one of the first studies on basic parasite ecology in the OB. Previous works in the OB (Acosta & Fernández, 2009; Falcón-Ordaz et al., 2012) reported 11 flea species on 6 rodent species. Here we duplicated host and parasite numbers by visiting more localities, allowing us to have a greater representation of species and a better understanding of interactions inside rodent and parasite communities.

For this work, only the dry valleys of the OB were sampled. However, this area shows habitat variety such as small hills alternated with plains covered by native vegetation or agriculture fields (Valdéz & Ceballos, 1997). This habitat mosaic allows several rodent species and other mammals to live there, as well as their ectoparasites. Flea and rodent diversity was low with values below 2 (Begon et al., 1988).

However, Lareschi, Ojeda, and Linardi (2004) in a desert biome in Argentina, obtained similar values and reported that the diversity of fleas is high. Here we can consider that diversity was higher in fleas than in rodents, probably because fleas are more abundant and diverse in small and medium sized mammals (Krasnov, Shenbrot, Medvedev, Vatschenok, & Khokhlova, 1997), and/or because most fleas are generalists, meaning that 1 flea species may parasitize more than 1 host species (Marshall, 1981; Traub, 1985). Additionally, flea diversity in an area is not determined only by host species, but by environmental parameters inherent to the habitat, that will determine nest and den conditions (temperature, humidity, and construction material; Krasnov et al., 1997). All these characteristics will complete basic flea needs like food, habitat and mating opportunities (Marshall, 1981), favoring flea species and population abundance.

Total flea prevalence for the OB is >90% for rodents, but fleas with the highest prevalence were *Plusaetis parus*, *P. mathesoni*, *M. altipecten*, and *Polygenis vazquezi*. The first one was found in more than 40% of the rodents collected in the OB. Fleas of the genus *Plusaetis* are very diverse in Mexico, and very abundant (Ponce & Llorente, 1996) in central and southern parts of the country.

Most of the flea species collected here were previously found in the states forming the OB (Tlaxcala, Puebla, or Veracruz; Acosta et al., 2008; Acosta & Fernández, 2009; Ayala-Barajas, Morales, Wilson, Llorente, & Ponce, 1988; Table 4), but some of the species reported here are new records for Tlaxcala (*Polygenis vazquezi*), Puebla (*Anomiopsyllus perotensis* Acosta and Fernández, 2009, *A. sinuatus* Holland, 1965, and *Opisocrostitis hirsuta* Baker, 1895), and Veracruz (*Strepsylla villai* Traub and Barrera, 1955, *A. sinuatus*, *Dactylopsylla megasona*, and *O. hirsuta*).

The record of *Opisocrostitis hirsuta* is relevant because it is the first siphonapteran collected on the OB endemic *Xerospermophilus spilosoma perotensis* (the Perote ground squirrel). Hall and Dalquest (1963) collected flea specimens from this species, but they did not publish their findings. According to Best and Ceballos (1995) there are no ectoparasite record for this taxa. On the other hand, Fernández (2012) recently suggested the inclusion of *X. perotensis* as a *X. spilosoma* subspecies. For *X.*

spilosoma there are several flea records (*Thrassis pansus* (Jordan, 1925), *T. fotus* (Jordan, 1925), and *E. gallinacea*; Streubel, 1975; Sumrell, 1949). However, *O. hirsuta* is not mentioned.

