

## Ecology and health: Control of emerging and re-emerging infectious diseases transmitted by wildlife.

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UNAM, México.



## Microorganisms and life on earth

Microorganisms (virus, prions, bacteria, protozoa) have higher species diversity than their hosts and represent +- 60 % of the biomass on earth.

They produce at least half of the oxygen we breath (Gans et al, 2005)



## Viruses and life on earth

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Viruses infect bacteria, archaeobacteria and microeukaryotes, driving biogeochemical cycles (C, N, and P), altering food web and biodiversity.

We only know 83 families of viruses +- 2600 virus according to the (ICTV) (King et al 2012). Each family has different reproduction strategies (Macnaughton y Lai 2006).

We estimate around 320,000 viruses for mammals worldwide (Anthony et al 2013).

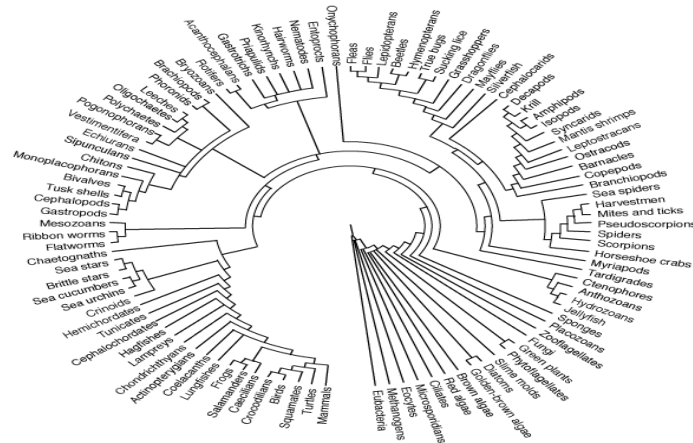
## Viruses and life on earth

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Viruses affect reproduction, population dynamics, and induce population and species extinction.

Contrary, when ecosystems are dominated by few species, viruses create new ecological niches, increasing biodiversity.

## Viral ubiquity



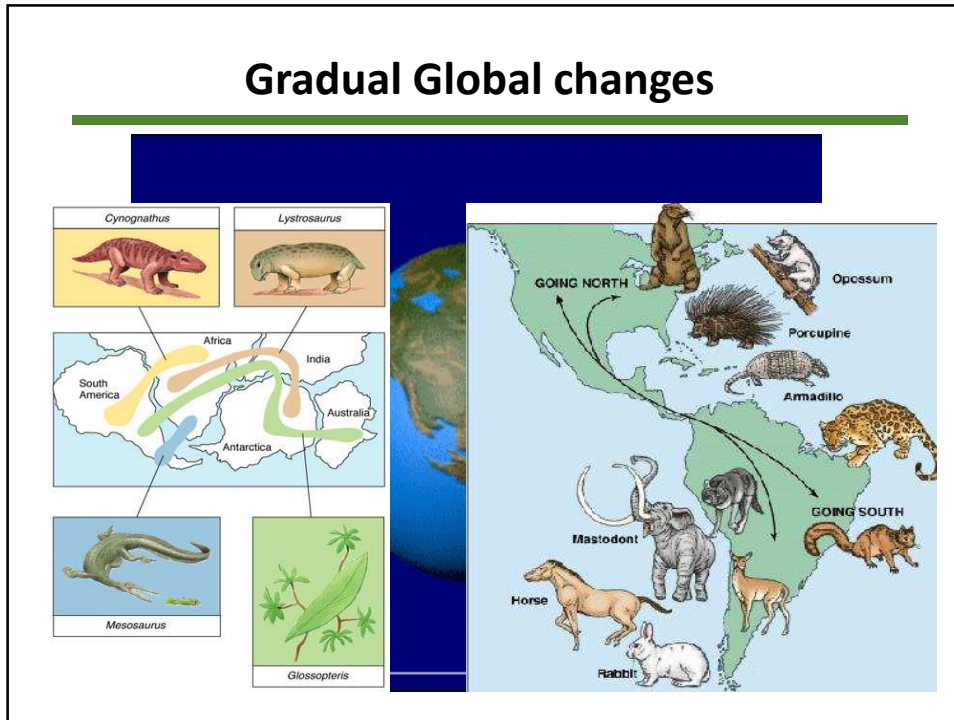
Tree of Life. Phylogenetic (evolutionary) tree diagram tracing the past four billion years of life on Earth. The tree is based primarily on ribosomal RNA datasets. (Graphic courtesy David M. Hillis)

## Different points of view

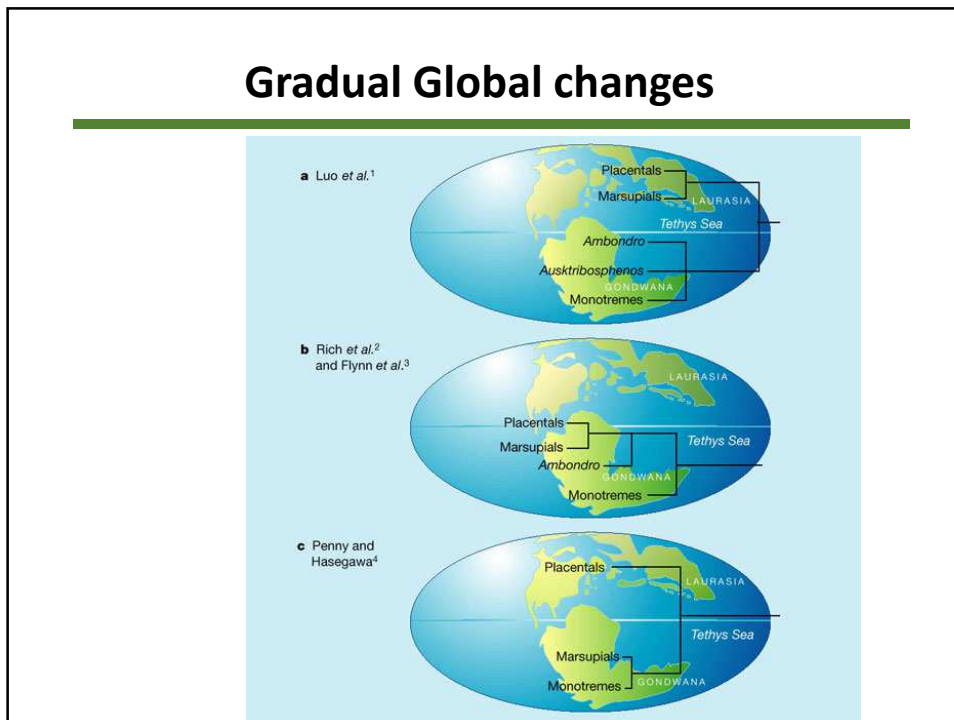
Medawar 1960 “Virus is a piece of bad news wrapped in a protein” (Health sciences)

In ecology and evolution, viruses can transfer genes across species boundaries increasing biodiversity.

