IMPLICATIONS OF CLIMATE CHANGE ON THE DISTRIBUTION OF THE TICK VECTOR *IXODES SCAPULARIS* AND RISK FOR **LYME DISEASE**

Maria D. Esteve-Gassent, PhD

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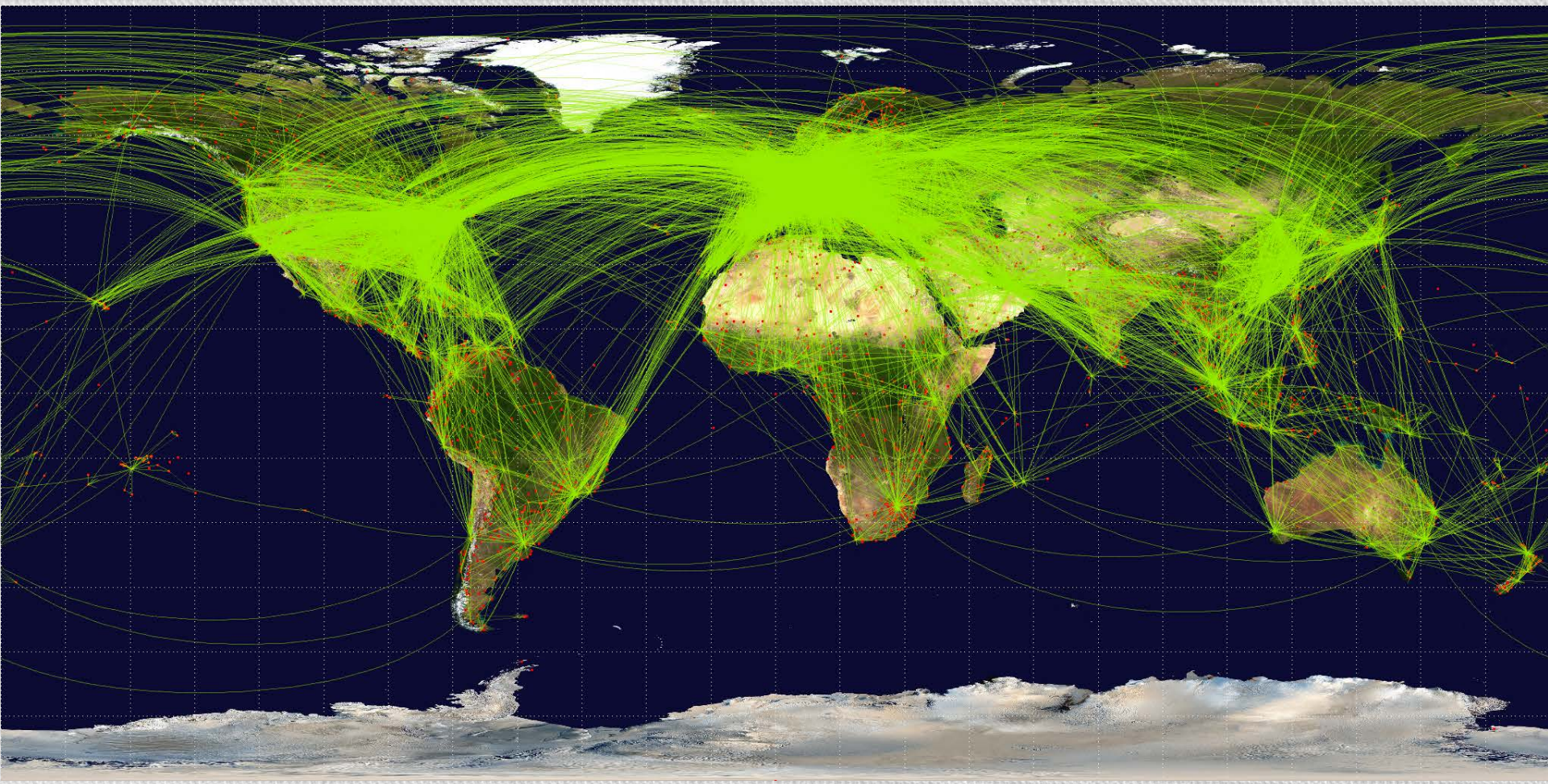
Global air transportation



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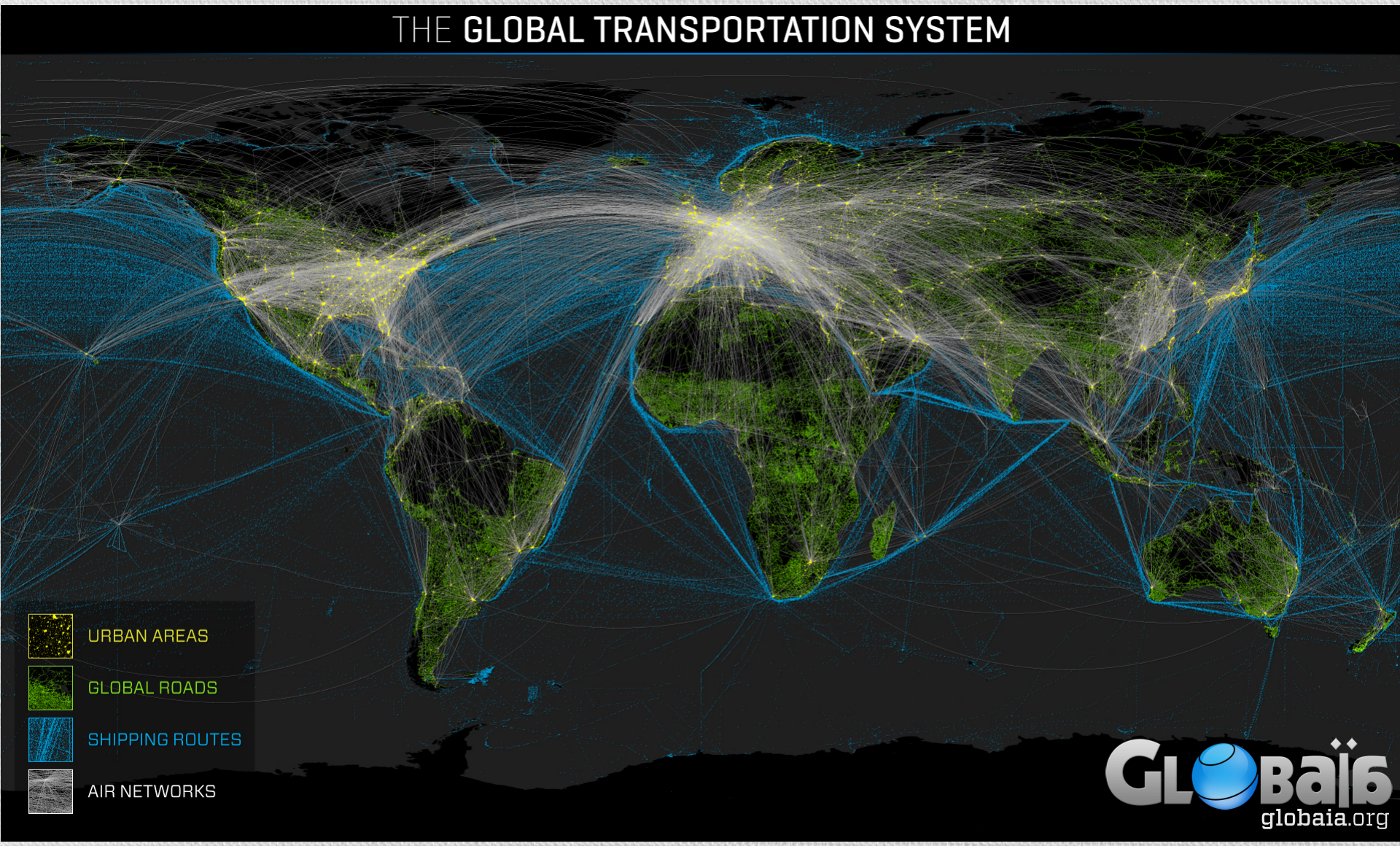
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URBAN AREAS
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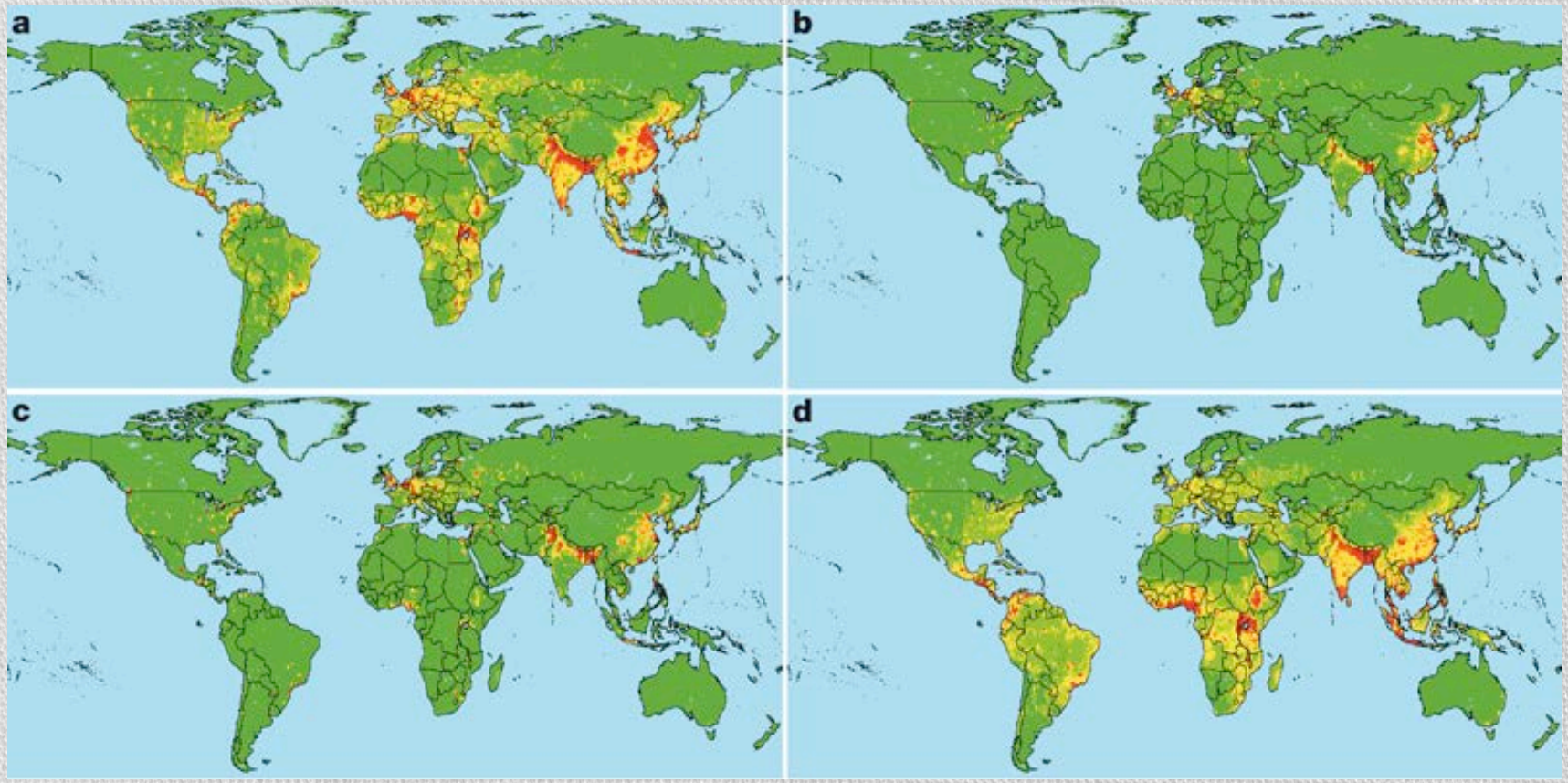
Global change and Human Health



