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Scientific Research

Potential Species Distribution and Richness of Ixodidae Ticks Associated with Wild Vertebrates from Michoacán, Mexico

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Abstract

Ticks are regarded as the most relevant vectors of disease-causing pathogens in domestic and wild animals. The diversity of Ixodidae is known for a very small number of genera. *Ixodes* are represented by 26 species, and in 2007 the first reported ticks vectors in Mexico for the causal agent of Lyme disease. Recent rise in tick-borne disease in many parts of the world is a phenomenon in need of an explanation. The main objective of the present work was to map at a regional scale (1:2,000,000) of the distribution of ticks of the family Ixodidae that are potentially present on the wild fauna of state of Michoacan, Mexico. We compiled all available literature on ticks at a national level together with complete cartographic and bibliographic georeferenced information of the distribution of hosts in order to build a spatial database in ArcView 3.3. The results indicated that the wild fauna in the state's territory could potentially include 31 species of ticks of Ixodidae. The map of potential species richness of ixodid ticks on the wild fauna of the state can be categorized into five classes of species richness. The highest potential concentration of ixodid species on wild fauna occurs in the volcanic area of Pico de Tancítaro.

Keywords

Ticks, Ixodidae, Michoacán, Geographic Distribution, Potential Species Richness

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1. Introduction

Ticks (Acari: Ixodida) are external parasites of terrestrial vertebrates that feed on blood and tissue of their hosts; and are considered to be the second only to mosquitoes worldwide vectors of human diseases, but they are regarded as the most prevalent vectors of disease-causing pathogens in domestic and wild animals [1], and transmit more pathogen species than any other group of blood-feeding arthropods worldwide [2]. In cases of high infestations, blood loss can be sufficiently extensive to cause the death of small animals [3]. For the development and implementation of control strategies, it is important to identify the vector ticks and their transmission pattern of the pathogens in the target geographical region [4]. However, damage caused by ticks may be still more important because they are vectors of pathogenic organisms that are directly transmitted to vertebrates during attachment and feeding, or indirectly through contact with tick fluids released with the products of coxal glands or with feces.

Ticks are grouped into three families: Argasidae (193 species), Ixodidae (702 species) and Nuttalliellidae (monotypic) [5]. Only the first two families are known from Mexico.

Ticks have been reported by indigenous since Pre Hispanic times, including the Tarascas people from Michoacán, Mexico; who called them *turicata* [6] [7]. However, knowledge of the number of tick species and of their distribution in Mexico is very scarce. The diversity of Ixodidae is known for a very small number of genera. In Mexico some specilist [8], one of the most species-rich genera worldwide recorded 26 species of *Amblyomma*. *Ixodes* are represented by 26 species [9] [10], Vargas and cols [11] for the first time reported in Mexico species Ixodidae vectoring the causal agent of Lyme disease, the spirochatae *Borrelia burgdorferi* and added six new ixodid species records for the country. Hoffmann and Lopéz-Campos [12] recorded 52 valid species of 5 genera for Mexico. Since then, 23 records have been added, accumulating a total of 75 species in 5 genera of Ixodidae known from Mexico [9]-[11].

In Michoacán, as in certain other states from Mexico, problems associated with the drug trade make it unsafe for biologist to collect in certain areas. In addition, high rates of changes in environment and land use [13] are causing local extinctions and changes in distribution of wildlife that are hosts of many species of ticks. For these reasons, predictive models can be useful tools for estimating the potential distribution of ixodid tick species, and thus infer their species richness in Michoacán and other regions of Mexico. Furthermore, because the ticks are vectors disease agents that affect humans and their domestic animals, the possibility of particular species can alert health authorities to confirm suspected cases of zoonosis in the reservoir hosts and vector ticks predicted to occur in the region [14] [15].

Maping the distribution of ticks using published records, field inventories and environmental factors such as vegetation type or land use, has been successful in explaining the spatial distribution of ticks, as often prognostic maps are based on the distribution of covariates such as land use, where high correlations were obtained between observed and expected geographic distribution [16] [17].

The objectives of this study were using literature records, our field work and environmental features to create maps of the potential distribution of tick species of the family Ixodidae associated with wildlife in Michoacán, and to develop spatial estimators of their potential richness using cartographic hypothesis; they will help to direct future geographic.