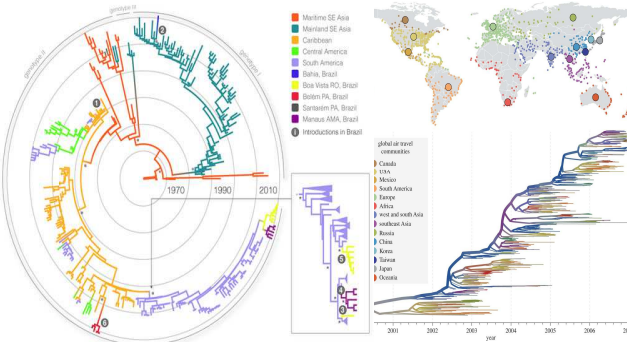
## Gradual Global changes



## Gradual Global changes



## Actual changes and viral diversification

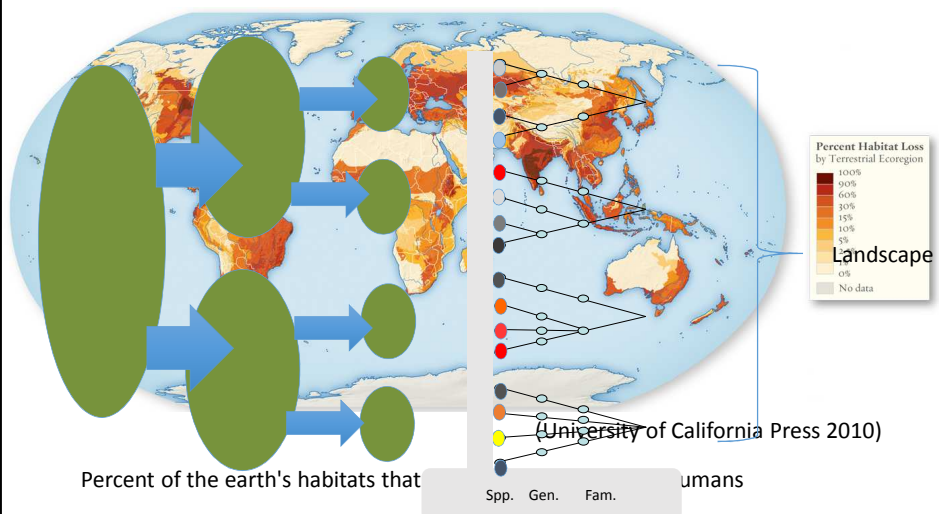


Dengue virus

H3 N2

## Actual Global changes

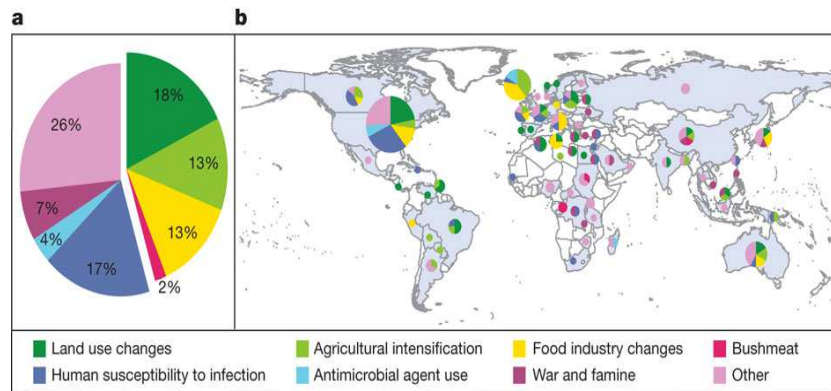
Changes in biotic interactions produce changes in Ecological and Evolutionary relationships



Percent of the earth's habitats that

Spp. Gen. Fam. humans

## Global changes and zoonotic disease emergence



Drivers and locations of emergence events for zoonotic infectious diseases in humans from 1940–2005. Keesing et al 2010

## New approaches are required

- **Ecological and evolutionary** approaches are required to identify underlying causes of infectious disease maintenance and occurrence and are needed to provide proper management and prevention strategies.
- The ecological complexity of infectious diseases requires novel research tools and the integration of **multidisciplinary** approaches at different scales of analyses in time and space within population, metapopulation, community and ecosystem perspectives .

# Habitat Fragmentation

- Often related to increased disease risks for both humans and wildlife



Research Meeting Report

## Unhealthy Landscapes: Policy Recommendations on Land Use Change and Infectious Disease Emergence

Jonathan A. Patz,<sup>1</sup> Peter Daszak,<sup>2</sup> Gary M. Tabor,<sup>3</sup> A. Alonso Aguirre,<sup>4</sup> Mary Pearl,<sup>4</sup> Jon Epstein,<sup>2</sup> Nathan D. Wolfe,<sup>5</sup> A. Marm Kilpatrick,<sup>6</sup> Johannes Foufopoulos,<sup>6</sup> David Molyneux,<sup>7</sup> David J. Bradley,<sup>8</sup> and Members of the Working Group on Land Use Change and Disease Emergence

## Effects of Habitat Fragmentation on Choke Disease (*Epichloe bromicola*) in the Grass *Bromus erectus*



Kathleen Groppé; Thomas Steinger; Bernhard Schmid; Bruno Baur; Thomas Bollner

*Journal of Mammalogy*, 89(3):684-690, 2008

*The Journal of Ecology*, Vol. 89, No. 2, (Apr., 2001), pp. 247-255.

## EPIDEMIOLOGICAL CONSIDERATIONS OF RODENT COMMUNITY COMPOSITION IN FRAGMENTED LANDSCAPES IN PANAMA

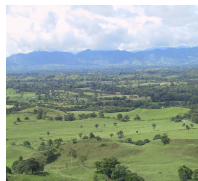
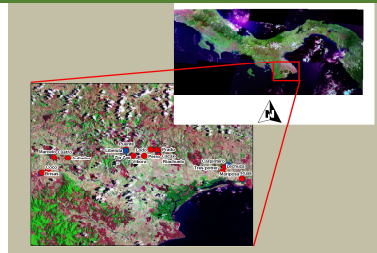
GERARDO SUZÁN,\* ANIBAL ARMÉN, JAMES N. MILLS, ERIKA MARCÉ, GERARDO CEBALLOS, MARIO ÁVILA, JORGE SALAZAR-BRAVO, LUIS RUEDAS, BLAS ARMÉN, AND TERRY L. YATES

*Am. J. Trop. Med. Hyg.*, 74(6), 2006, pp. 1103-1110  
Copyright © 2006 by The American Society of Tropical Medicine and Hygiene

## MODELING HANTAVIRUS RESERVOIR SPECIES DOMINANCE IN HIGH SEROPREVALENCE AREAS ON THE AZUERO PENINSULA OF PANAMA

GERARDO SUZÁN, J. TOMASZ GIERMAKOWSKI\*, ERIKA MARCÉ, HUMBERTO SUZÁN-AZPIRI, BLAS ARMÉN, AND TERRY L. YATES

Museum of Southwestern Biology and Department of Biology, University of New Mexico, Albuquerque, New Mexico; Escuela de Biología, Facultad de Ciencias Naturales, Universidad Autónoma de Querétaro, Querétaro, México; Instituto Conmemorativo GORGAS, Ciudad de Panamá, Panamá







### Responses of Small Mammals to Habitat Fragmentation: Epidemiological Considerations for Rodent-Borne Hantaviruses in the Americas

André V. Rubio,<sup>1</sup> Rafael Ávila-Flores,<sup>2</sup> and Gerardo Suzán<sup>1</sup>

<sup>1</sup>Departamento de Ecología, Fauna Silvestre y Animales de Laboratorio, Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional Autónoma de México, Ciudad Universitaria, C.P. 04510 México, Distrito Federal, México  
<sup>2</sup>División Académica de Ciencias Biológicas, Universidad Juárez Autónoma de Tabasco, Km 0.5 Carretera Villahermosa-Cárdenas, C.P. 86039 Villahermosa, Tabasco, México

\* Hantavirus strains known to produce disease in humans.

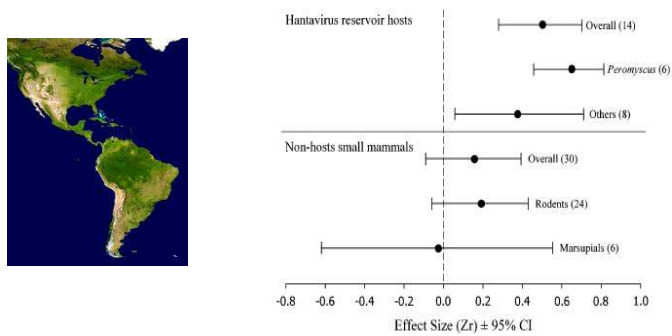
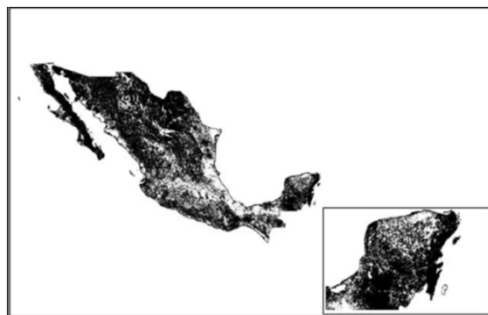


Figure 1. Effect sizes  $\pm 95\%$  CI of small mammal abundances (hantavirus reservoir host and non-host small mammals) associated with patch size reduction. Sample size of effect sizes are shown in parentheses. The vertical dashed line indicates the 0 value. Effects are statistically significant when the 95% CI of effect sizes do not overlap with 0.