Global trends in emerging infectious diseases. Kate E. Jones, Nikkita G. Patel, Marc A. Levy, Adam Storeygard, Deborah Balk, John L. Gittleman & Peter Daszak, Nature 451, 990-993(21 February 2008) doi:10.1038/nature06536

Climate Change and Human Health

- Increased frequency of extreme whether events:
  - Floods
  - Droughts
  - Sever storms
  - Tornados and Hurricanes
  - Winter storms, etc.
- Has an impact o human heath
  - Decreased air quality
  - Availability of water and energy
  - Threats to mental health
  - Increase in disease transmitted by:
    - Water,
    - Food,
    - Vectors (mosquitoes, ticks, etc.)

Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

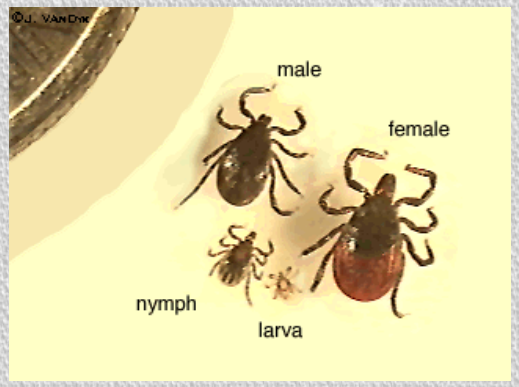
Climate Change and Lyme Disease

- Changes in the geographic distribution of the tick vector
  - Expanding its range towards the North (Canada-US border)
- Lengthen transmission season
  - Shorter winters and longer springs
    - Late onset of cold and frost
    - Earlier onset of higher temperatures
- Higher tick densities
  - Milder winters that help expand rodent (reservoir) population
- Change in human behaviors
  - Increased time outdoors increases the risk of exposure

Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

Lyme disease (LD)

- Most prevalent arthropod borne disease in the US
  - Over 30,000 cases reported yearly to CDC
  - Transmitted by *Ixodes scapularis* and *I. pacificus* tick bite (in the US)
  - Mammalian reservoirs are small rodents
- Caused by the spirochetal pathogen *Borrelia Burgdorferi*
- Multi-phase disorder in humans
  - Early LD (70% Erythema migrans)
  - Early disseminated LD (Flu like symptoms)
  - Chronic LD (Arthritis and carditis)



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Implications of climate change on the distribution of the tick vector *Ixodes scapularis* and risk for Lyme disease in the Texas-Mexico transboundary region

Teresa P Feria-Arroyo[1†], Ivan Castro-Arellano[2†], Guadalupe Gordillo-Perez[3†], Ana L Cavazos[1], Margarita Vargas-Sandoval[4], Abha Grover[5], Javier Torres[3], Raul F Medina[6], Adalberto A Pérez de León[7] and Maria D Esteve-Gassent[5*]

Abstract

Background: Disease risk maps are important tools that help ascertain the likelihood of exposure to specific infectious agents. Understanding how climate change may affect the suitability of habitats for ticks will improve the accuracy of risk maps of tick-borne pathogen transmission in humans and domestic animal populations. Lyme disease (LD) is the most prevalent arthropod borne disease in the US and Europe. The bacterium *Borrelia burgdorferi* causes LD and it is transmitted to humans and other mammalian hosts through the bite of infected *Ixodes* ticks. LD risk maps in the transboundary region between the U.S. and Mexico are lacking. Moreover, none of the published studies that evaluated the effect of climate change in the spatial and temporal distribution of *I. scapularis* have focused on this region.

Methods: The area of study included Texas and a portion of northeast Mexico. This area is referred herein as the Texas-Mexico transboundary region. Tick samples were obtained from various vertebrate hosts in the region under study. Ticks identified as *I. scapularis* were processed to obtain DNA and to determine if they were infected with *B. burgdorferi* using PCR. A maximum entropy approach (MAXENT) was used to forecast the present and future (2050) distribution of *B. burgdorferi*-infected *I. scapularis* in the Texas-Mexico transboundary region by correlating geographic data with climatic variables.

Results: Of the 1235 tick samples collected, 109 were identified as *I. scapularis*. Infection with *B. burgdorferi* was detected in 45% of the *I. scapularis* ticks collected. The model presented here indicates a wide distribution for *I. scapularis*, with higher probability of occurrence along the Gulf of Mexico coast. Results of the modeling approach applied predict that habitat suitable for the distribution of *I. scapularis* in the Texas-Mexico transboundary region will remain relatively stable until 2050.

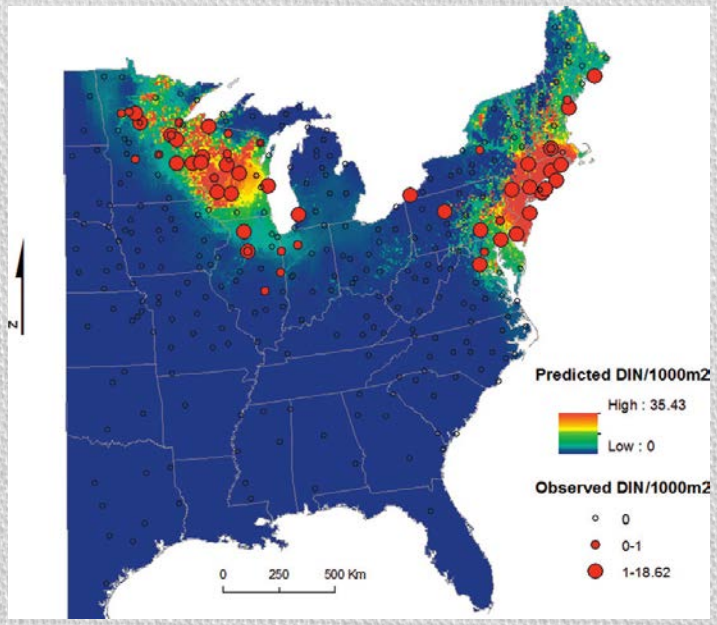
Conclusions: The Texas-Mexico transboundary region appears to be part of a continuum in the pathogenic landscape of LD. Forecasting based on climate trends provides a tool to adapt strategies in the near future to mitigate the impact of LD related to its distribution and risk for transmission to human populations in the Mexico-US transboundary region.