Peromyscus difficilis is an endemic rodent with a wide distribution in Mexico, and fleas from at least 5 families have been collected on this species. However, *Polygenis vazquezi* is a new record (Fernández, García-Campusano, & Hafner, 2010). Most of the existing records were obtained from the northern part of its distribution (Acosta, 2003, 2005; Acosta et al., 2008; Ayala-Barajas et al., 1988; Barrera, 1953, 1968; Hastriter, 2004; Tipton & Méndez, 1968) and include the following families and species: Ctenophthalmidae: *Anomiopsyllus sinuatus*, *Ctenophthalmus haagi* Traub, 1950, *C. micropus* Traub, 1950 (T. M. Pérez-Ortiz, personal communication), *C. pseudagrytes* Baker, 1904, *C. tecpin* Morrone et al., 2000, *Epitedia wernmanni* (Rothschild, 1904), *Meringis arachis* (Jordan, 1929), *Stenoponia ponera* Traub & Johnson, 1952, *Strepsylla mina* Traub, 1950, *S. taluna* Traub & Johnson, 1952, *S. villai* and *S. davisae* Traub & Johnson, 1952; Hystricopsyllidae: *Atyphloceras tancitari* Traub & Johnson, 1952, *Hystriochopsylla llorentei* Ayala & Morales, 1990, and *H. occidentalis* Holland, 1949; Ceratophyllidae: *Jellisonia breviloba* Traub, 1950, *J. grayi* Hubbard, 1958, *J. hayesi* Traub, 1950, *J. ironsi* (Eads, 1947), *J. wisemani* Eads, 1951, *Kohlsia martini* Holland, 1971, *K. pelaezi* Barrera, 1956, *Pleochaetis mundus*, *P. paramundus* Traub, 1950, *Plusaetis apollinaris* (Jordan & Rothschild, 1921), *P. asetus* (Traub, 1950), *P. aztecus* (Barrera, 1954), *P. dolens* (Jordan & Rothschild, 1914), *P. mathesoni*, *P. sibynus* (Jordan, 1925), *P. soberoni* (Barrera, 1958), and 1 species of the genus *Thrassis*; Leptopsyllidae: *Peromyscopsylla hesperomys* (Baker, 1904), and Pulicidae: *Echidnophaga gallinacea*, and *Euhoplopsyllus glacialis* (Taschenberg, 1880).

For *R. fulvescens*, 2 fleas have been recorded: *Peromyscopsylla scotti* Fox, 1939 and *Orchopeas leucopus* (Baker, 1904) in Texas (McAllister & Wilson, 1992), and there are records of specimens of the genus *Polygenis* in Mexico (Petersen, 1978; Spencer & Cameron, 1982). Several fleas have been collected for the nimble-footed mouse *Peromyscus levipes* Merriam, 1898 (Acosta, 2003; Whitaker & Morales-Malacara, 2005). Here we found *Kholsia warthoni* Traub & Johnson, 1952 representing a new record for this rodent.

The flea *Dasypsyllus megasoma* has only been recorded in Distrito Federal, State of México, and Oaxaca, on Merriam's Pocket gopher (*Cratogeomys merriami*). Hafner et al. (2005) studied the *C. merriami* complex and elevated the Oriental basin Pocket Gopher *Cratogeomys fulvescens* to specific level. Here, we reported for the first time a flea species for *C. fulvescens* and for the state of Veracruz, being a new host and locality record. The record of *Meringis altipecten* for *C. fulvescens* is considered as accidental because this flea has been found mainly on heteromyid rodents, as well as on the genus *Polygenis* (Whitaker, Wren, & Lewis, 1993). As Marshall (1981) pointed out, flea presence in not common hosts might be due to accidental transference or parasite interchange while visiting the nest or other rodent dens.

In *Heteromys irroratus* 3 flea species have been reported previously (*Hoplopsyllus glacialis* Taschenberg 1880, *Polygenis*

gwyni (Fox, 1914), and *P. martinezbaezi* Vargas, 1951; Eads & Menzies, 1949; Eads, 1950; Genoways, 1973). Another 3 flea species were found for this rodent in the OB. The blackish deer mouse *Peromyscus furvus* was known for harboring only 1 flea species: *Ctenophthalmus pseudagrytes*. Here we reported another 4 distinct flea species (Table 1). Until Jones and Genoways (1975) publication, not a single ectoparasite was known for *D. phillipsii*. Recently Vargas, Pérez, and Polaco (2009) reported 3 species of acari and here we reported 3 fleas parasitizing *D. phillipsii*.