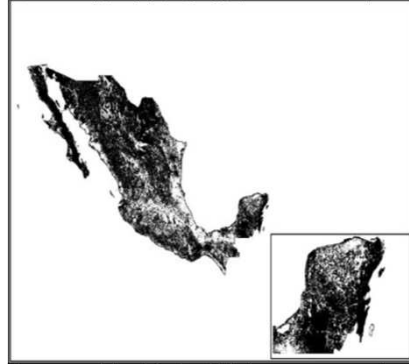
## Habitat deforestation in Mexico



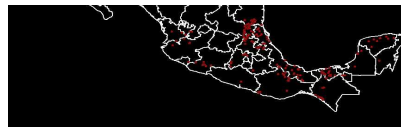
Transformed habitat (white areas) and untransformed habitat (black areas) projected nationwide, based on the Inventario Nacional Forestal (Sanchez-Cordero et al., 2005)

- In Mexico, annual rates of deforestation are over 1% nationwide.

## Bovine Rabies and vampire bats



Las pérdidas directas por concepto de mortalidad de 935 cabezas de ganado durante 2012 asciende a \$7, 526, 750 (US Dis. \$ 589,408.77)

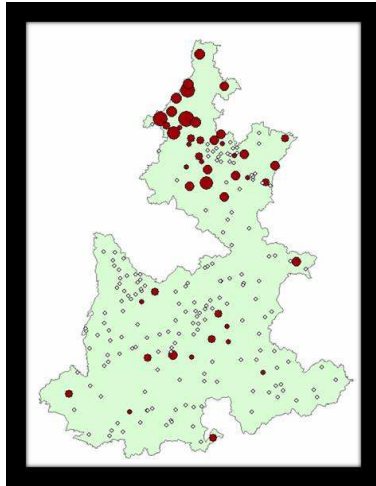


## Bovine Paralytic Rabies



- ☐ Death of more than 4000 animals per year with large economic impact in Mexico

## Bovine Rabies in the State of Puebla Mexico



Committee of Animal Health and Health State department

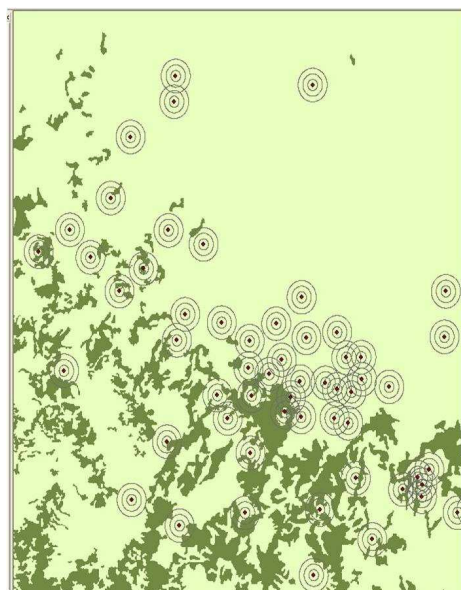
Bovine Rabies Cases , primarily focused on Northern Sierra. Years 1997 to 2000

Carrasco-Hernández et al. unpublished data

## Landscape scale

To describe the surrounding landscape, we counted the amount of pixels corresponding to edge zones between conserved vegetation and antropogenic land use, around towns and cities of the State of Puebla, Mexico

We also considered the surrounding temperatures, precipitations, elevations, slopes and conserved vegetation area to build a niche model for bovine rabies using MAXENT software.



## Landscape scale

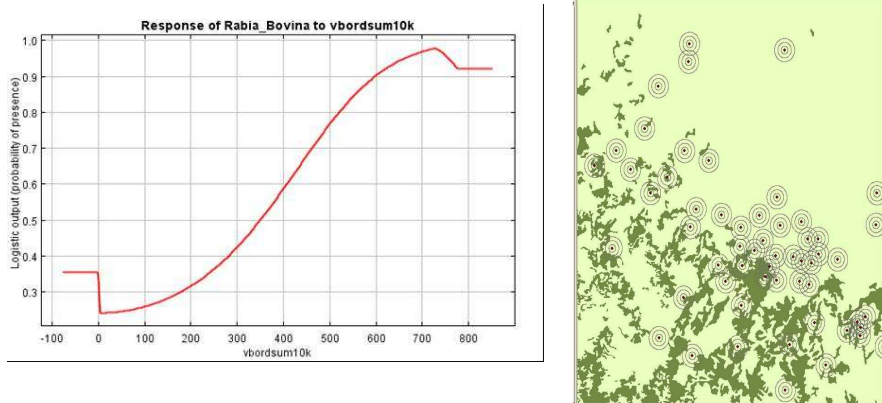
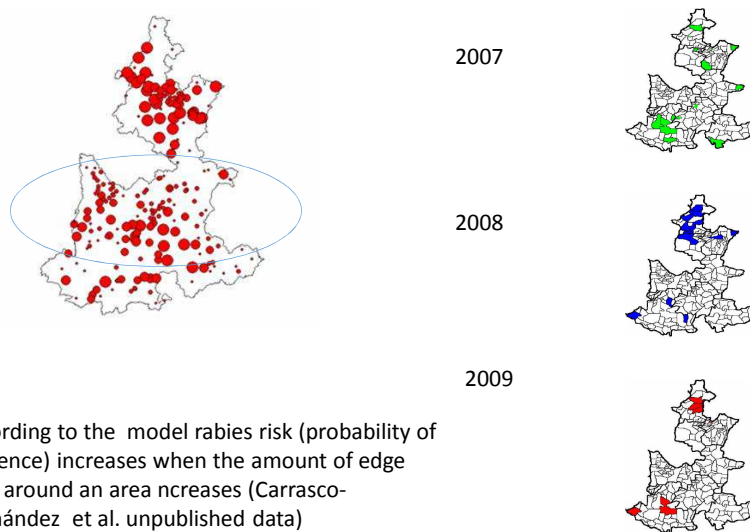


Figure 2 . - Modeled suitability (y axis) vs. edge area surrounding counties between 5 and 10Km (X axis) .

According to the model rabies risk (probability of presence) increases when the amount of edge area around a single city increases. This modeled trend is due to the high edge area around training points ( towns and cities with reported rabies cases that were used to build the model)

Carrasco-Hernández et al. unpublished data

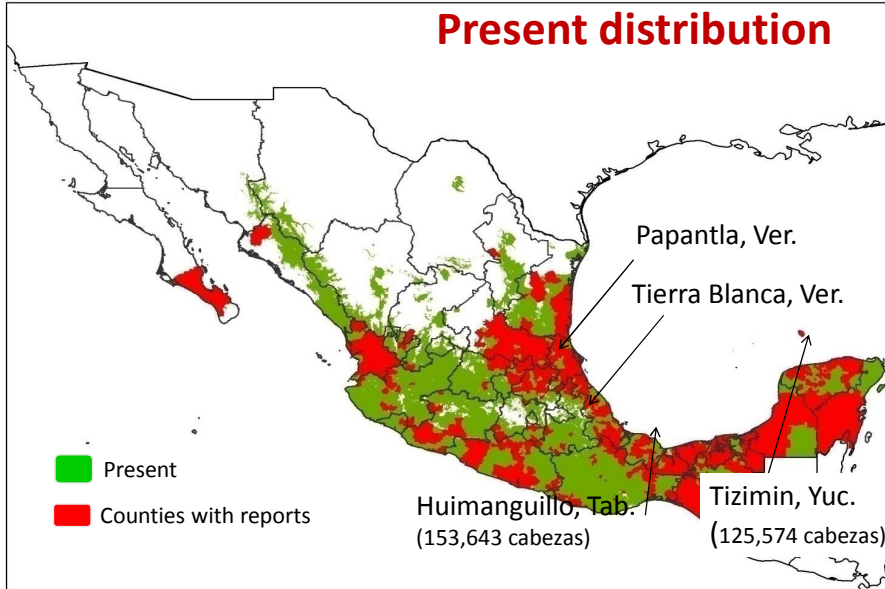
## Geographical Model of Bovine Rabies Risk for the State of Puebla, México