2. Materials and Methods

2.1. Study Area

The state of Michoacán forms part of Central Western Mexico, approximately between 18˚09' and 20˚23' north latitude and 103˚44' and 100˚04' west longitude. It encompasses 58,370 km^2 [18] and represents 3% of the land area of Mexico. It includes nearly 217 km of coastline along the Pacific Ocean between the mouths of the Balsas and the Coahuayana Rivers. To the north it abuts with the states of Jalisco and Guanajuato, to the northeast with Querétaro, to the east with the state of México, to the southeast with Guerrero, to the west with Colima and to the southwest, with the Pacific Ocean (**Figure 1**).

In order to know the potential geographic distribution of ixodid ticks in Michoacán the following methodology was carried out:

2.1.1. Literature and Cartographic Survey

To obtain a list of potential hosts of ixodids in Michoacán, we performed a literature review of ixodids and their

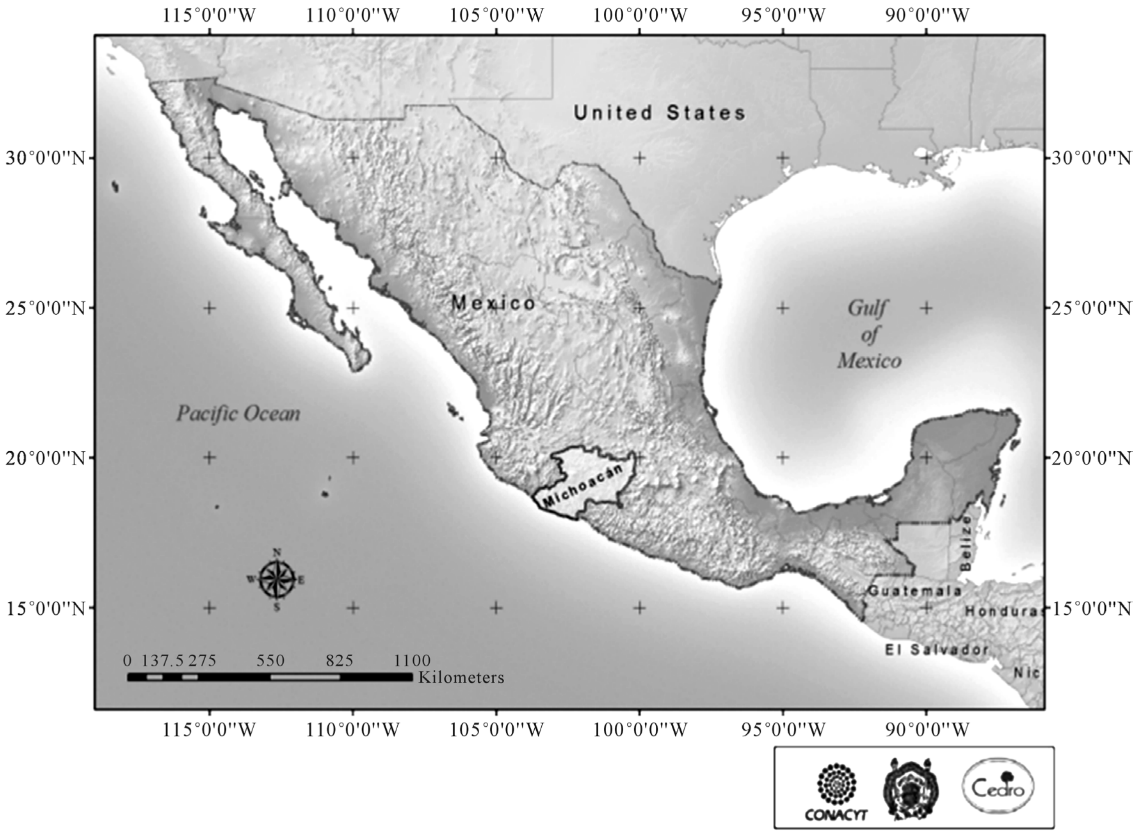

Figure 1. Geographic localization of Michoacán state in Mexico.

hosts as recorded for Mexico was carried out as well as the species of amphibians, reptiles, birds and mammals recorded in Michoacán, and with which ticks have been associated. In all potential hosts, the association supports the evidence host-parasite relationship recorded for Mexico [8]-[12] [19]-[25]. The cartographic survey involved compilation of the most recent geological maps, relief, climate, soils and vegetation and land use [26]-[30] available for the study area, and georeferenced data on the distribution of terrestrial vertebrate wildlife in Michoacán [31]. The contours of vegetation and land use are assumed as polygons to display the distribution of potential hosts.