On the other hand, the harvest mouse (*R. fulvescens*), and the Perote ground squirrel (*X. spilosoma perotensis*) were only parasitized by 1 flea species. However, these records may not be representative because only a few specimens of these rodents were collected. Collection of the Perote ground squirrel was restricted because it is an endangered taxon (Semarnat, 2010), and it is not distributed in every sampled locality.

Fleas were collected in 4 summer seasons, and flea abundance values were high, probably because rodent abundance is high in this season. Particularly, *P. difficilis* is very abundant, which can explain flea abundance. As mentioned by Morand and Poulin (1998), and Krasnov and Matthee (2010), population density is an important factor influencing dispersion and/or propagation, and distribution of parasites among individuals, as well as parasite specific richness. This fact might explain seasonal abundance. Collecting trips during winter would add valuable information about parasites population behavior.

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References

- Acosta, R. (2003). New records of rodent fleas from Querétaro, Mexico (Siphonaptera). *Zootaxa*, 369, 1–15.
- Acosta, R. (2005). Relación huésped-parásito en pulgas (Insecta: Siphonaptera) y roedores (Mammalia: Rodentia) del estado de Querétaro. *Folia Entomologica Mexicana*, 4, 37–47.
- Acosta, R. (2014). Biodiversidad de Siphonaptera en México. *Revista Mexicana de Biodiversidad (Suplem. Biodiversidad de México)*, 85, 345–352.
- Acosta, R., Fernández, J. A., & Falcón-Ordaz, J. (2006). New records of mammal fleas (Siphonaptera) in northern and central Mexico. *Entomological News*, 117, 69–72.
- Acosta, R., Fernández, J. A., Llorente, J., & Jimenez, M. C. (2008). *Catálogo de pulgas (Insecta: Siphonaptera), Serie de Catálogos del Museo de Zoología "Alfonso L. Herrera" UNAM*. México, D.F.: Las Prensas de Ciencias.
- Acosta, R., & Fernández, J. A. (2009). A new species of *Anomiopsyllus* Baker, 1904 (Insecta: Siphonaptera), and noteworthy records of fleas from Nelson's Woodrat, *Neotoma nelsoni* (Rodentia: Cricetidae), in the Oriental Basin, México. *Journal of Parasitology*, 95, 532–535.