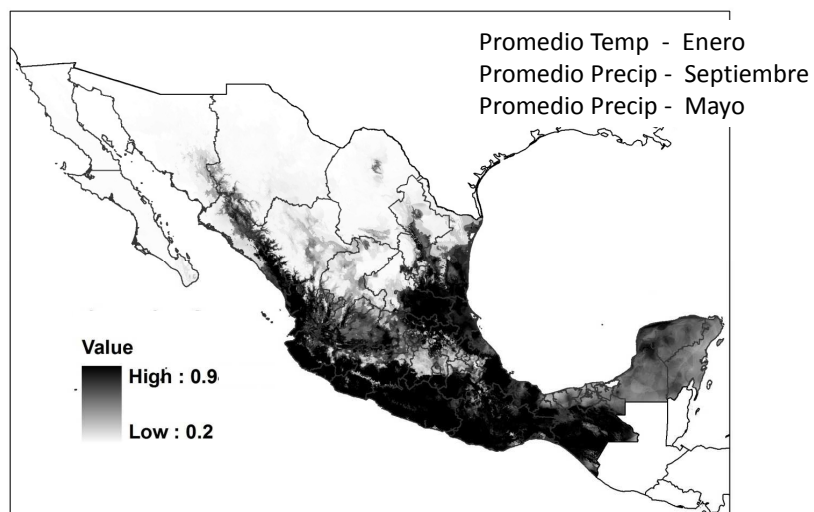
According to the model rabies risk (probability of presence) increases when the amount of edge area around an area increases (Carrasco-Hernández et al. unpublished data)

## Modeling vampire bats

### Present distribution

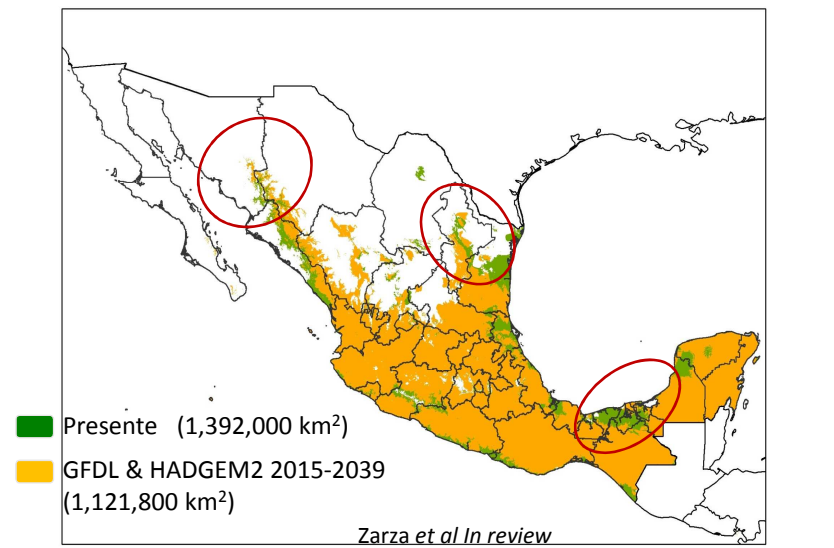


## Potential distribution of vampire bats in México

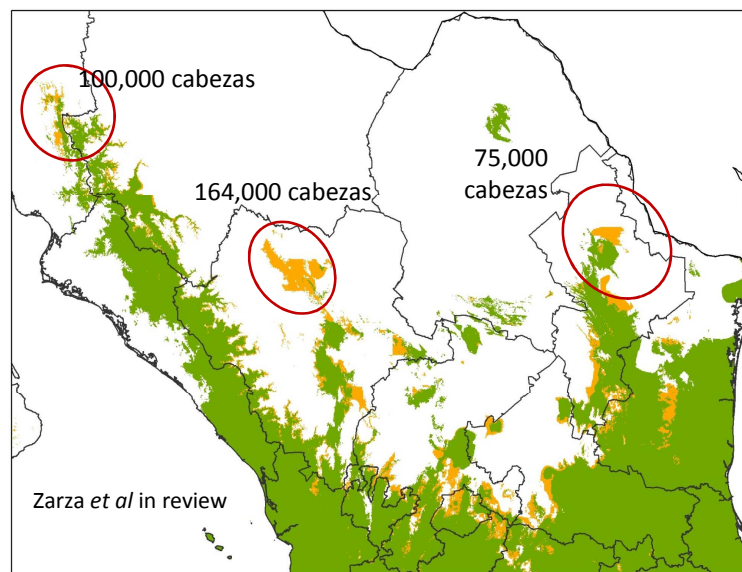


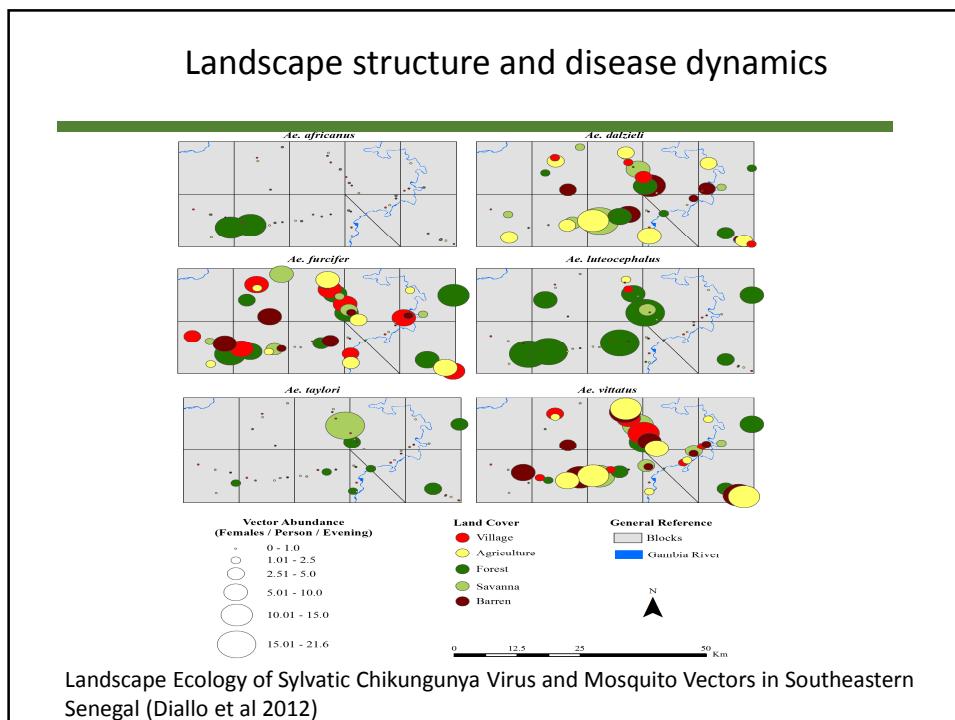
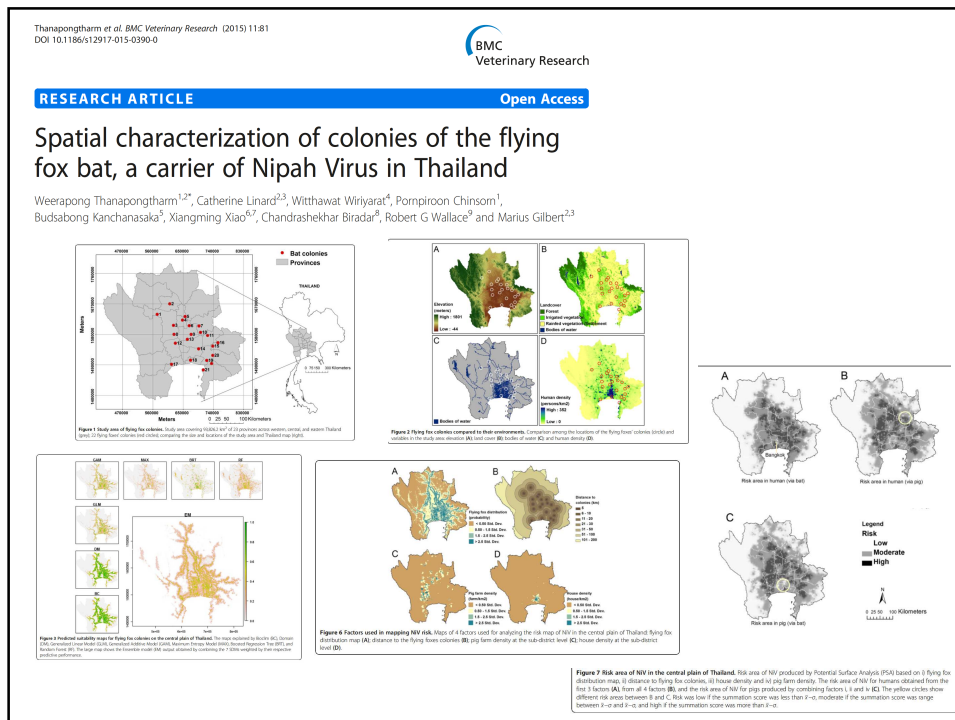
Área bajo la curva: 0.92 Zarza *et al in Review*