2.1.2. Field Surveys Conducted

We collected a number of new locality and host recorded for ixodes in Michoacán in Nuevo Urecho (101˚52'W, 19˚09'N, 5 July 2009) we collected one female and 10 male *Amblyomma imitator* on vegetation with a sweep net. In Aquila (3.2 km, 19.5 KmW Aquila, 130 m, December 19, 1990) rodent were collected with Shermann traps and were placed in individual plastic bags and frozen in dry ice to be transported and reviewed in the laboratory under a stereomicroscope. From these we found one nymph and one female *A. maculatum* on the ear of *Sigmodon hispidus* (Muridae), which were extracted with fine forceps. From a farm in the town of Coahuayana (Management Unit for conservation of wildlife UMA, 103˚41'47.5"W, 18˚39'28.6"N, 4 m, May 29, 2009) we collected one male and one female *A. dissimile* on *Iguana iguana*. All ticks were placed in 70% alcohol and were identified under a stereoscopic microscope using the available literature [19]-[22] [32] [33] in the Laboratory of Acarology "Isabel Bassols", National School of Biological Sciences, National Polytechnic Institute and verified determination in laboratory scientific collection.

2.1.3. Database Production

With all the above information, we prepared a geo-referenced database containing information on the vertebrates present on Michoacán and the tick species reported in literature on Michoacán and those collected during the fieldwork, all with the geographic coordinates for processing platform ArcView 3.3 [34].

The production of predictive maps: to create the maps of Potential Distribution of ixodid species, all the points having fieldwork, reported in literature and potential hosts of ixodid were plotted on the map of the state of Michoacán and individual maps for each tick species were generated at a 1:250,000 scale. To find out if there were any spatial relationships between landscape components and distribution of ticks and their hosts, we performed map overlaid of these maps in the GIS and thus try to find some spatial patterns. Were used geological maps, relief, climate, soils and vegetation and land use [26]-[30].

To create the map of Potential Species Richness for ixodids in Michoacán, a five-class cartogram was prepared by the method of natural breaks [34] using the information in the previously made maps referred to vegetation cover and land use polygons that were predictive of the habitat of the hosts. All the spatial information was integrated, processed and edited with the support of the Geographic Information System ArcView 3.3. The working scale was 1:250,000 and the final edition was made at a 1:2,000,000 scale, considering the density of available information.

3. Results

Factors affecting the distribution of tick ectoparasites of terrestrial vertebrates are the same that affect the distribution of their hosts. Thus, the hypothesis of potential distribution was estimated taking into account the prior record of the species in Mexico, its association with wild vertebrate or registered in the state and the information from six ecological variables: geological, relief, climate (annual precipitation maximum and minimum) temperature, soil, vegetation and land use change.

With the information, were generated individual maps by species at 1:250,000 scale for 31 species of ticks (**Table 2**). Four examples of these maps are presented for *Ixodes tancitarus*, *Ixodes texanus*, *Amblyomma parvum* and *Dermacentor occidentalis* (**Figure 2**).

In **Table 1** we summarizes the species of ixodids reported in literature and those collected during our