Keywords: *Ixodes scapularis*, *Borrelia burgdorferi*, Transboundary disease, Lyme disease risk map, Climate change

* Correspondence: Mesteve-Gassent@cvm.tamu.edu
† Equal contributors
[5]Department of Veterinary Pathobiology, College of Veterinary Medicine and Biomedical Sciences, Texas A&M University, College Station, TX 77843, USA
Full list of author information is available at the end of the article

Lyme disease in the Trans-boundary Region

- Number of studies in the Northeast and Midwest
- Limited information in southern US and Mexico



Diuk-Wasser MA, Hoen AG, Cislo P, Brinkerhoff R, Hamer SA, Rowland M, Cortinas R, Vourc'h G, Melton F, Hickling GJ, Tsao JI, Bunikis J, Barbour AG, Kitron U, Piesman J, Fish D: **Human risk of infection with *Borrelia burgdorferi*, the Lyme disease agent, in eastern United States**. Am J Trop Med Hyg 2012, 86(2):320–327.

Lyme disease in the Trans-boundary Region

- Lyme disease has been described in Mexico sin the late 90's
- There is one study considering the distribution of *Ixodes* ticks in Mexico

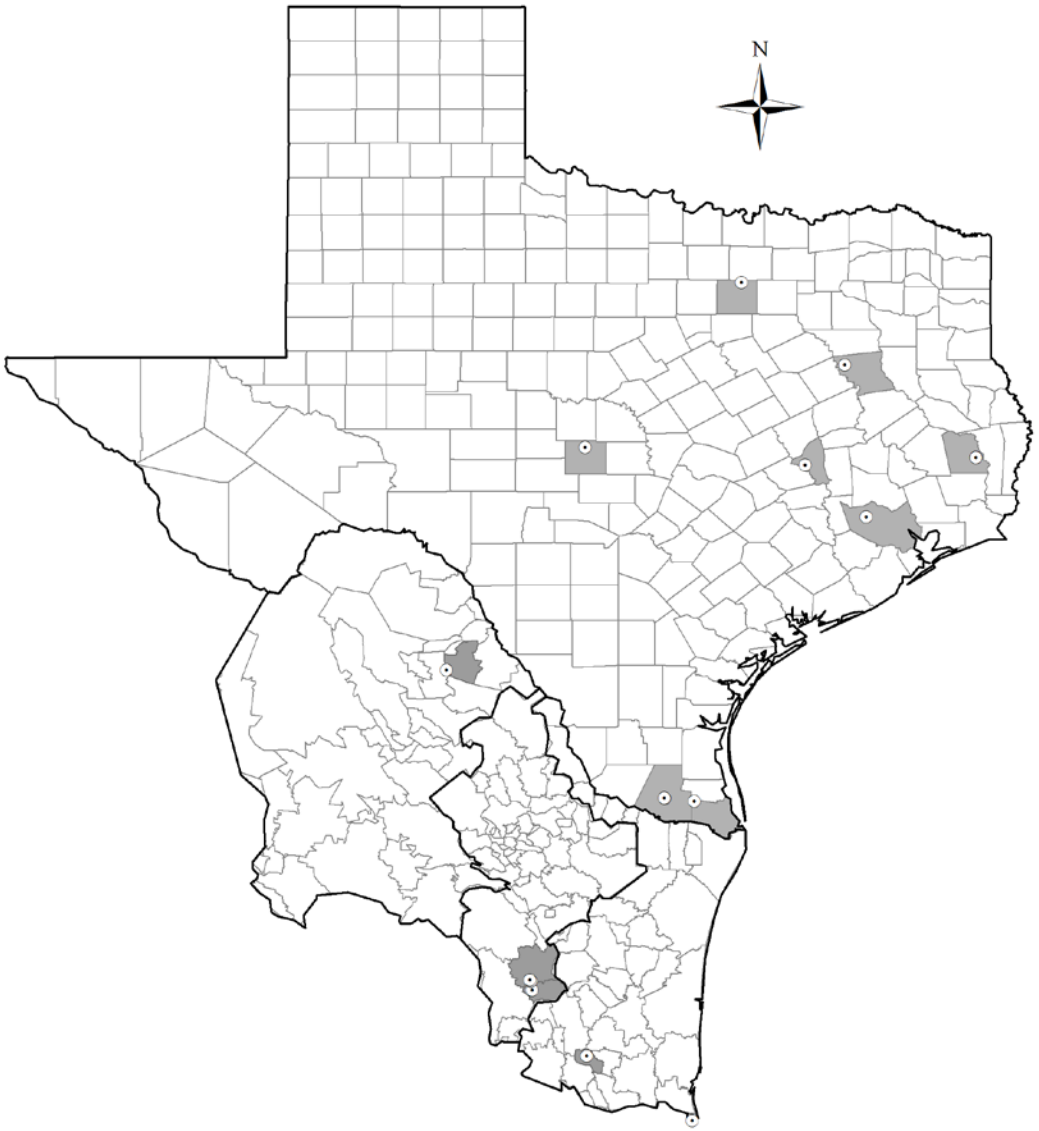
Illoldi-Rangel P, Rivaldi CL, Sissel B, Trout Fryxell R, Gordillo-Perez G, Rodriguez-Moreno A, Williamson P, Montiel-Parra G, Sanchez-Cordero V, Sarkar S: **Species distribution models and ecological suitability analysis for potential tick vectors of Lyme disease in Mexico.** *J Trop Med* 2012, **2012:**959101.

Study Area

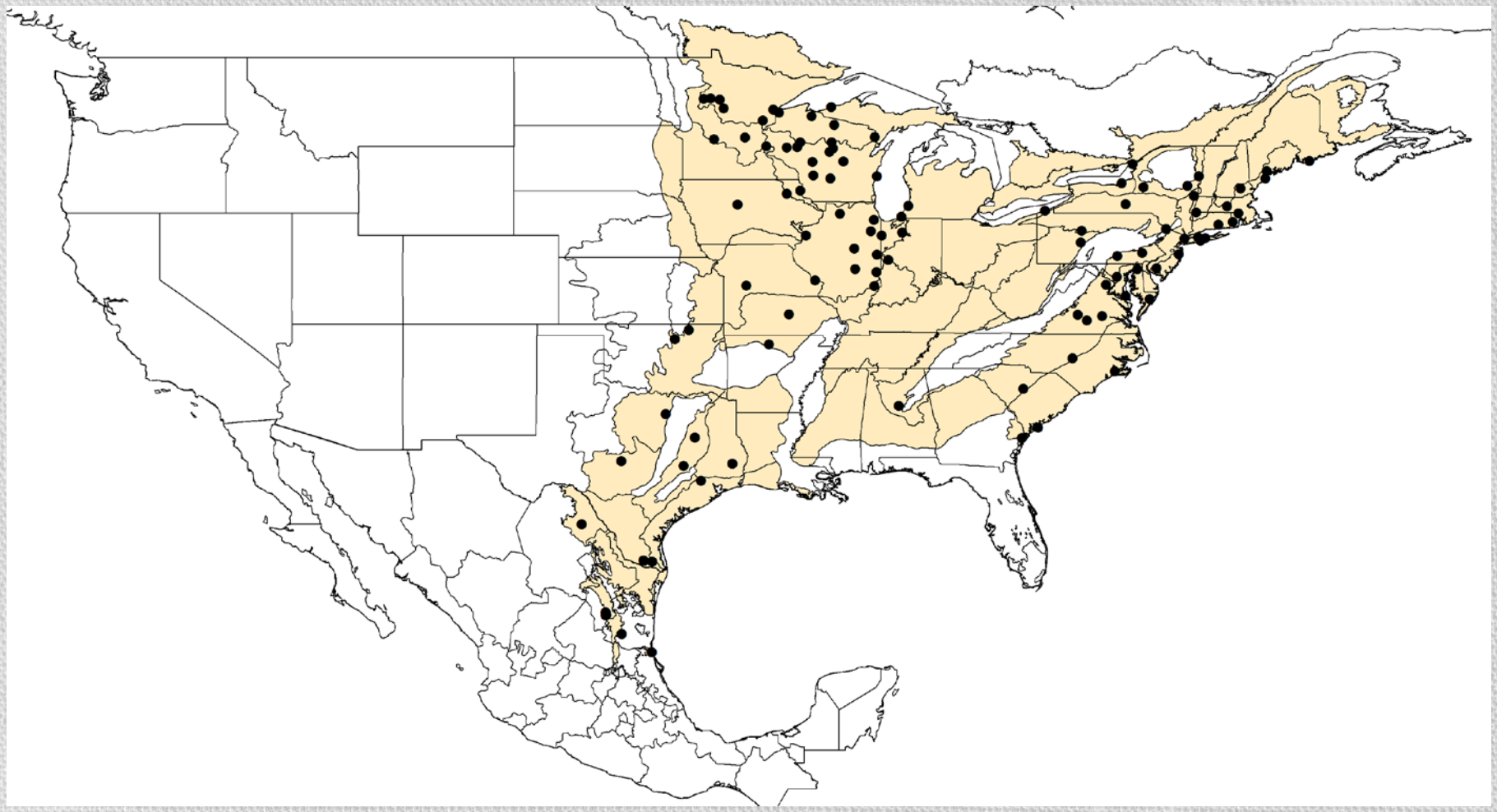
- Texas-Mexico transbounday region
  - **TEXAS:**
    - Three Texas Parks and Wildlife Management areas covering 5 Counties
      - Anderson, Cameron, Hidalgo, Mason and Willacy
    - Animal Shelter (Brazos, Co.)
    - Veterinary Clinics from 13 Counties
      - Bee, Collin, Edwards, Fort Bent, Harris, Kerr, Maverick, Montaue, Montgomery, Robertson, Tarrant, Travis, and Uvalde
    - Big Thicket National Part (Tyler Co.)
  - **Mexico:**
    - Parks in the States of Tamaulipas, Nuevo León and Coahuila