### Future scenarios



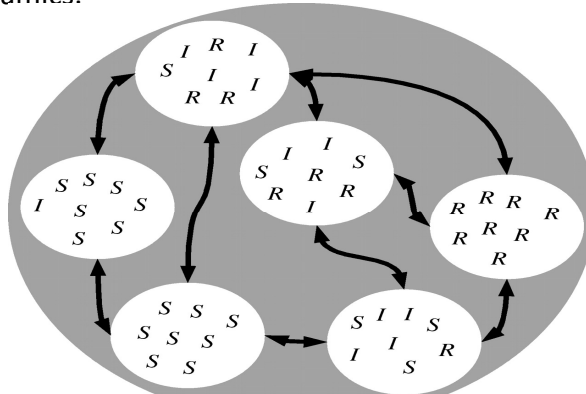
### Future scenarios





## Metapopulation and diseases

- Several species have a metapopulation structure
- Spatial structure of host population affect infectious dynamics.

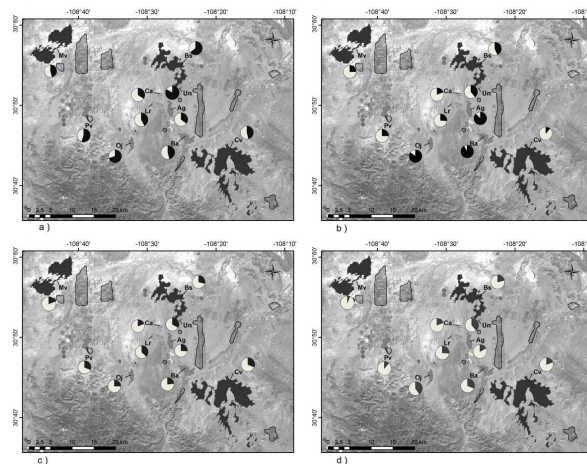


DOI: 10.7554/2013-10-259

Journal of Wildlife Diseases, 51(1), 2015, pp. 26–35  
© Wildlife Disease Association, 2015

### RISK FACTORS ASSOCIATED WITH PREVALENCE OF ANTIBODIES TO *LEPTOSPIRA INTERROGANS* IN A METAPOPULATION OF BLACK-TAILED PRAIRIE DOGS IN MEXICO

Ana Montiel-Arteaga,<sup>1,3</sup> Daniel Atilano,<sup>1</sup> Alejandra Ayanegui,<sup>1</sup> Gerardo Ceballos,<sup>2</sup> and Gerardo Suzán<sup>1</sup>





## Species diversity and disease ecology

### Plants

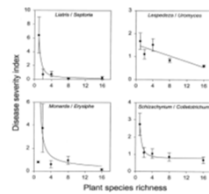
- Teophrastus (372-288 B.C.)
- Diversity disease hypothesis. (Elton, 1958, Knops, et al., 1999).



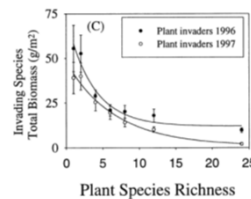
## Species diversity loss and infectious diseases

*Ecology Letters*, (1999) 2: 286–293

### Effects of plant species richness on invasion dynamics, disease outbreaks, insect abundances and diversity



Knops et al 1999



**Table 1 | Biodiversity loss can increase transmission**

Disease	Mechanism	Reference
Amphibian limb malformation	B	12
Bacteriophage of <i>Pseudomonas syringae</i>	B	52
Coral diseases	A	53
Fungal disease of <i>Daphnia</i>	B	54
Hantavirus disease	A, B	23, 55–57
Helminthic parasite of fish	A*	58
Lyme disease	A, B	18, 22, 59
Malaria	A	60
<i>Puccinia</i> rust infection of ryegrass	A*	10
Schistosomiasis	B	12
Trematode diseases of snails and birds	B	61–63
West Nile fever	A*, B*	7–9, 64

Disease examples are since 2005. A more complete table, including several counterexamples, is available from the corresponding author. Mechanisms for effects were reported by authors or demonstrated in the text (A = host/vector abundance; B = host/vector/parasite behaviour; see Box 1 for details). Asterisks indicate a suggested mechanism. Other studies have been reviewed elsewhere<sup>21, 65</sup>.

Keesing et al 2010

OPEN ACCESS Freely available online

PLoS one

## Experimental Evidence for Reduced Rodent Diversity Causing Increased Hantavirus Prevalence

Gerardo Suzán<sup>1†</sup>, Erika Marcé<sup>1</sup>, J. Tomasz Giernakowski<sup>1</sup>, James N. Mills<sup>2</sup>, Gerardo Ceballos<sup>3</sup>, Richard S. Ostfeld<sup>4\*</sup>, Blas Armien<sup>5</sup>, Juan M. Pascale<sup>5</sup>, Terry L. Yates<sup>1</sup>

**†** Museum of Southwestern Biology and Department of Biology, University of New Mexico, Albuquerque, New Mexico, United States of America, **2** Division of Viral and Rickettsial Diseases, Centers for Disease Control and Prevention, Atlanta, Georgia, United States of America, **3** Instituto de Ecología, Universidad Nacional Autónoma de México, Ciudad Universitaria, México, Distrito Federal, México, **4** Cary Institute of Ecosystem Studies, Millbrook, New York, United States of America, **5** Instituto Conmemorativo GORGAS, Ciudad de Panamá, Panamá

\* [ostfeld@care.cdc.gov](mailto:ostfeld@care.cdc.gov)

• Both the reservoir abundance and seroprevalence of hantavirus competent reservoirs in wild rodent communities will **increase** when non-reservoirs are removed.