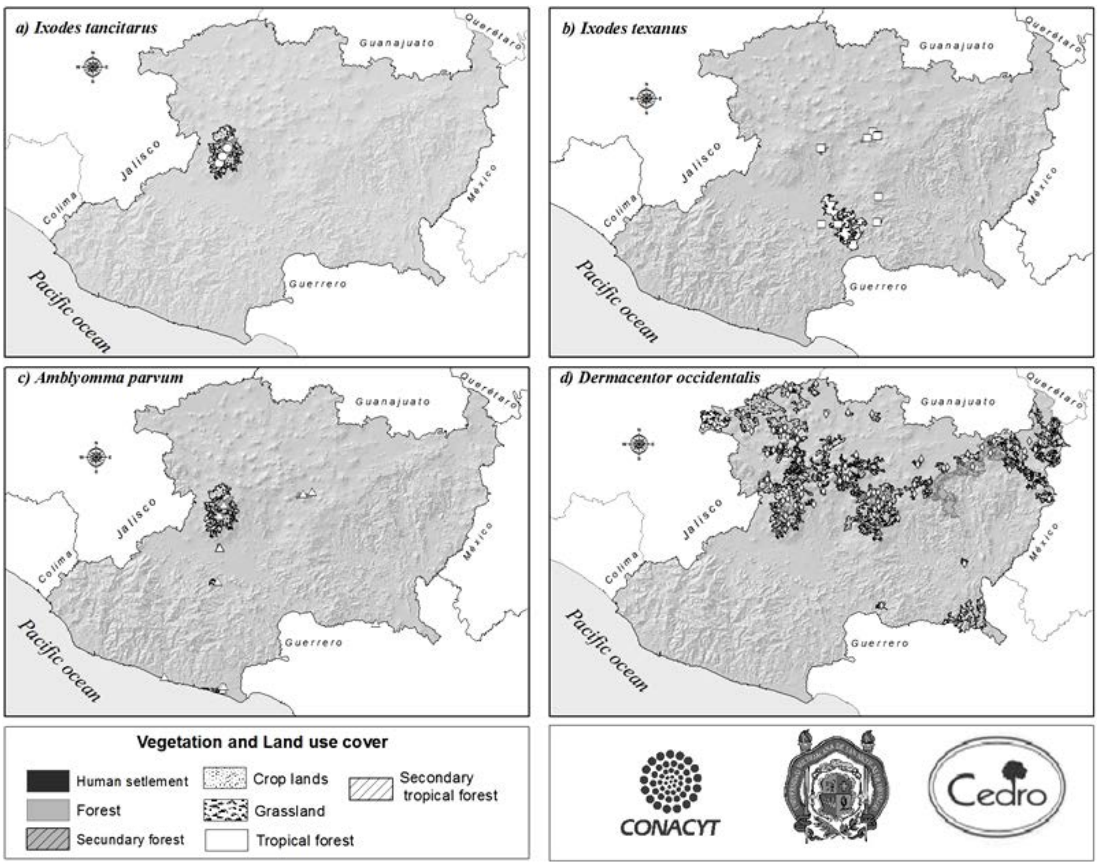

Figure 2. Potential distribution of *Ixodes tancitarus*, *Ixodes texanus*, *Amblyomma parvum* and *Dermacentor occidentalis* from Michoacan, Mexico.

Table 1. Ixodidae ticks reported in literature and those collected during the fieldwork in the state of Michoacán.

Ixoxidae	Host	Locality	Reference
Ixodes mexicanus Cooley and Kohls, 1942	*Heleodyctes gularis* sic (=*Campylorhynchus gularis*, birds: Troglodytidae)	Michoacán	Hoffmann and López-Campos, 2000
	Junco phaeonotus (Birds: Emberizidae)	Cerro Tancítaro	Guzmán-Cornejo *et al.*, 2007
I. tancitarus Cooley and Kohls, 1942	*Reithrodontomys* sp. (Rodentia: Muridae)	Cerro Tancitaro	Cooley and Kohls, 1942
	Reithrodontomys sp.	Cerro Tancítaro	Hoffmann and López-Campos, 2000; Guzmán-Cornejo *et al.*, 2007
Amblyomma auricularium (Conil, 1878)	*Dasypus novemcintus* (Xenarthra: Dasypodidae)	Michoacán	Hoffmann and López-Campos, 2000; Jones *et al.*, 1972
	Bufo marinus (Amphibia: Bufonidae)		Hoffmann and López-Campos, 2000
A. dissimile Koch, 1844	*Iguana iguana* (Sauropsida: Iguanidae)	Tumbiscatio	Gaxiola *et al.*, 1997
		Coahuayana	Authors' fieldwork
A. imitator Kohls, 1958	Not a host	New Urecho	Authors' fieldwork
A. maculatum Koch, 1844	*Sigmodon* sp. (Rodentia: Muridae)	Aquila	Authors' fieldwork
A. parvum Aragao, 1908		Tumbiscatio	Gaxiola *et al.*, 1997 [39]
A. rotundatum Koch, 1844	*Phrynosoma* sp. (Sauropsida: Phrynosomidae)	Michoacán	Hoffmann and López-Campos, 2000
Dermacentor albipictus (Packard, 1869)	Deer, horses, cows	Michoacán	Hoffmann and López-Campos, 2000

Note: *Dermacentor albipictus* was not incorporated into predictive map.

fieldwork in the state of Michoacán. A total of nine species of the family were found being present in the state's territory.