Geographic Area of Study

Each county in Texas, Tamulipas, Nuevo León and Coahuila from which *I. scapularis* was collected.



Geographic distribution of *I. scapularis* by biogeographic regions



Detection of *B. burgdorferi* in *I. scapularis* ticks

Table 2 Texas counties and Mexico districts from which *I. scapularis* ticks were collected

	State	County or District	*Localities*	Ticks collected	*I. scapularis* (%)#	*I. scapularis* infected (%)**	Host⌘
US	Texas	Anderson	1	64	26/64 (40.6)	13/26 (50.0)	WTD (13)
	Texas	Brazos	1	45	5/45 (11.1)	3/5 (60.0)	Dog (2)
							WTD (1)
	Texas	Cameron	1	32	3/32 (9.4)	2/3 (66.7)	WTD (2)
	Texas	Fort Bent	1	65	1/65 (1.5)	1/1 (100.0)	Dog (1)
	Texas	Hidalgo	2	7	1/7 (14.3)	0/1 (0.0)	Dog
	Texas	Mason	1	148	5/148 (3.4)	2/5 (40.0)	Oryx (2)
	Texas	Tarrant	1	4	3/4 (75.0)	2/3 (66.7)	Cat (2)
	Texas	Tyler	1	37	29/37 (78.4)	13/29 (44.8)	Questing (13)
	TOTAL		9	574	74/574 (12.9)	37/74^ (50.0)	
Mexico	Nuevo Leon	San Josesito, Zaragoza	*3*	230	31/230 (13.5)	8/25 (29)	*Sylvilagus floridanus*
			1			1/6	*Lyomis pictus*
	Tamaulipas	Tampico	*1*	51	2/51 (3.9)	2/2 (100)	Vegetation
	Tamaulipas	El Cielo, Gomez Farias	*1*	379	1/379 (0.02)	1/1 (100)	*Panthera onca*
	Coahuila	La Rosita, San Pedro	*1*	1	1/1 (100)	0/1(0)	-
	TOTAL		7	661	35/661 (5.29)	12/35 (34.28)	

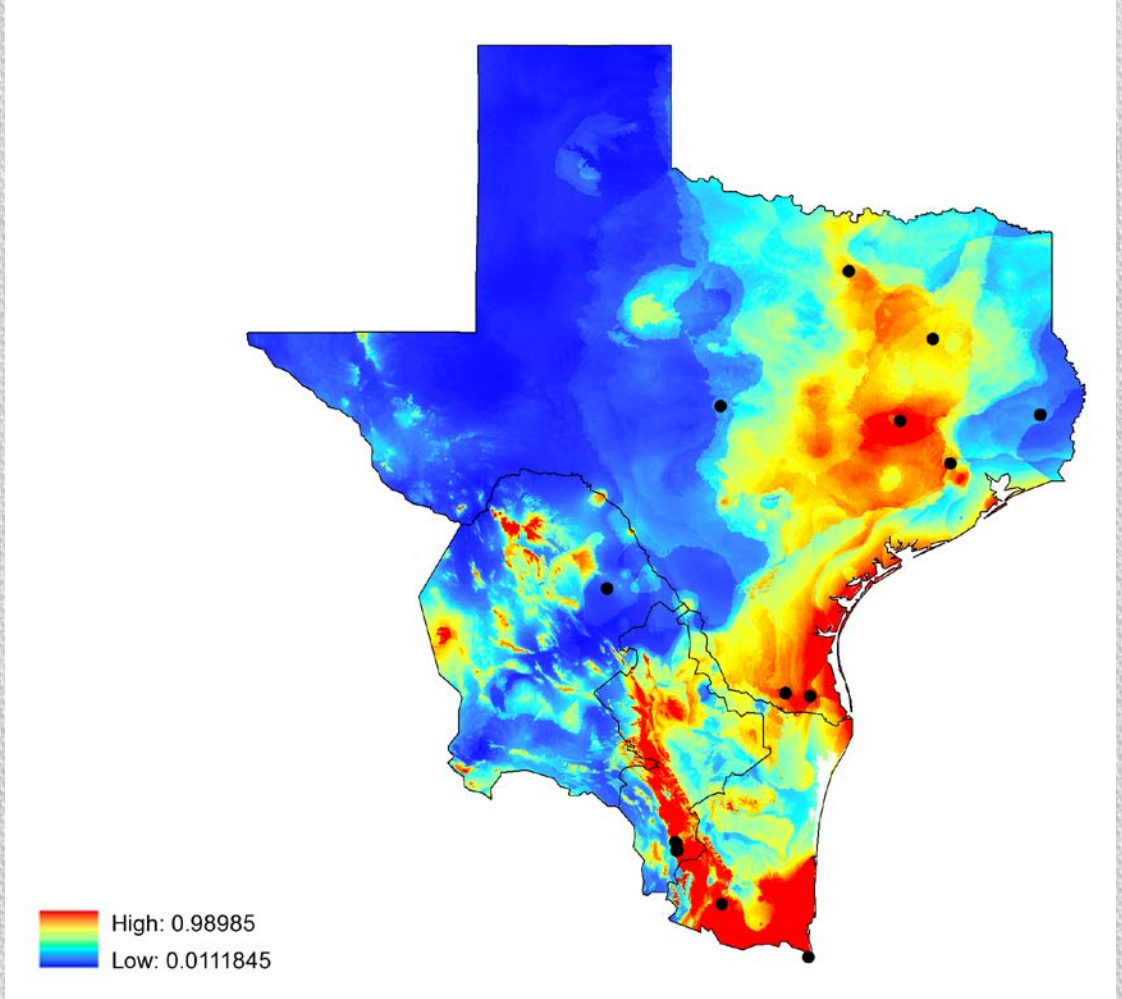
#: Percentage of *I. scapularis* found in each county among other tick species.
**: Percentage of *I. scapularis* infected per county.
^: 6.445% of all ticks collected were *Ixodes scapularis* infected with *Borrelia burgdorferi*.
⌘: in parenthesis is represented the numbers of infected *Ixodes scapularis* ticks isolated from each host.

Environmental variables used in this study

Variable	Description
BIO1	Annual Mean Temperature
BIO3	Isothermality
BIO5	Maximum Temperature of Warmest Month
BIO6	Minimum Temperature of Coldest Month
BIO7	Temperature Annual Range (maximum temperature of warmest month – minimum temperature of coldest month)
BIO9	Mean Temperature of Driest Quarter
BIO10	Mean Temperature of Warmest Quarter
BIO11	Mean Temperature of Coldest Quarter
BIO12	Annual Precipitation
BIO13	Precipitation of Wettest Month
BIO14	Precipitation of Driest Month
BIO15	Precipitation Seasonality (Coefficient of Variation)
BIO16	Precipitation of Wettest Quarter
BIO17	Precipitation of Driest Quarter
BIO18	Precipitation of Warmest Quarter
BIO19	Precipitation of Coldest Quarter