- Acosta, R., & Morrone, J. J. (2003). Clave ilustrada para la identificación de los taxones supraespecíficos de Siphonaptera de México. *Acta Zoológica Mexicana Nueva Serie*, 89, 39–53.
- Ayala-Barajas, R., Morales, J. C., Wilson, N., Llorente, J. E., & Ponce, H. E. (1988). *Catálogo de las pulgas (Insecta: Siphonaptera) en el Museo de Zoología, Facultad de Ciencias, Universidad Nacional Autónoma de México. I. Colección Alfredo Barrera*. México, D.F.: Serie de Catálogos del Museo de Zoología “Alfonso L. Herrera”, UNAM.
- Barnes, A. M., Tipton, V. J., & Wildie, J. A. (1977). The subfamily Anomiopsyllinae (Hystrichopsyllidae: Siphonaptera). I. A revision of the genus *Anomiopsyllus* Baker. *Great Basin Naturalist*, 37, 138–206.
- Barrera, A. (1953). Sinopsis de los sifonápteros de la Cuenca de México (Ins., Siph.). *Anales de la Escuela Nacional de Ciencias Biológicas*, 7, 155–245.
- Barrera, A. (1968). Distribución cliserial de los Siphonaptera del Volcán Popocatepetl, su interpretación biogeográfica. *Anales del Instituto de Biología, Universidad Nacional Autónoma de México (Serie Zoología)*, 39, 35–100.
- Begon, M., Harper, J. L., & Townsend, C. R. (1988). *Ecología, individuos, poblaciones y comunidades*. Barcelona: Omega.
- Best, T. L., & Ceballos, G. (1995). *Spermophilus perotensis*. *Mammalian Species*, 507, 1–3.
- Brooks, T. M., da Fonseca, G. A. B., & Rodrigues, A. S. L. (2004a). Protected areas and species. *Conservation Biology*, 18, 616–618.
- Brooks, T. M., da Fonseca, G. A. B., & Rodrigues, A. S. L. (2004b). Species, data, and conservation planning. *Conservation Biology*, 18, 1682–1688.
- Bush, A. O., Lafferty, K. D., Lotz, J. M., & Shostak, A. W. (1997). Parasitology meets ecology on its own terms: Margolish et al. revisited. *Journal of Parasitology*, 83, 575–583.
- Christe, P., Michaux, J., & Morand, S. (2006). Biological conservation and parasitism. In S. Morand, B. R. Krasnov, & R. Poulin (Eds.), *Micromammals and macroparasites: from evolutionary ecology to management* (pp. 593–613). New York: Springer-Verlag.
- Eads, R. B. (1950). *The fleas of Texas*. Austin: Texas State Health Department.
- Eads, R. B., & Menzies, G. C. (1949). A preliminary list of the Siphonaptera of Texas. *Texas Journal of Science*, 1, 33–39.
- Falcón-Ordaz, J., Acosta, R., Fernández, J. A., & Lira-Guerrero, G. (2012). Helmintos y sifonápteros parásitos de cinco especies de roedores en localidades de la Cuenca Oriental, en el centro de México. *Acta Zoológica Mexicana (nuevaserie)*, 28, 287–304.
- Fernández, J. A. (2012). Phylogenetics and biogeography of the microendemic rodent *Xerospermophilus perotensis* (Perote ground squirrel) in the Oriental Basin of Mexico. *Journal of Mammalogy*, 93, 1431–1439.
- Fernández, J. A., & Acosta, R. (2005). First records of fleas (Insecta: Siphonaptera) from the Nelson’s kangaroo rat *Dipodomys nelsoni* (Rodentia: Heteromyidae) in Durango, Mexico. *Journal of New York Entomological Society*, 113, 230–233.
- Fernández, J. A., García-Campusano, F., & Hafner, M. S. (2010). *Peromyscus difficilis*. *Mammalian Species*, 42, 220–229.
- Ferrier, S., Powell, G. V. N., Richardson, K. S., Manion, G., Overton, J. M., Allnutt, T. F., et al. (2004). Mapping more of terrestrial biodiversity for global conservation assessment. *Bioscience*, 54, 1101–1109.
- Genoways, G. G. (1973). Systematics and evolutionary relationships of spiny pocket mice, genus *Liomys*. *Special Publications Museum Texas Tech University*, 5, 1–368.
- González-Ruíz, N., & Álvarez-Castañeda, S. T. (2005). *Peromyscus bullatus*. *Mammalian Species*, 770, 1–3.
- González-Ruíz, N., Ramírez-Pulido, J., & Genoways, H. H. (2006). Geographic distribution, taxonomy, and conservation status of Nelson’s woodrat (*Neotoma nelsoni*) in Mexico. *The Southwestern Naturalist*, 51, 112–116.