Considering the wild vertebrate fauna of Michoacán, the results of field inventory and the previous report of those tick species in Mexico and Michoacan, a total of 31 ixodid species likely to be associated with wild vertebrates in this state (**Table 2**). Given that 75 species of the family Ixodidae are known for Mexico, our analysis suggests that 44.3% of these species might be present in Michoacán, even though it represents only 3% of Mexico's territory. This marked disproportion points to the importance of further collection and research on ixodids in Michoacán, more so when it is considered that this prediction is restricted to wild vertebrates and hence excludes the ticks present in cattle and other domestic animals.

As indicated in **Table 2**, taking into account the hosts, there is a whole spectrum of tick's spatial distribution of Ixodidae family, with species whose hosts have to date more than 120 collection record, and others less than 10. Considering that not all ticks species have high host specificity, suggests that some species of ticks may have a greater distribution than the potential distribution mapped here, while others may be very restricted. In particular it may be observed that *Ixodes tancitarus* is a strict local endemic [9], and just been collected in the Pico de Tancítaro volcano (which gave origin to its specific name).

The unresolved taxon *Ixodes* sp. had the largest number of hosts, with five in total, but since it has not been determined at species level, introduces uncertainty about the total number of species involved (one or more). In this case it is necessary to wait until the taxonomic analyses are completed before its geographic distribution in the state may be determined.

Figure 3 shows the spatial distribution of all known records of ixodid genus and hosts in Michoacán, and potential ixodid and hosts for the state at a regional scale of 1:2,000,000.

4. Discussion

By overlaying in the GIS maps of natural components (climate, geology, topography, soils, vegetation and land use) the following general statements may be made from the results of the GIS analysis:

Table 2. Ticks of the family Ixodidae, potentially and current found in wild fauna from Michoacan.

Tick species	Collection points of hosts	Recorded and potential hosts of ticks in Michoacán
*Amblyomma auricularium**	30	*Dasypus novemcinctus* (M)*, *Bufo marinus* (A)*
*Amblyomma dissimile**	60	*Iguana iguana* (R)*, *Kinosternon integrum* (R) and *Bufo marinus*
*Amblyomma maculatum**	16	*Urocyon cinereoargenteus* (M), *Sigmodon* sp. (M)*
Amblyomma oblongoguttatum	14	*Odocoileus virginianus* (M)
*Amblyomma parvum**	14	*Dasypus novemcinctus*
*Amblyomma rotundatum**	40	**Phrynosoma asio* (R), *Phrynosoma coronatum* (R), *Dasypus novemcinctus** and *Bufo marinus**
Amblyomma scutatum	31	*Ctenosaura similis* (R) and *Ctenosaura pectinata* (R)
Dermacentor andersoni	25	*Neotoma mexicana* (M)
Dermacentor halli	15	*Lepus callotis* (M)
Dermacentor occidentalis	97	*Peromyscus melanophrys* (M) and *Peromyscus maniculatus* (M)
Dermacentor parumapertus	32	*Peromyscus melanosis* (M), *Lepus callotis* and *Perognathus flavus* (M)
Dermacentor variabilis	15	*Lepus callotis*
Haemaphysalis leporispalustris	132	*Crotophaga sulcirostris* (B), *Sylvilagus floridanus* (M) and *Lepus callotis*
Ixodes affinis	4	*Nasua narica* (M)
Ixodes augustus	25	*Neotoma mexicana*
Ixodes boliviensis	30	*Urocyon cinereoargenteus* and *Odocoileus virginianus*
Ixodes cookei	26	*Bassariscus astutus* (M) and *Urocyon cinereoargenteus*
Ixodes cuernavacensis	6	*Streptoprocne semicollaris* (B)
Ixodes dentatus	53	*Sylvilagus floridanus*
Ixodes eadsi	82	*Liomy sirroratus* (M)
Ixodes kingi	27	*Spermophilus variegates* (M)
Ixodes luciae	37	*Didelphis virginiana* (M)
Ixodes marxi	63	*Sciurus aureogaster* (M)
*Ixodes mexicanus**	37	*Campylorhynchus gularis* (B) and *Junco phaeonotus* (B)
Ixodes rubidus	129	*Peromyscus maniculatus*, *Bassariscus astutus*, *Spermophilus variegatus* and *Urocyon cinereoargenteus*
Ixodes scapularis	53	*Sylvilagus floridanus*
Ixodes sinaloa	160	*Oryzomys couesi* (M) and *Liomys pictus* (M)
Ixodes sp.	136	*Liomys pictus*, *Sorex saussurei* (M), *Peromyscus difficilis* (M), *Reithrodontomys microdon* (M) and *Peromyscus melanocarpus* (M)
Ixodes spinipalpis	53	*Sylvilagus floridanus*
Ixodes texanus	10	*Bassariscus astutus*
*Ixodes tancitarus**	9	*Reithrodontomys chrysopsis* (M) and *Reithrodontomys sumichrasti* (M)
Ixodes tovari	15	*Lepus callotis*

The hosts are amphibians (A), reptiles (R), mammals (M), and birds (B). *Indicated known records of ixodid species and hosts in Michoacán; taxa without asterisks are predicted to occur in this state.