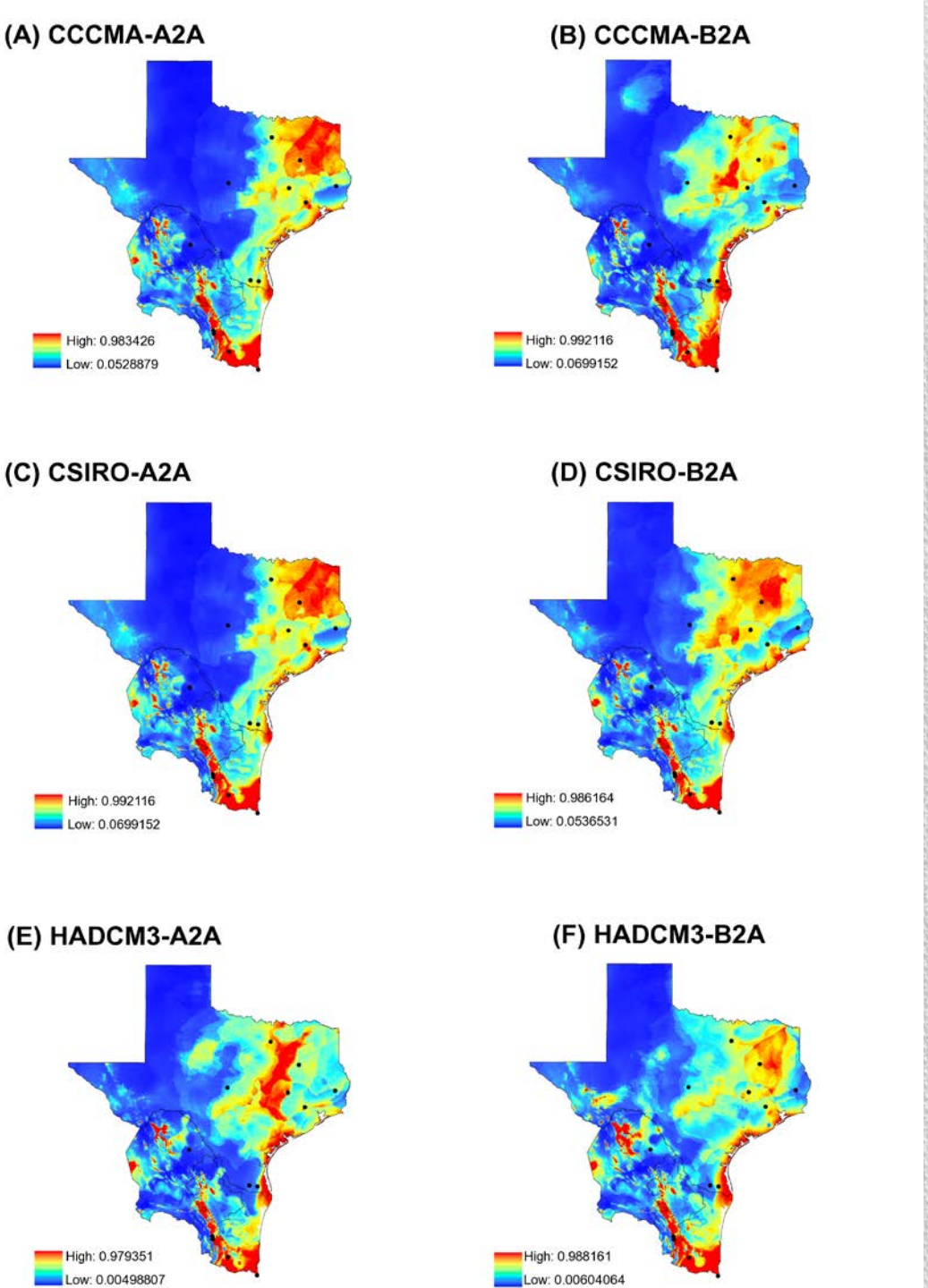
Present suitable habitats for *I. scapulatis*

Obtained with a Maximum-Entropy Approach considering 17 different climatic variables (temperature-precipitation)



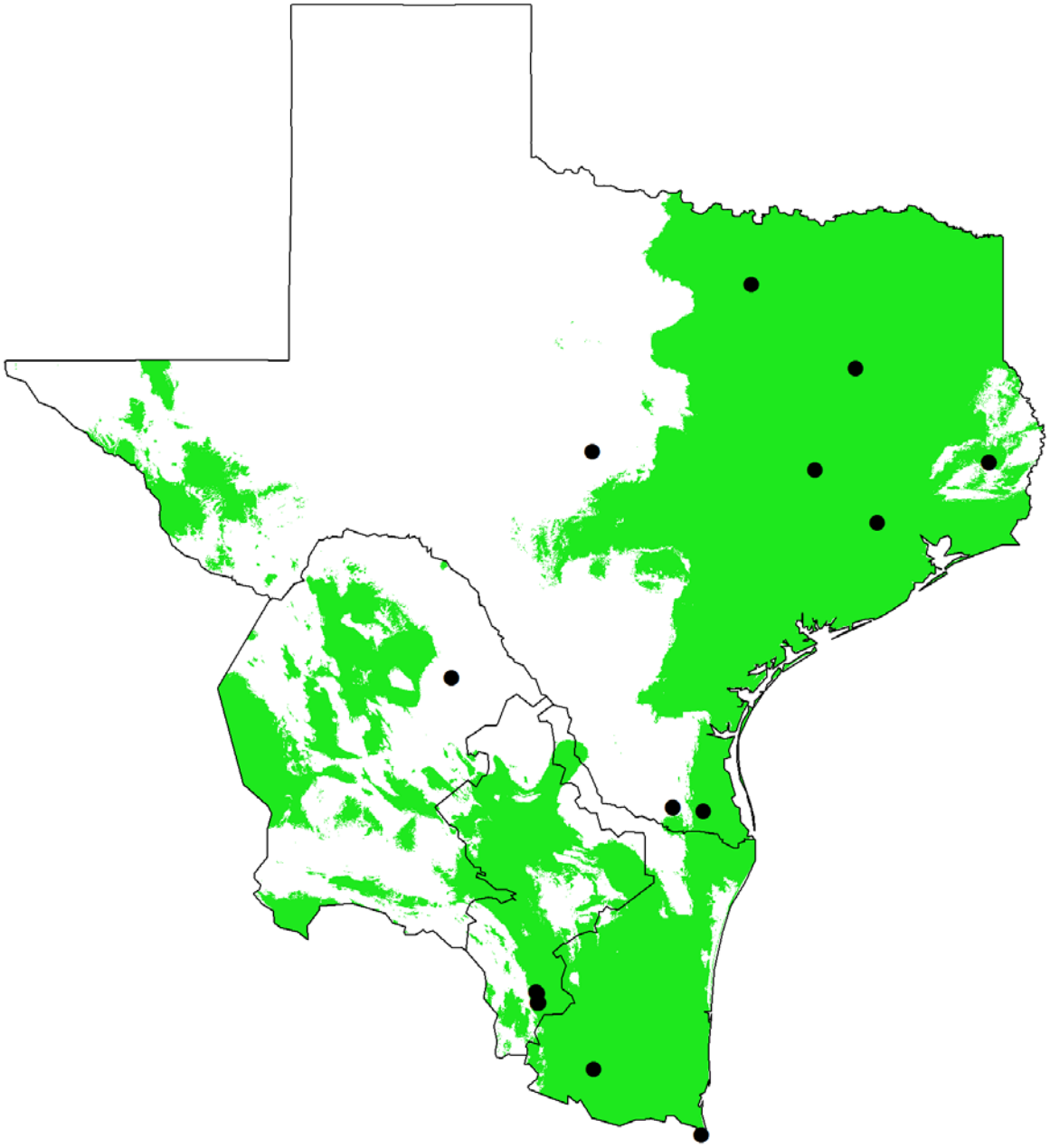
FUTURE
Year 2050

Suitable habitat for *I. scapularis* obtained using a maximum entropy approach



Stable area for *I. scapularis* distribution

Regardless of the forecasting scenario: 569,910Km^2



Environmental variables affecting model

Of all variables tested in this study these are those mostly affecting the developed model

Variable	Percent contribution
Isothermality (Mean Diurnal Range/Temperature Annual Range) Å~ 100	20.0
Precipitation of Wettest Quarter	18.1
Max Temperature of Warmest Month	14.6
Precipitation of Wettest Month	11.5

Conclusions

- The model presented here shows:
  - The distribution *of I. scapularis* can potentially be widely occurring in
    - East Texas
    - Northern Mexico
  - Extreme climate change conditions predict the maintenance of suitable areas for *I. scapularis*
  - The Ecology of Lyme disease in the Texas-México transboundary region is not fully understood
    - Further studies in regards to the distribution of the tick vector and reservoirs