- Gutiérrez-Velázquez, A. L., Acosta, R., & Ortiz, L. (2006). Distribución del orden Siphonaptera. In J. J. Morrone, & J. Llorente (Eds.), *Componentes bióticos principales de la entomofauna mexicana* (pp. 591–628). México, D.F.: Las prensas de Ciencias.
- Hafner, M. S., Light, J. E., Hafner, D. J., Brant, S. V., Spradling, T. A., & Demastes, J. W. (2005). Cryptic species in the Mexican pocket gopher *Cratogeomys merriami*. *Journal of Mammalogy*, 86, 1095–1108.
- Hafner, D. J., & Riddle, B. R. (2005). Mammalian phylogeography and evolutionary history of Northern Mexico’s deserts. In J. L. Cartron, G. Ceballos, & R. S. Felger (Eds.), *Biodiversity, ecosystems, and conservation in Northern Mexico* (pp. 225–245). New York: Oxford University Press.
- Hall, E. R. (1981). *The mammals of North America*. New York: John Wiley & Sons.
- Hall, E. R., & Dalquest, W. W. (1963). The mammals of Veracruz. *University of Kansas, Publications Museum of Natural History*, 14, 165–362.
- Hastriter, W. M. (2004). Revision of the flea genus *Jellisonia* Traub, 1944 (Siphonaptera: Ceratophyllidae). *Annals of Carnegie Museum*, 73, 213–238.
- Holland, G. P. (1965). New species and subspecies of *Anomiopsyllus* Baker from Mexico (Siphonaptera: Hystrichopsyllidae). *The Canadian Entomologist*, 97, 1051–1058.
- Hopkins, G. H. E., & Rothschild, M. (1956). *An illustrated catalogue of the Rothschild collection of fleas (Siphonaptera) in the British Museum of Natural History. II. Coptosyllidae, Vermipsyllidae, Stephanocircidae, Ischnopsyllidae, Hypsophthalmidae and Xiphopsyllidae [Macropsyllidae]*. London: British Museum of Natural History.
- Hopkins, G. H. E., & Rothschild, M. (1962). *An illustrated catalogue of the Rothschild collection of fleas (Siphonaptera) in the British Museum of Natural History. III. Hystrichopsyllidae (Acedestiinae, Anomiopsyllinae, Hystrichopsyllinae, Neopsyllinae, Rhadinopsyllinae and Stenoponiinae)*. London: British Museum of Natural History.
- Hopkins, G. H. E., & Rothschild, M. (1966). *An illustrated catalogue of the Rothschild Collection of fleas (Siphonaptera) in the British Museum of Natural History. IV. Hystrichopsyllidae*. London: British Museum of Natural History.
- Jones, J. K., & Genoways, H. H. (1975). *Dipodomys phillipsii*. *Mammalian Species*, 51, 1–3.
- Kelt, D. A., Hafner, M. S., & The American Society of Mammalogists’ Ad Hoc Committee for guidelines on handling rodents in the field. (2010). Updated guidelines for protection of mammalogists and wildlife researchers from hantavirus pulmonary syndrome (HPS). *Journal of Mammalogy*, 91, 1524–1527.
- Krasnov, B. R., & Matthee, S. (2010). Spatial variation in gender-biased parasitism: host-related, parasite-related and environment-related effects. *Parasitology*, 137, 1526–1537.
- Krasnov, B. R., Shenbrot, G. I., Medvedev, S. G., Vatschenok, V. S., & Khokhlova, I. S. (1997). Host–habitat relations as an important determinant of spatial distribution of flea assemblages (Siphonaptera) on rodents in the Negev Desert. *Parasitology*, 114, 159–173.
- Lareschi, M., Ojeda, R., & Linardi, P. M. (2004). Flea parasites of small mammals in the Monte Desert biome in Argentina with new host and locality records. *Acta Parasitologica*, 49, 63–66.
- Linardi, M. P., & Guimarães, L. R. (2000). *Sifonápteros do Brasil*. São Paulo: Museu de Zoologia.
- Marshall, A. (1981). *The ecology of ectoparasitic insects*. London: Academic Press.
- McAllister, C. T., & Wilson, N. (1992). Two additions to the flea (Siphonaptera: Hystrichopsyllidae, Leptopsyllidae) fauna of Texas. *Texas Journal of Science*, 442, 245–247.
- Morand, S., & Poulin, R. (1998). Density, body mass and parasite species richness of terrestrial mammals. *Evolutionary Ecology*, 12, 717–727.
- Petersen, M. K. (1978). *Rodent ecology and natural history observations on the mammals of Atotonilco de Campa, Durango, Mexico*. Ames, IA: Carter Press.