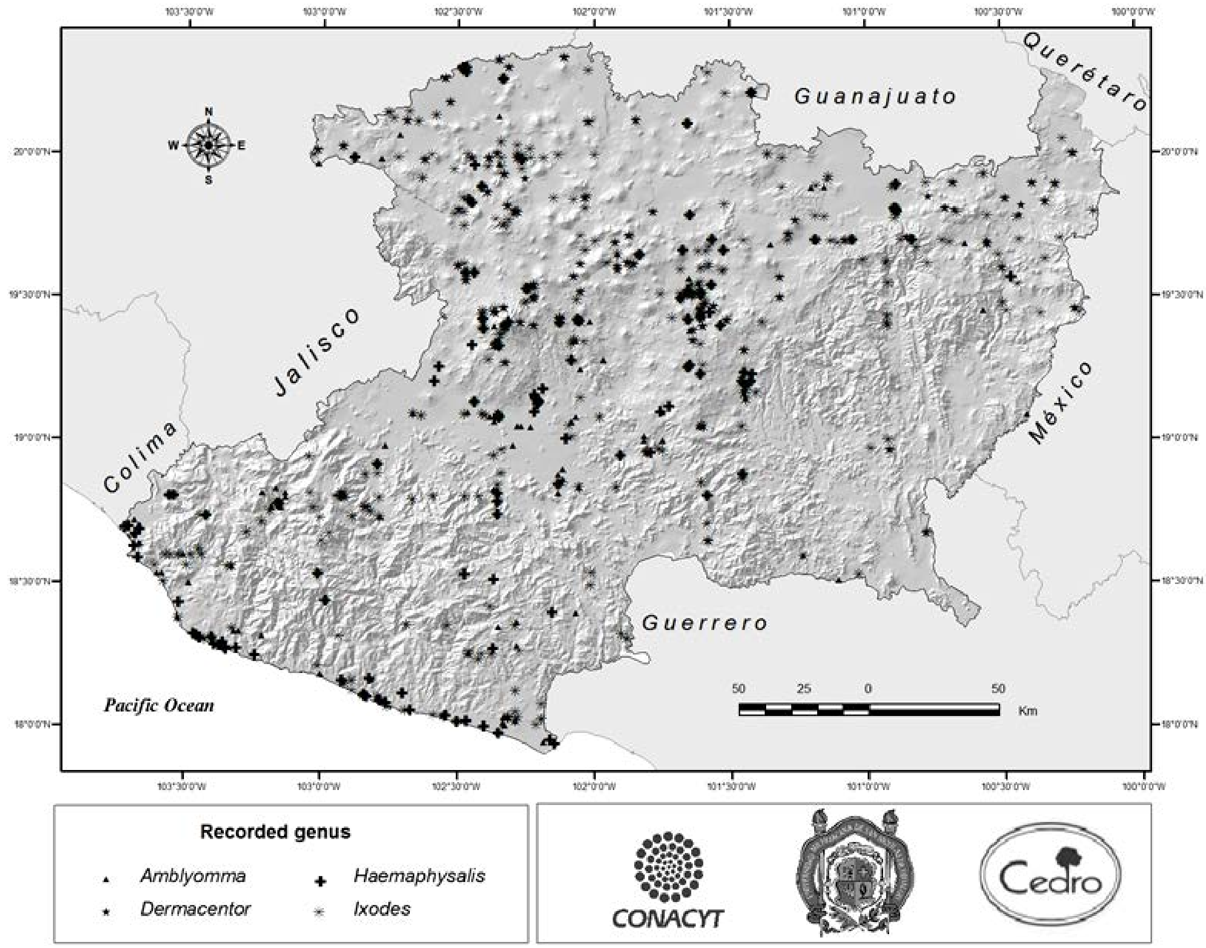

Figure 3. Geographic distribution of the localities of real and potential hosts of tick genus of the family Ixodidae in Michoacán state.