Small mammal trapping

New study in Collaboration with TSU

Area of Study

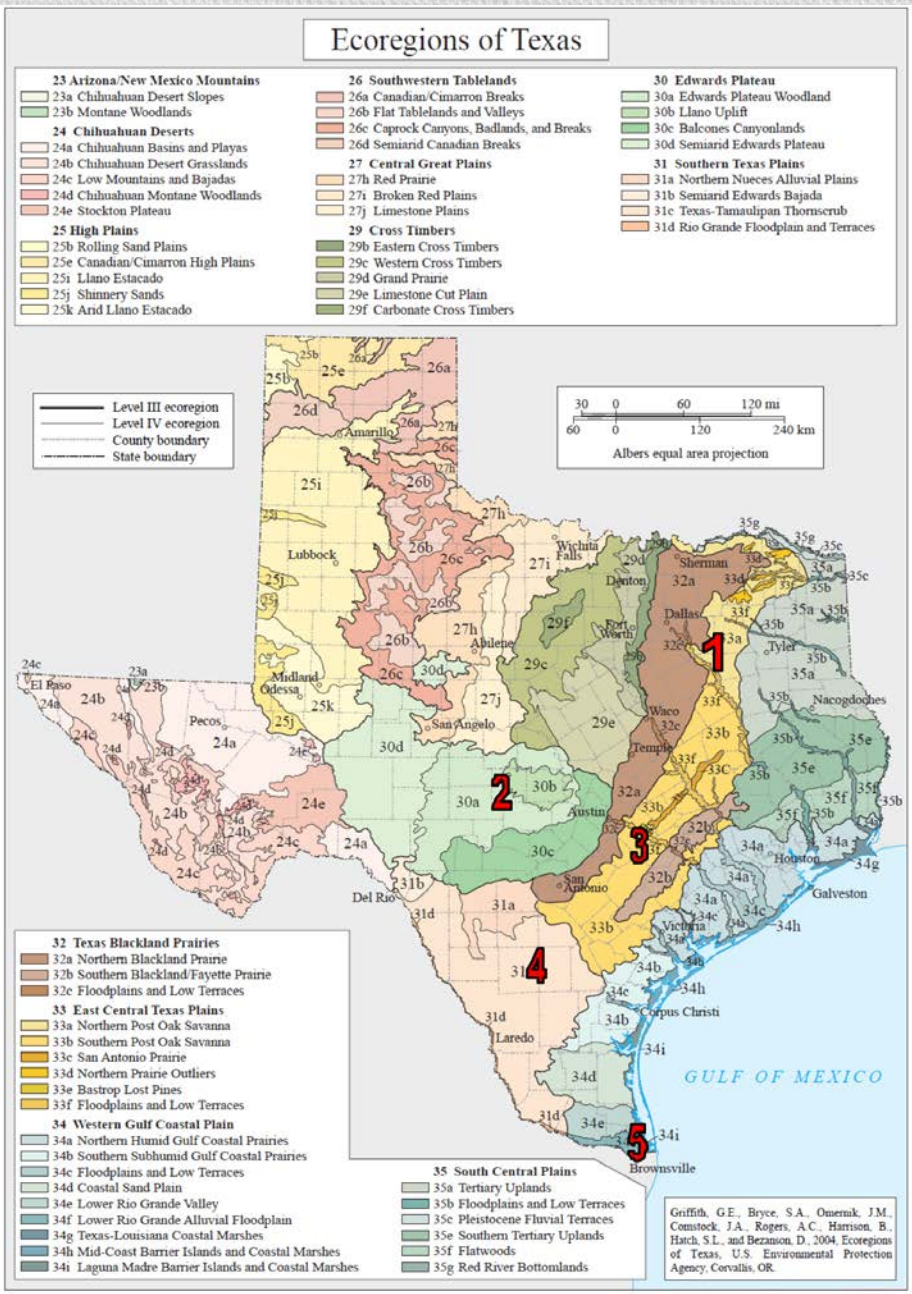
1: Anderson Co.

2: Mason Co.

3: Hays Co.

4: Dimmit Co.-La Salle Co.

5: Cameron Co.-Willacy Co



Trapping Effort

All sites were sampled in

- Late Winter
- Spring
- Fall

Trapping success was 5.41% with a total of 592 individuals collected.

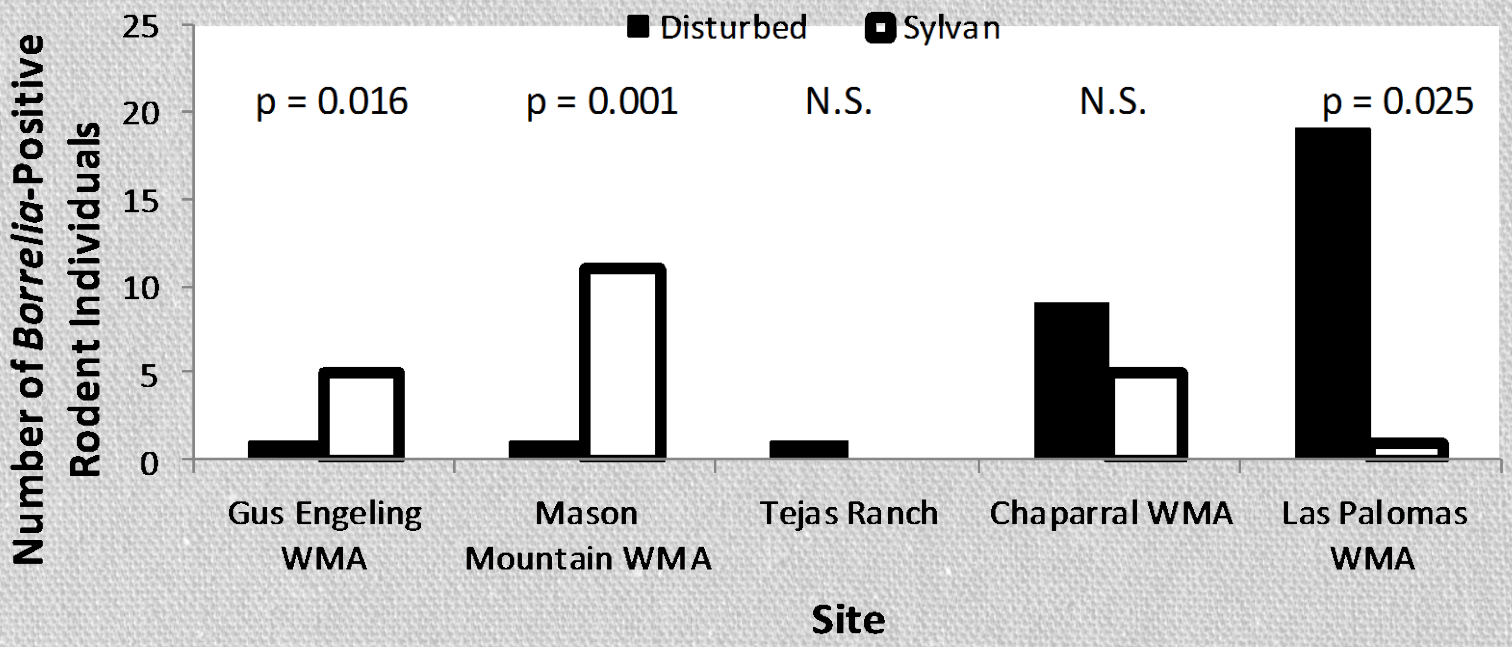
Location	Habitat	Trapping Period	Number of Captures	Number of Traps Set	Trapping Success
Mason Mountain WMA	Disturbed	Preliminary	11	300	3.67%
Mason Mountain WMA	Sylvan	Preliminary	11	300	3.67%
Gus Engeling WMA	Disturbed	Late Winter	15	450	3.33%
Gus Engeling WMA	Sylvan	Late Winter	13	450	2.89%
Tejas Ranch	Disturbed	Late Winter	12	450	2.67%
Tejas Ranch	Sylvan	Late Winter	9	450	2.00%
Las Palomas WMA - Arroyo Colorado Unit	Disturbed	Late Winter	30	150	20.00%
Las Palomas WMA - Arroyo Colorado Unit	Sylvan	Late Winter	10	150	6.67%
Chaparral WMA	Disturbed	Late Winter	18	175	10.29%
Chaparral WMA	Sylvan	Late Winter	7	150	4.67%
Mason Mountain WMA	Disturbed	Late Winter	29	300	9.67%
Mason Mountain WMA	Sylvan	Late Winter	13	300	4.33%
Tejas Ranch	Disturbed	Spring	10	500	2.00%
Tejas Ranch	Sylvan	Spring	16	525	3.05%
Chaparral WMA	Disturbed	Spring	56	150	37.33%
Chaparral WMA	Sylvan	Spring	9	150	6.00%
Gus Engeling WMA	Disturbed	Spring	35	450	7.78%
Gus Engeling WMA	Sylvan	Spring	8	450	1.78%
Mason Mountain WMA	Disturbed	Spring	15	300	5.00%
Mason Mountain WMA	Sylvan	Spring	18	300	6.00%
Las Palomas WMA - Arroyo Colorado Unit	Disturbed	Spring	23	300	7.67%
Las Palomas WMA - Arroyo Colorado Unit	Sylvan	Spring	13	300	4.33%
Mason Mountain WMA	Disturbed	Fall	5	450	1.11%
Mason Mountain WMA	Sylvan	Fall	22	450	4.89%
Gus Engeling WMA	Disturbed	Fall	2	450	0.44%
Gus Engeling WMA	Sylvan	Fall	7	450	1.56%
Chaparral WMA	Disturbed	Fall	28	450	6.22%
Chaparral WMA	Sylvan	Fall	14	450	3.11%
Las Palomas WMA - Arroyo Colorado Unit	Disturbed	Fall	84	150	56.00%
Las Palomas WMA - Arroyo Colorado Unit	Sylvan	Fall	18	150	12.00%
Tejas Ranch	Disturbed	Fall	20	450	4.44%
Tejas Ranch	Sylvan	Fall	11	450	2.44%
TOTAL			592	10950	5.41%