OPEN ACCESS Freely available online

PLoS one

## Experimental Evidence for Reduced Rodent Diversity Causing Increased Hantavirus Prevalence

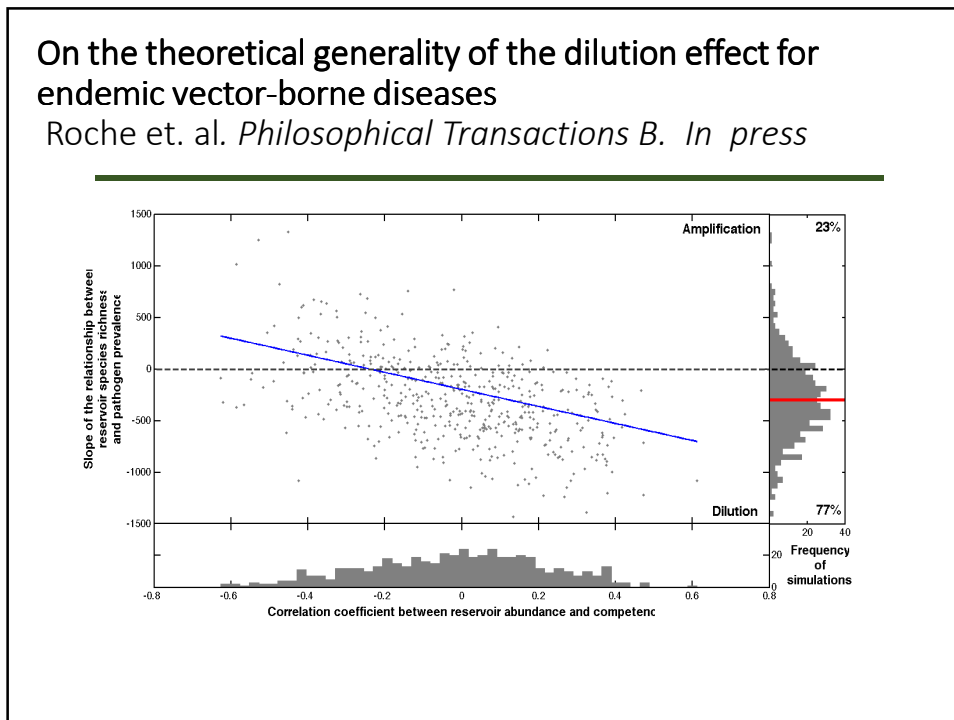
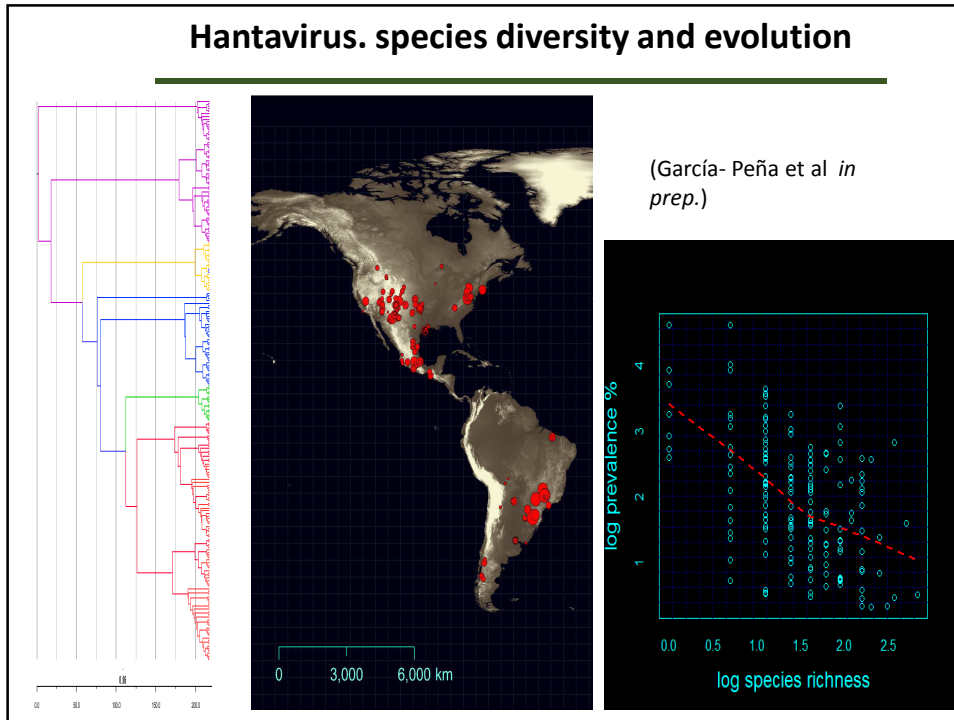
Gerardo Suzán<sup>1†</sup>, Erika Marcé<sup>1</sup>, J. Tomasz Giernakowski<sup>1</sup>, James N. Mills<sup>2</sup>, Gerardo Ceballos<sup>3</sup>, Richard S. Ostfeld<sup>4\*</sup>, Blas Armien<sup>5</sup>, Juan M. Pascale<sup>5</sup>, Terry L. Yates<sup>1</sup>

**†** Museum of Southwestern Biology and Department of Biology, University of New Mexico, Albuquerque, New Mexico, United States of America, **2** Division of Viral and Rickettsial Diseases, Centers for Disease Control and Prevention, Atlanta, Georgia, United States of America, **3** Instituto de Ecología, Universidad Nacional Autónoma de México, Ciudad Universitaria, México, Distrito Federal, México, **4** Cary Institute of Ecosystem Studies, Millbrook, New York, United States of America, **5** Instituto Conmemorativo GORGAS, Ciudad de Panamá, Panamá

\* [ostfeld@care.cdc.gov](mailto:ostfeld@care.cdc.gov)

**Box 2 figure | Effects of experimental removal of species** a. Mean (± standard error) population abundance of hantavirus hosts in *Peromyscus* in field plots before and after non-host species had been removed (solid line), and in unmanipulated controls (dashed line). Hosts on control plots underwent a strong seasonal decline in abundance, whereas those on plots where non-hosts were experimentally removed did not. b. Mean (± standard error) density of competitive (currently or previously indexed) animals on plots from which non-hosts had been removed and on control plots. Analyzed from data provided in ref. 23.

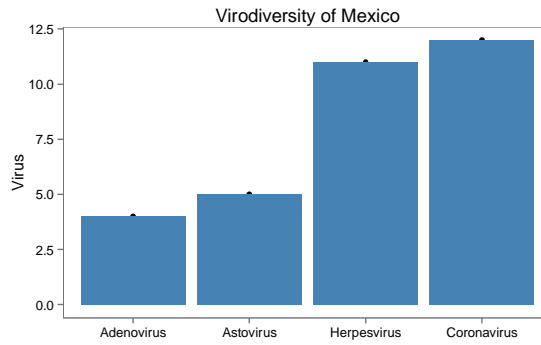
**Figure 3. Relationship between competitive reservoir abundance (C. rickardsi and O. leucogaster) and seroprevalence for hantavirus in control and experimental sites.** a and b. Scatter plots showing the relationship between competitive reservoir abundance (log scale) and seroprevalence (log scale) for control sites (left column) and experimental sites (right column). a. Relationship between *C. rickardsi* abundance and seroprevalence. b. Relationship between *O. leucogaster* abundance and seroprevalence. Linear regression analysis revealed a significant positive relationship between abundance and seroprevalence in experimental plots.