- Host species for the genus *Amblyomma* are widely distributed throughout the state and do not display any environmental preference, being found in warm, temperate, dry or humid climates, in any geomorphologic situation (mountains, plains, valleys, piedmonts), and in any soil or vegetation types. The same pattern is observed for the hosts of genus *Haemaphysalis*.
- Host species for the genus *Dermacentor* are strongly associated temperate climate and its only record in the Sierra-Costa region is on mountain slopes where the climate is less warm.
- Hosts of the species of the genus *Ixodes* have the most varied associations. Some hosts have only been found in temperate climate and others in warm zones, while over half of the host may be found in any hydro-climatic or geoecological condition; *i.e.*, they may be found in any part of the state regardless of geology, relief, soil, vegetation, climate, etc.

It is important to point out that the map in **Figure 3** only displays the information related to the distribution of hosts of ticks of the Ixodidae family present in the wild fauna. For that reason, the zones occupied by cultivated or induced grasslands appear in the map as without reports of ticks. This suggests that when adding records of ticks found in domestic animals at present [35], it will be necessary to increase the scale of the map in order to appreciate the geographic distribution of such records at an adequate resolution.

In **Table 3** and **Figure 4** show the results of the distribution of the categories of species richness of the family Ixodidae in the state of Michoacán. These results were calculated using the areas of the polygons where documented hosts of these ticks had been recorded. The potential species richness class Very Low, which comprises up to five species of ticks, had an ample predominance in the state's territory covering over 70% of the zones with reports of wild hosts, being found both in areas having a temperate climate and in the warm coastal

Table 3. Distribution of the potential species richness (R) of ticks in the family Ixodidae for the state of Michoacán for natural breaks method.

		Species richness area	
Classes	No. of species	km^2	%
Very Low	$R \leq 5$	14553.8	70.32
Low	$6 \leq R \leq 9$	2950.4	14.25
Medium	$10 \leq R \leq 13$	1805.5	8.71
High	$14 \leq R \leq 17$	843.8	4.08
Very High	$R \geq 18$	547.6	2.64
Total		20701.1	100