Data collected

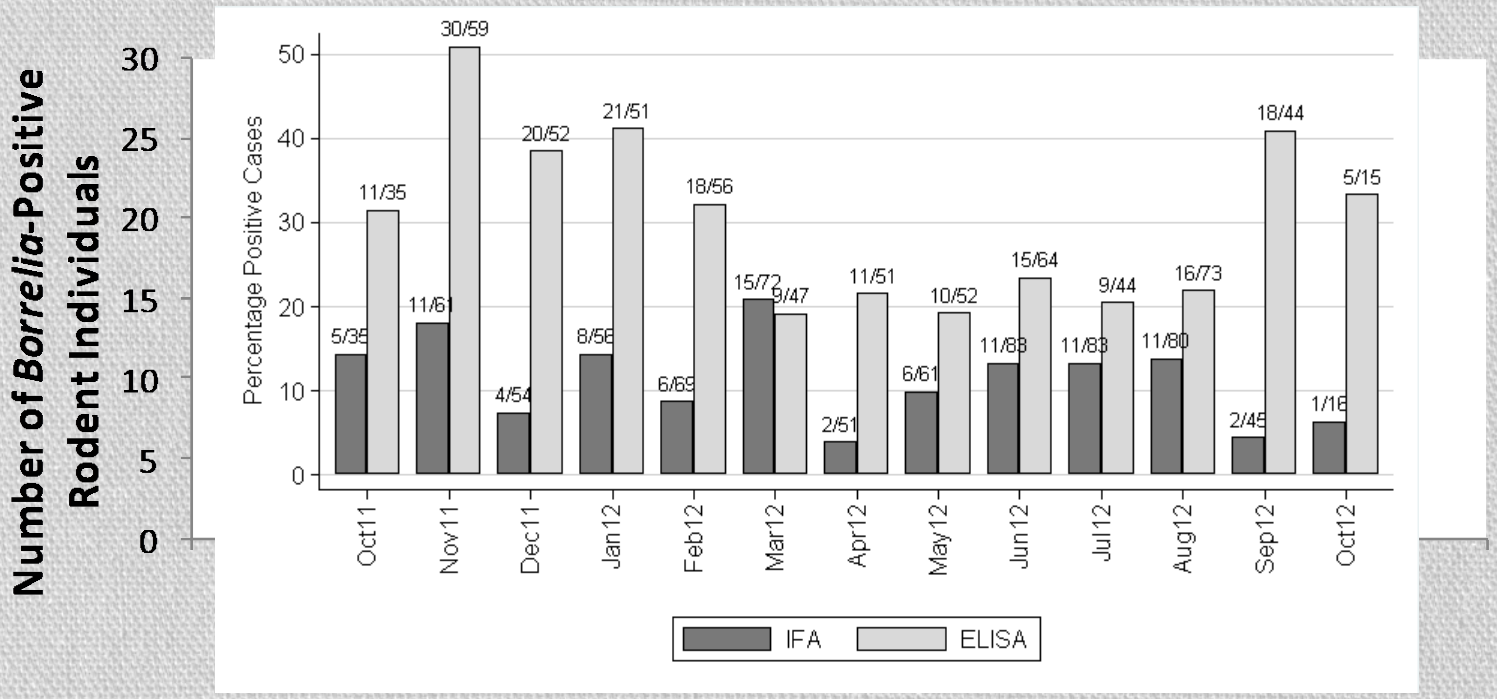
- Efforts were supervised by Dr. Ivan Castro-Arellano
- For each transect (Sylvan vs. Peridomestic):
  - Small mammal diversity
  - Tick load per individual collected
  - Tick species and stage per individual collected

- All transects were sampled at different times of the year and same information was collected
- Tissues and ticks submitted for molecular testing (blind)
  - *B. burgdorferi* PCR (fla and IGR)
  - Tick ID

Presence of *B. burgdorferi* positive mammals



Time where Mammals show infection



Small mammals and *B. burgdorferi*

Small mammal species highly infested with ticks in the different season sampled.

Rodent Species	# captured	Total number of ticks
Late Winter		
Peromyscus spp.	46	52
Oryzomys palustris	2	24
Peromyscus maliculatus	18	15
Spring		
Neotoma micropus	2	98
Neotoma lucodon	2	22
Sigmodon hispidus	26	25
Peromyscus leucopus	15	13
Peromiscus maniculatus	32	21
Peromiscus spp	54	20
Fall		
Peromyscus spp.	38	13
Peromyscus maniculatus	34	26
Sigmodon hispidus	25	52

Tick species on small mammals

Stage	Number
Adult	1 *
Nymph	1103
Larvae	214

* *Dermacentor variabilis*

Tick Species	# of ticks
Amblyomma auricularium	3
Amblyomma parvum	21
Amblyomma sp	1
Carios capensis	85
Dermacentor andersoni	1
Dermacentor variabilis	69
Ixodes affinis	4
Rhipicephalus spp	2
Total	**186**

Conclusions

- Rodent species with high tick loads change depending not only on location but also time of the year.
- Rodents show higher infection rates during fall
- Larger rodents tend to be more infested than *Peromyscus*
  - *Sigmodon hispidus*, *Neotoma leucodon* and *N. micropus* were the species highly infected in this study
    - Not present in Northeastern US
    - Might be playing an important role in the ecology of this pathogen in the South
      - Are these potential reservoirs?
- **Work in progress**

Thanks!

Small mammals and *B. burgdorferi*

Number of **ticks** found **on individual rodent** specimens in **disturbed habitats** for all sites sampled in Texas.

Site	Number of Ticks
Gus Engeling WMA	45
Mason Mountain WMA	26
Tejas Ranch	31
Chaparral WMA	114
Las Palomas WMA	107
TOTAL	**323**

Number of **ticks** found **on individual rodent** specimens in **sylvan habitats** for all sites sampled in Texas.

Site	Number of Ticks
Gus Engeling WMA	6
Mason Mountain WMA	1
Tejas Ranch	29
Chaparral WMA	27
Las Palomas WMA	20
TOTAL	**83**

Results from one-way ANOVAs for the comparison of the average number of ticks per rodent individual captured in Texas across three seasons.

Season	Total Number of Rodent Individuals	Number of Rodent Species	ANOVA		
			P	F	DF
Late Winter	125	16	< .001	4.673246	15
Spring	178	14	< .001	22.439	13
Fall	159	12	.732	.706	11

Global change and Human Health

- As World globalizes borders open:
  - Constant flow of goods and products
  - Pathogen dissemination
- Humans expand to new geographic locations:
  - Increases the possibility of close contact with pathogens
- Climate change
  - Impact directly the emergence of zoonotic diseases
    - 60% of new EID are zoonotic
    - 72% originate from wildlife
  - Transboundary zoonotic diseases

Esteve-Gassent et al (2014) Pathogenic landscape of transboundary zoonotic diseases in the Mexico-US border along the Rio Grande. Frontiers in Public Health (Submitted)

Hot Spots for Emerging Diseases

Map shows an analysis of the future likelihood of infectious diseases originating in wildlife that have the potential to infect humans.

KEY: GREATER RISK

Factors in the analysis included population density, proximity to and variety of wildlife, and climate.

West Nile virus A mosquito-borne illness that causes symptoms in about a fifth of those exposed. One in 150 becomes severely ill with encephalitis.

ANIMAL RESERVOIR Various birds, especially robins in the U.S.

FIRST HUMAN CASE West Nile district of Uganda, 1937; first U.S. case was in Queens in 1999.

WHY IT EMERGED International air travel.

SUSCEPTIBLE HOSTS Humans; birds, especially crows; horses.

SARS A severe viral respiratory infection that quickly spread from China to more than two dozen countries. The outbreak was contained, and since 2004 no new cases have been reported.

ANIMAL RESERVOIR Horseshoe bats.

FIRST HUMAN CASE Guangdong Province, China, 2003.

WHY Wildlife markets and trade; global travel.

SUSCEPTIBLE Humans, civets (inset, left).