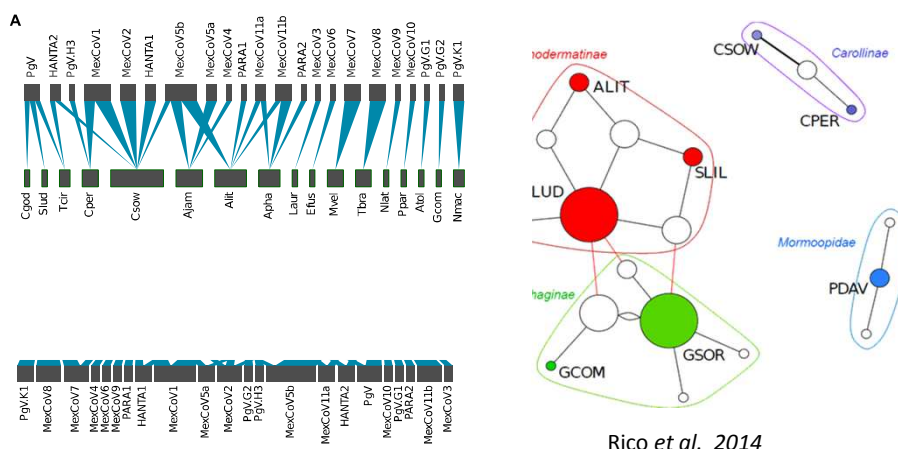
## Virodiversity in México

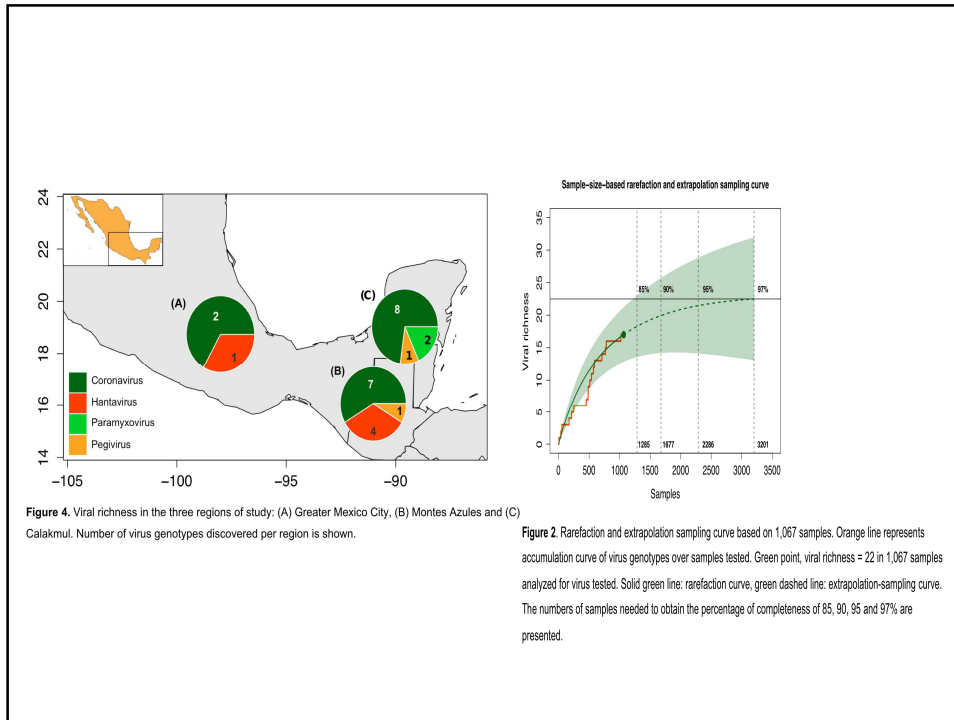
13 Families identified by consensus PCR :

- Coronavirus
- Adenovirus
- Herpesvirus
- Astrovirus
- Paramyxovirus
- Alphavirus
- Filovirus
- Flavivirus
- Lyssavirus
- Seadornavirus
- Arenavirus
- Hantavirus
- Bocavirus



## Viral diversity of bat communities in human-dominated landscapes in Mexico.

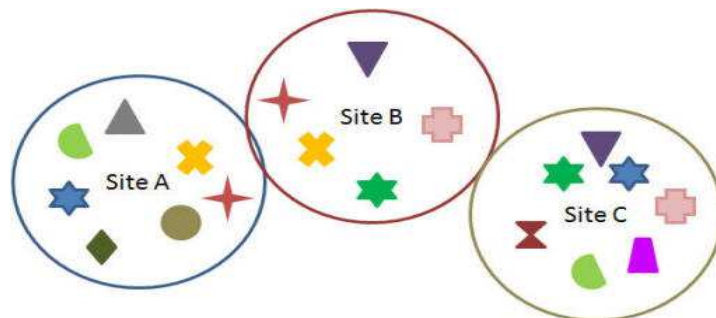




## Community level (alfa diversity)

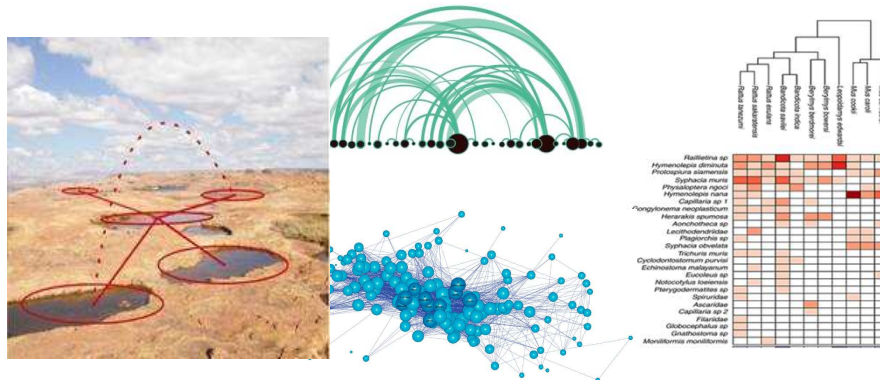
Most studies on the ecology of zoonotic diseases caused by pathogens hosted by wildlife reservoirs and vectors focus at the level of local populations and communities and the environment in which these interactions occur (Karesh et al. 2012).

Most of the studies focused on **richness, relative abundance, species diversity and species composition**



## Different spatial scales of analysis

Understanding how local and regional processes affect the structure of ecological communities including host vectors and parasites, calls for integrating both ecological and evolutionary relationships at landscape level.



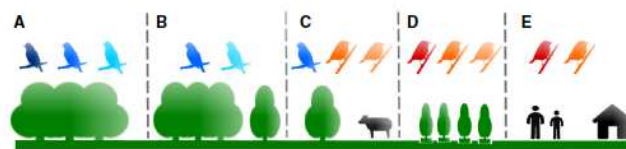
## Ecology and Evolution

Open Access

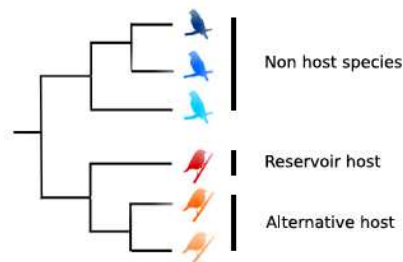
### HYPOTHESES

### Metacommunity and phylogenetic structure determine wildlife and zoonotic infectious disease patterns in time and space

Gerardo Suzán<sup>1</sup>, Gabriel E. García-Peña<sup>1,2,3</sup>, Ivan Castro-Arellano<sup>4</sup>, Oscar Rico<sup>1</sup>, André V. Rubio<sup>1</sup>, María J. Tolsá<sup>1</sup>, Benjamin Roche<sup>5</sup>, Parvaz R. Hosseini<sup>6</sup>, Annapaola Rizzoli<sup>6</sup>, Kris A. Murray<sup>7</sup>, Carlos Zambrana-Torrel<sup>8</sup>, Marion Vittecoq<sup>9</sup>, Xavier Bailly<sup>9</sup>, A. Alonso Aguirre<sup>9</sup>, Peter Daszak<sup>9</sup>, Anne-Hélène Prieur-Richard<sup>9</sup>, James N. Mills<sup>10</sup> & Jean-François Guegan<sup>1</sup>