- Ponce, H. E., & Llorente, J. E. (1996). Siphonaptera. In J. E. Llorente, A. N. García, & E. González (Eds.), *Biodiversidad, taxonomía y biogeografía de artrópodos de México: hacia una síntesis de su conocimiento* (pp. 553–565). México, D.F.: Instituto de Biología, UNAM, Conabio y Facultad de Ciencias, UNAM.
- Rothschild, M. (1975). Recent advances in our knowledge of the order Siphonaptera. *Annual Review of Entomology*, 20, 241–259.
- Salceda-Sánchez, B., & Hastriter, M. W. (2006). A list of the fleas (Siphonaptera) of Mexico with new host and distribution records. *Zootaxa*, 1296, 2–43.
- Semarnat (Secretaría de Medio Ambiente y Recursos Naturales). (2010). Norma Oficial Mexicana NOM-059-SEMARNAT-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. Diario Oficial de la Federación 6 de Septiembre de 2010. Retrieved from http://dof.gob.mx/nota_detalle.php?codigo=5173091&fecha=30/12/2010
- Shreve, F. (1942). The desert vegetation of North America. *Botanical Review*, 8, 195–246.
- Sikes, R. S., Gannon, W. L., & the Animal Care and Use Committee of the American Society of Mammalogists. (2011). Guidelines of the American Society of Mammalogists for the use of wild mammals in research. *Journal of Mammalogy*, 92, 235–253.
- Smit, F. G. A. M. (1957). *Handbook for the identification of British insects (Siphonaptera)* (Vol. 1. Part 16) London: Royal Entomological Society of London.
- Spencer, S. R., & Cameron, G. N. (1982). *Reithrodontomys fulvescens*. *Mammalian Species*, 174, 1–7.
- Stark, H. E. (1958). *The Siphonaptera of Utah*. Atlanta: U.S. Department of Health, Education, and Welfare.
- Streubel, D. P. (1975). *Behavioral features of sympatry of Spermophilus pilosoma and Spermophilus tridecemlineatus and some aspects of the life history of S. pilosoma* Doctor of Arts dissertation. Greeley: University of Northern Colorado.
- Sumrell, F. (1949). *A life history study of the ground squirrel Citellus pilosoma major (Merriam)*, Ms. thesis. Albuquerque: University of New Mexico.
- Tipton, V. H., & Méndez, E. (1968). New species of fleas (Siphonaptera) from Cerro Potosí, México, with notes on ecology and host–parasite relationships. *Pacific Insects*, 10, 177–214.
- Traub, R. (1950). Siphonaptera of Central America and Mexico. A morphological study of the aedeagus with descriptions of new genera and species. *Fieldiana Zoology*, 1, 1–127.
- Traub, R. (1985). Coevolution of fleas and mammals. In K. C. Kim (Ed.), *Coevolution of parasitic arthropods and mammals* (pp. 295–437). New York: Wiley-Inter-Science.
- Traub, R., & Hoff, C. (1951). Records and descriptions of fleas from New Mexico. *American Museum Novitates*, 1530, 1–23.
- Traub, R., Rothschild, M., & Haddow, J. (1983). *The Ceratophyllidae*. London: Robert Trauband Miriam Rothschild Publ. (British Museum).
- Valdéz, M., & Ceballos, G. (1997). Conservation of endemic mammals of Mexico: the Perote ground squirrel (*Spermophilus perotensis*). *Journal of Mammalogy*, 78, 74–82.
- Vargas, M., Pérez, T. M., & Polaco, O. J. (2009). The genus *Geomylichus* Fain (Acari: Lirophoridae) from Mexico, with descriptions of four new species. *International Journal of Acarology*, 25, 3–12.
- Whitaker, J. O., & Morales-Malacara, J. E. (2005). Ectoparasites and other associates (ectodytes) of mammals of Mexico. In V. Sánchez-Cordero, & R. A. Medellín (Eds.), *Contribuciones mastozoológicas en homenaje a Bernardo Villa* (pp. 535–666). México, D.F.: Instituto de Biología, UNAM/Instituto de Ecología, UNAM/Conabio.
- Whitaker, J. O., Wren, J. W., & Lewis, R. E. (1993). Parasites. In H. H. Genoways, & J. H. Brown (Eds.), *Special publication No. 10 Biology of the Heteromyidae* (pp. 386–478). Provo, Utah: The American Society of Mammalogists.
- Wilson, E. O. (1992). *The diversity of life*. New York, Cambridge: Belknap Press, WW Norton.