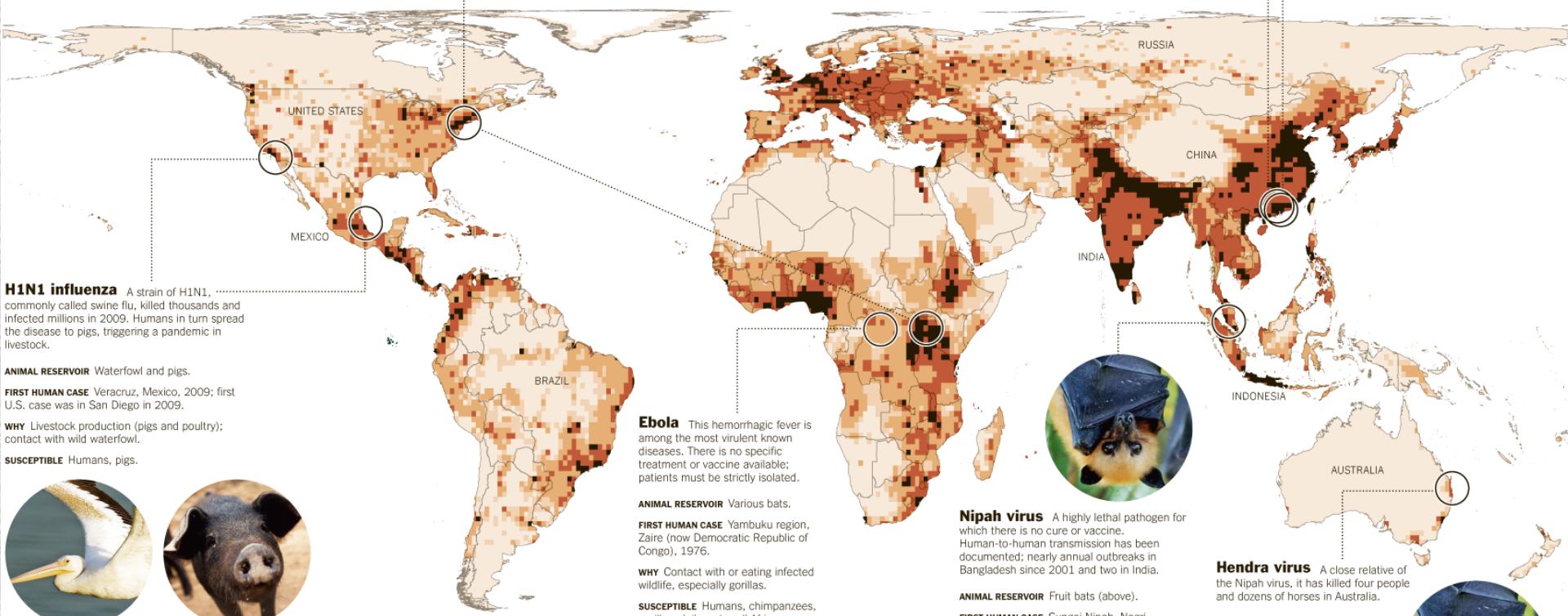
Bird flu A deadly strain of the avian influenza virus called H5N1 has spread to humans via contact with live or dead poultry.

ANIMAL RESERVOIR Wild waterfowl.

FIRST HUMAN CASE Hong Kong, 1997. It re-emerged widely in 2003 and 2004.

WHY Global expansion of intensive poultry farming; contact with infected birds.

SUSCEPTIBLE Humans, poultry, cats.



H1N1 influenza A strain of H1N1, commonly called swine flu, killed thousands and infected millions in 2009. Humans in turn spread the disease to pigs, triggering a pandemic in livestock.

ANIMAL RESERVOIR Waterfowl and pigs.

FIRST HUMAN CASE Veracruz, Mexico, 2009; first U.S. case was in San Diego in 2009.

WHY Livestock production (pigs and poultry); contact with wild waterfowl.

SUSCEPTIBLE Humans, pigs.

Ebola This hemorrhagic fever is among the most virulent known diseases. There is no specific treatment or vaccine available; patients must be strictly isolated.

ANIMAL RESERVOIR Various bats.

FIRST HUMAN CASE Yambuku region, Zaire (now Democratic Republic of Congo), 1976.

WHY Contact with or eating infected wildlife, especially gorillas.

SUSCEPTIBLE Humans, chimpanzees, gorillas, duikers (small African antelopes, below right).

Nipah virus A highly lethal pathogen for which there is no cure or vaccine. Human-to-human transmission has been documented; nearly annual outbreaks in Bangladesh since 2001 and two in India.

ANIMAL RESERVOIR Fruit bats (above).

FIRST HUMAN CASE Sungai Nipah, Negri Sembilan, Malaysia, 1998.

WHY Large-scale livestock production; presence of orchards on pig farms; date palm sap harvest (eating contaminated sap is a significant cause of infection).

SUSCEPTIBLE Humans, pigs, horses, dogs, cats.

Hendra virus A close relative of the Nipah virus, it has killed four people and dozens of horses in Australia.

ANIMAL RESERVOIR Fruit bats.

FIRST HUMAN CASE Hendra, a suburb of Brisbane, Australia, 1994.

WHY Urban encroachment of wild habitats.

SUSCEPTIBLE Humans, horses, dogs.

Number of tick per rodent Individual

Site	Season	Total Number of Rodent Individuals	Number of Rodents WIth No Ticks	Maximum Number of Ticks	Number of Rodents With Ticks	ANOVA		
						P	F	DF
Gus Engeling WMA	All	67	50	21	17	0.080	2.634	2
	Late Winter	23	15	21	8			
	Spring	35	26	2	9			
	Fall	9	9	0	0			
Mason Mountain WMA	All	100	95	22	5	0.349	1.065	2
	Late Winter	39	37	2	2			
	Spring	33	30	22	3			
	Fall	28	28	0	0			
Tejas Ranch	All	73	54	12	19	0.005	5.742	2
	Late Winter	19	9	12	10			
	Spring	26	24	1	2			
	Fall	28	21	9	7			
Chaparral WMA	All	114	93	80	21	0.310	1.182	2
	Late Winter	22	19	1	3			
	Spring	50	41	80	9			
	Fall	42	33	3	9			
Las Palomas WMA	All	108	73	36	35	0.915	0.089	2
	Late Winter	22	13	4	9			
	Spring	34	22	17	12			
	Fall	52	38	36	14			

Similar distribution by others

Considering the location of ticks from humans submitted for analysis and incidence of Lyme disease in the state of Texas.

Aviña A, CTiwari C, Williamson P, Oppong J, Atkinson S**: A Spatially Explicit Environmental Health Surveillance Framework for tick-borne diseases**. In Geospatial Analysis of Environmental Health, Chapter 18, Volume 4. Edited by Maantay JA, McLalterty S: Springer; 2011:357–371

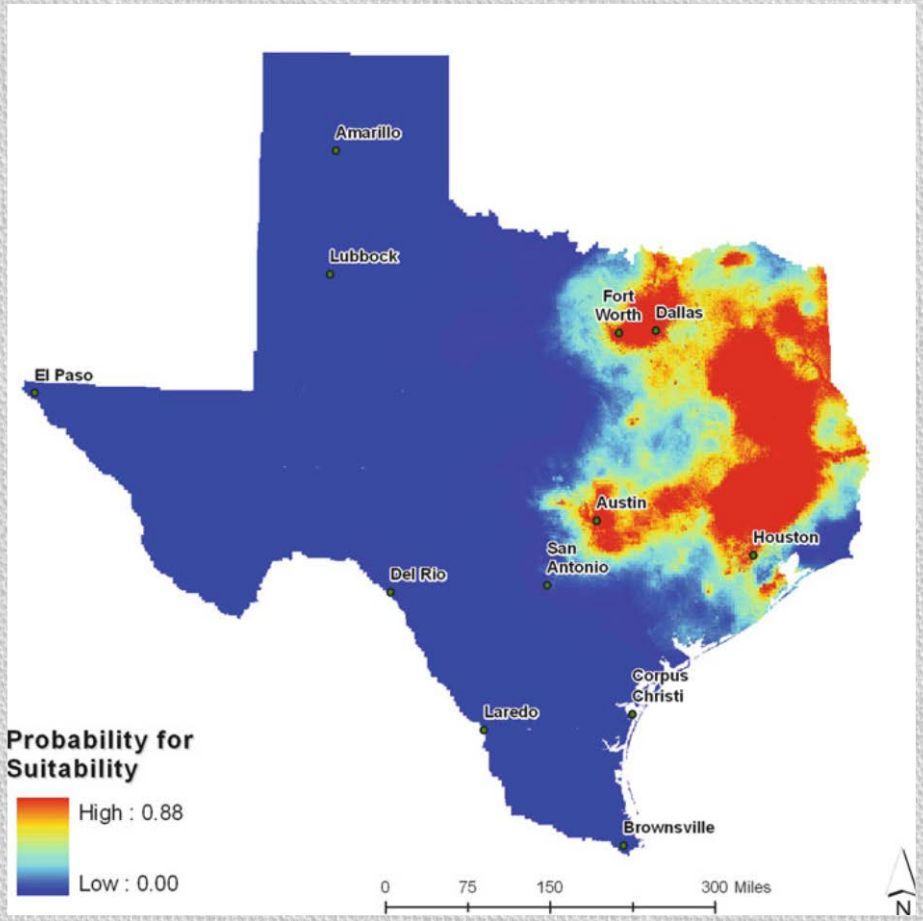


Fig. 18.4 Estimated distribution of *Ixodes scapularis*, based on environmental suitability