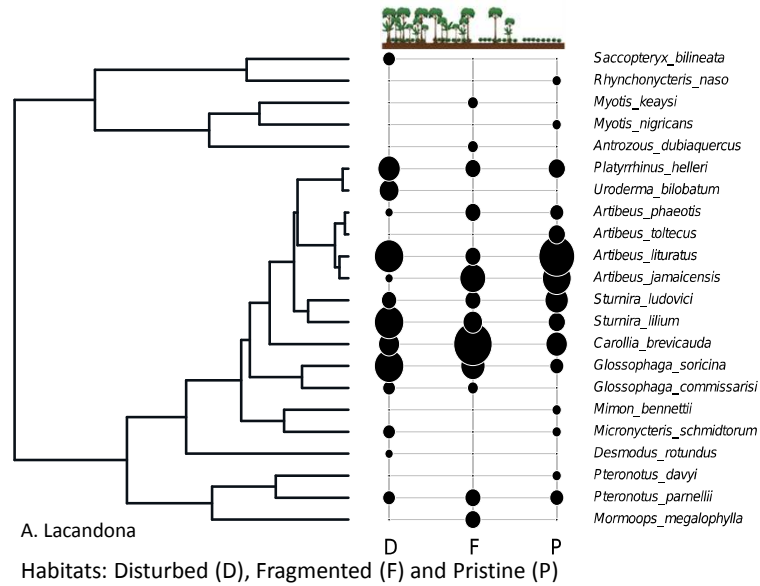


(A) Metacommunity

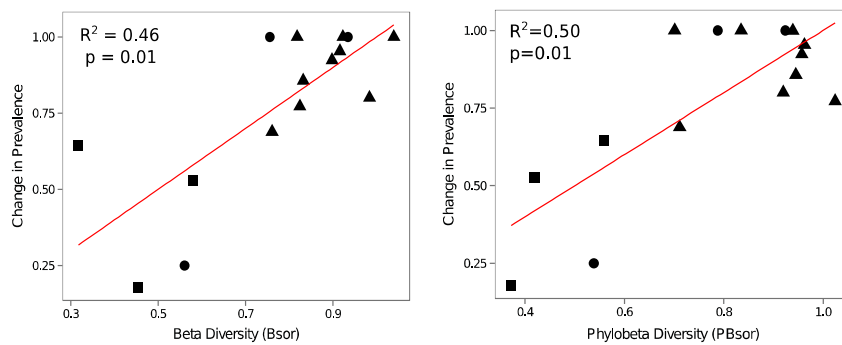


(B) Phylogeny

## At community and metacommunity level



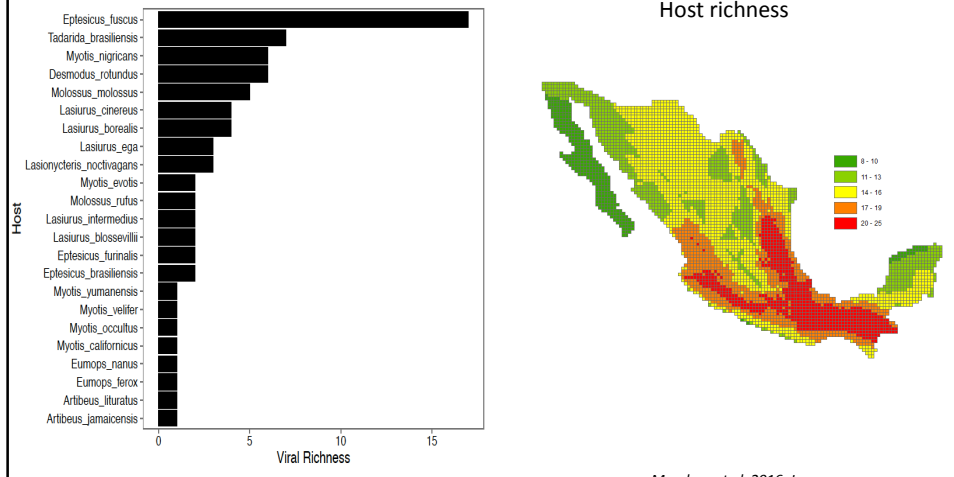
## At metacommunity level



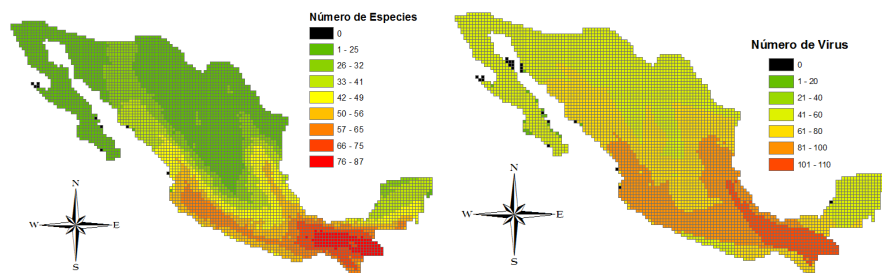
- There is a strong relationship between the change in species composition with the variation of rabies prevalence.

(Rico-Chávez et al unpublished data).

## Meta-analysis of rabies sequences and bats



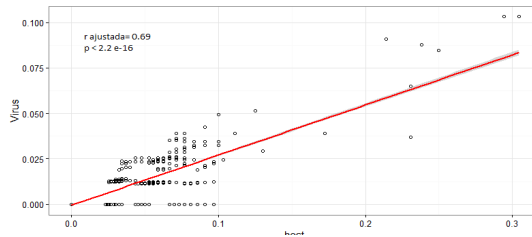
## Meta-analysis of viruses and bats



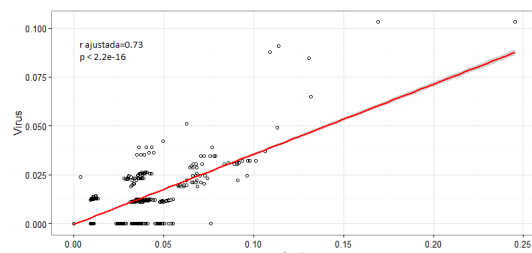


## Beta-diversity and virus diversity

Species diversity



Phylogenetic diversity



## ¿What is the best landscape structure to prevent rabies outbreaks?



## Conclusions

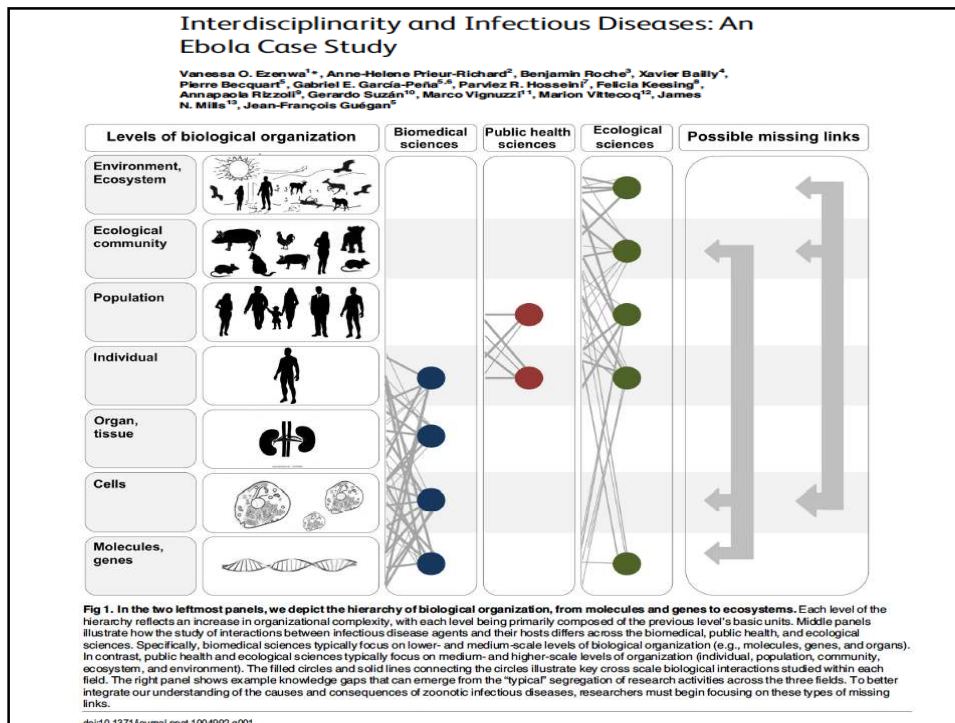
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- Infectious diseases are the result of complex ecological, evolutionary and anthropogenic interactions.
- Human activities including land-use changes impact disease dynamics and emergence.
- Landscape studies using a metacommunity framework can provide novel insights into the mechanisms of emergence of infectious diseases in wildlife including zoonoses.

## Conclusions

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- The integration of theoretical and empirical findings at multiscale approaches will help scientists and policy makers to build novel transdisciplinary solutions to predict, prevent and respond to different outbreaks including rabies.



## Collaborators

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- Oscar Rico
- Citalli Mendoza
- Paola Martínez
- Rafael Ávila
- Rafael Ojeda
- Heliot Zarza
- Gabriel García Peña
- Carlos Zambrana
- Peter Daszak



**EcoHealth Alliance**  
Local conservation.  
Global health.






**GRUPO DE ECOLOGÍA DE ENFERMEDADES  
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