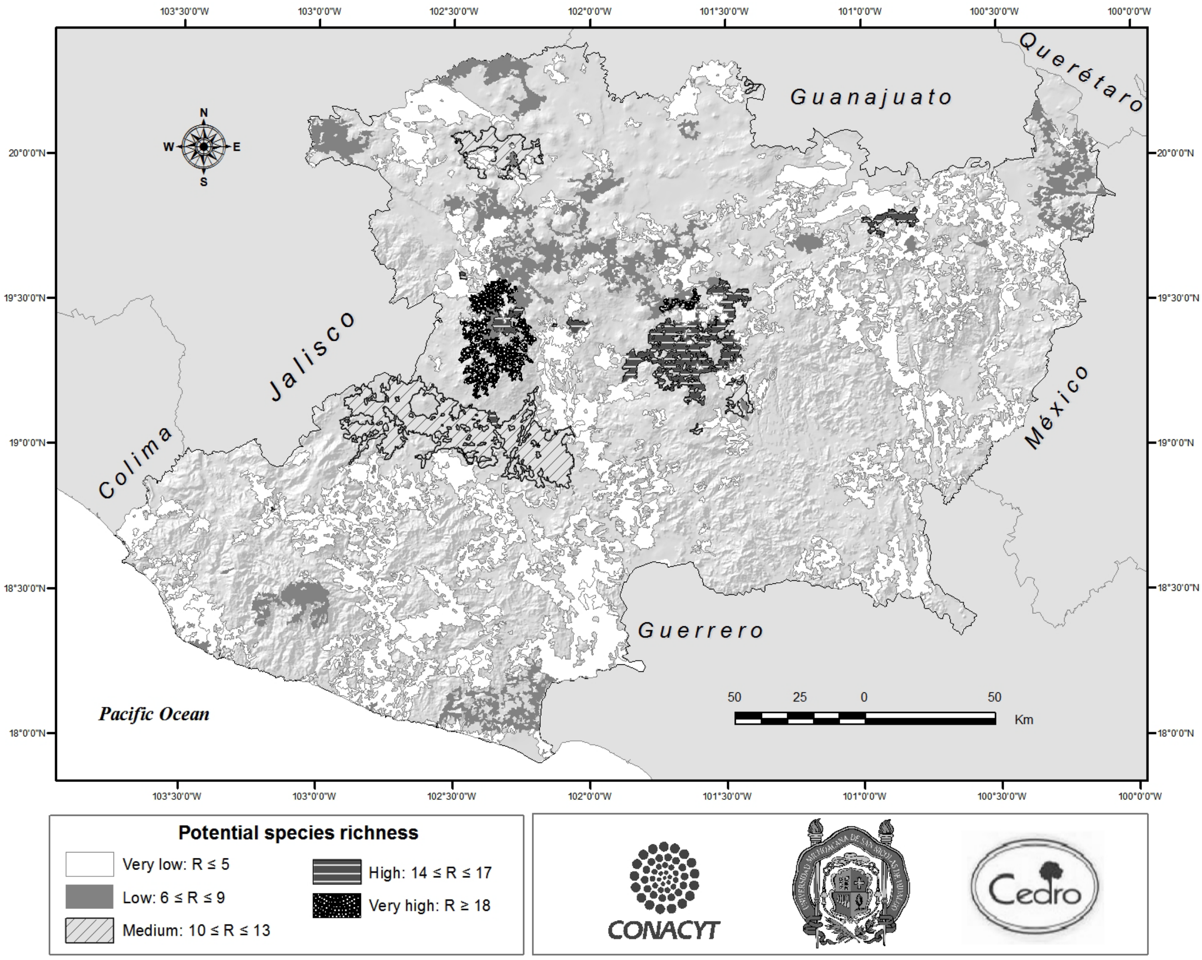

Figure 4. Potential species richness of ticks in the family Ixodidae in the wild fauna from the state of Michoacán, Mexico.

zones. The species richness class Low had a distribution having a pattern similar to the above category, but occupying a much smaller area. Beginning in the species richness class Medium, a strong concentration of polygons was appreciated with a noticeable reduction in distribution areas. The species richness class Medium was localized towards the central zone of the state, with a polygon located to the northeast, always in association with temperate climate zones. The species richness class High was concentrated in the center of the state and in a polygon near the border with the state of Guanajuato in northern Michoacán. The species richness class Very

High occupied an area south of Los Reyes and west of Uruapan, coincident with the Pico de Tancítaro. This area presented the only known collection sites of *Ixodes tancitarus* in Michoacán.

For a full understanding of the epidemiology, distribution and richness of ticks and their potential transmitted pathogens; it is essential understand the complex interaction between ticks, their host, their environment and the pathogens which they transmit over a long period to be able to determine annual variation [36].

Our method predicted that a total of 31 species of ixodids was hosts by wild animals from Michoacán. Some species had very few collection sites for their hosts, while other host species of ticks were likely to be abundantly distributed throughout the state regardless of climatic or other environmental conditions. Inclusion of ixodid present in cattle and other domestic animals will likely require changing to a more detailed geographic scale.

5. Conclusions

The spatial category of maximum species richness is correlated with deterioration of the host's habitat. According to the results of Cuevas [37], the areas having the largest potential concentration of ixodid species, *i.e.*, the better conserved zones within Natural Protected Areas have a 90% probability of suffering land use changes in the next coming years. This means that the zones of High and Very High species richness of ticks of the family Ixodidae in the wild fauna may experience a severe affectation of their ecosystems and increased activity by humans and livestock in these areas may result in domesticated animals coming in contact with unfamiliar species of ticks and the pathogens they carry, with all the implied zoo sanitary risks of this migration of hosts; as exemplified by the Lyme disease.

The forecasts of land use changes indicate that many areas presently occupied by these ticks and their hosts are strongly threatened, which implies potential risks of induced migration of the ticks to the domestic fauna, cattle and even to humans. Due to the recent examples of emerging diseases associated with transmissions of pathogenic organisms from animals to humans [38], it is necessary to complete the taxonomic records of these invertebrates and to adopt more detailed scales of spatial analysis.

The spatial configuration of the potential distribution of ticks obtained in the present work may be an initial guide for future cartographic hypotheses about the geographic distribution of species in the family Ixodidae in the state of Michoacán, and thus provides the basis for the design of sampling efforts and, furthermore, defines initial spatial priorities of tick management and control.

Studies of ticks in Michoacan and their evolution over time are not enough, because a slower rate of progression of taxonomic work and a high rate of environmental change may involve a high risk of local extinction, it's why we used a predictive model to estimate the potential distribution species, and the likely impact of environmental consequences. The predictive nature of such proposals can only be verified by intensifying the field and checking the presence of the species that were predicted in a given region.

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