

EcoHealth Alliance

Drivers of Infectious Disease: Connections Matter

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Executive Vice President for Health and Policy, EcoHealth Alliance

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Local conservation.
Global health.

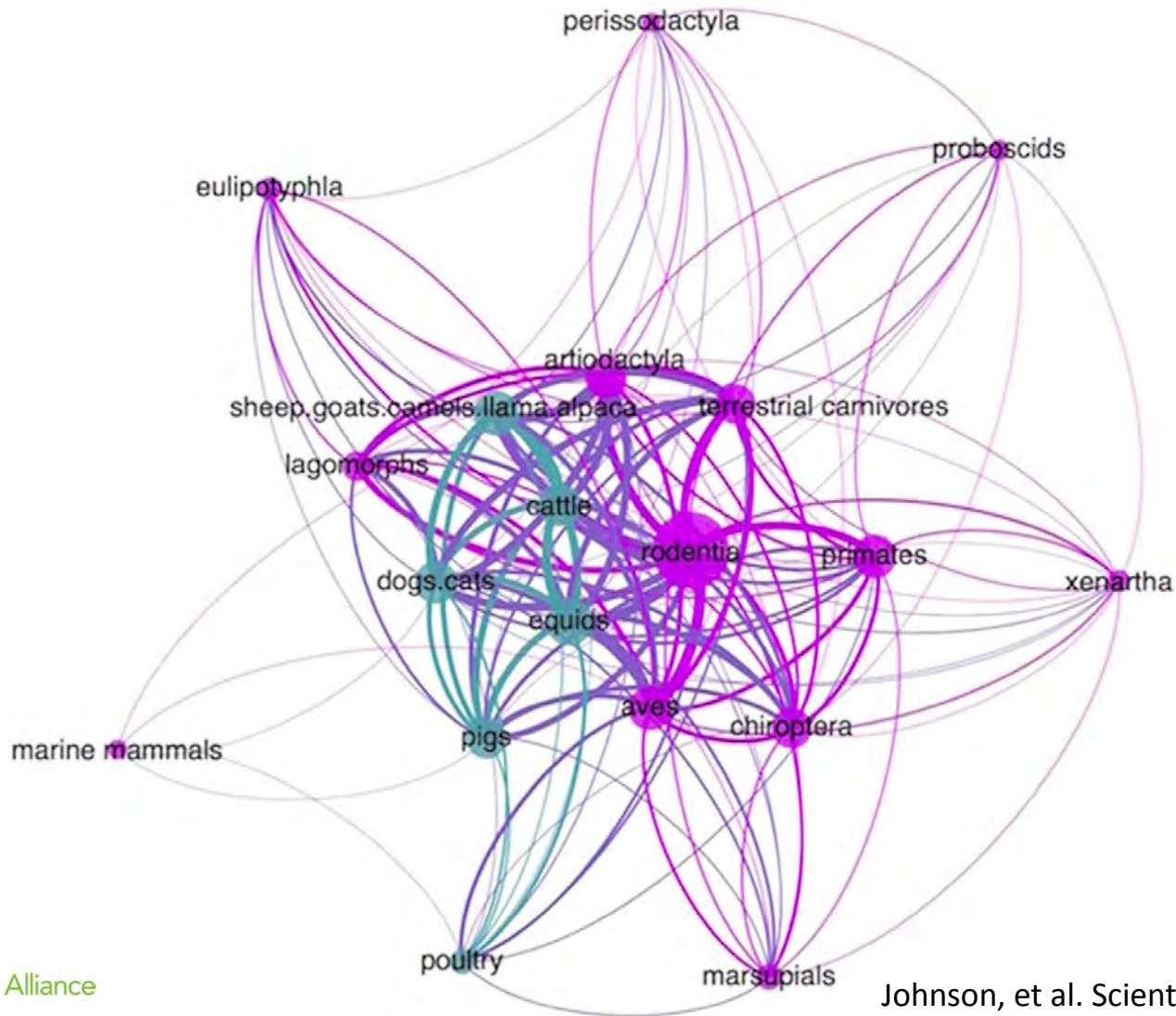
Zoonoses

Zoonotic disease organisms include those that are endemic in human populations or enzootic in animal populations with frequent cross-species transmission to people...

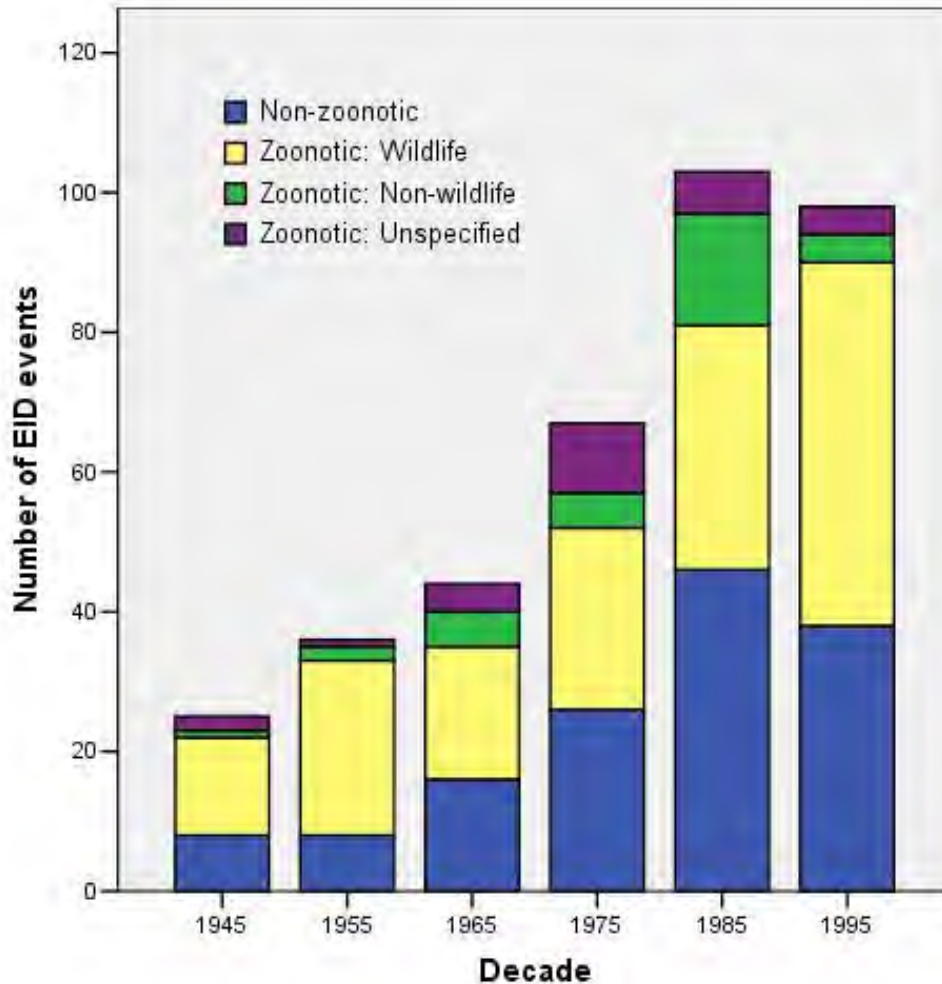
...with endemic and enzootic zoonoses causing about a billion cases of illness in people and millions of deaths every year.”

Zoonotic Viral sharing

Green = Domestic Animals Purple = Wild Animals



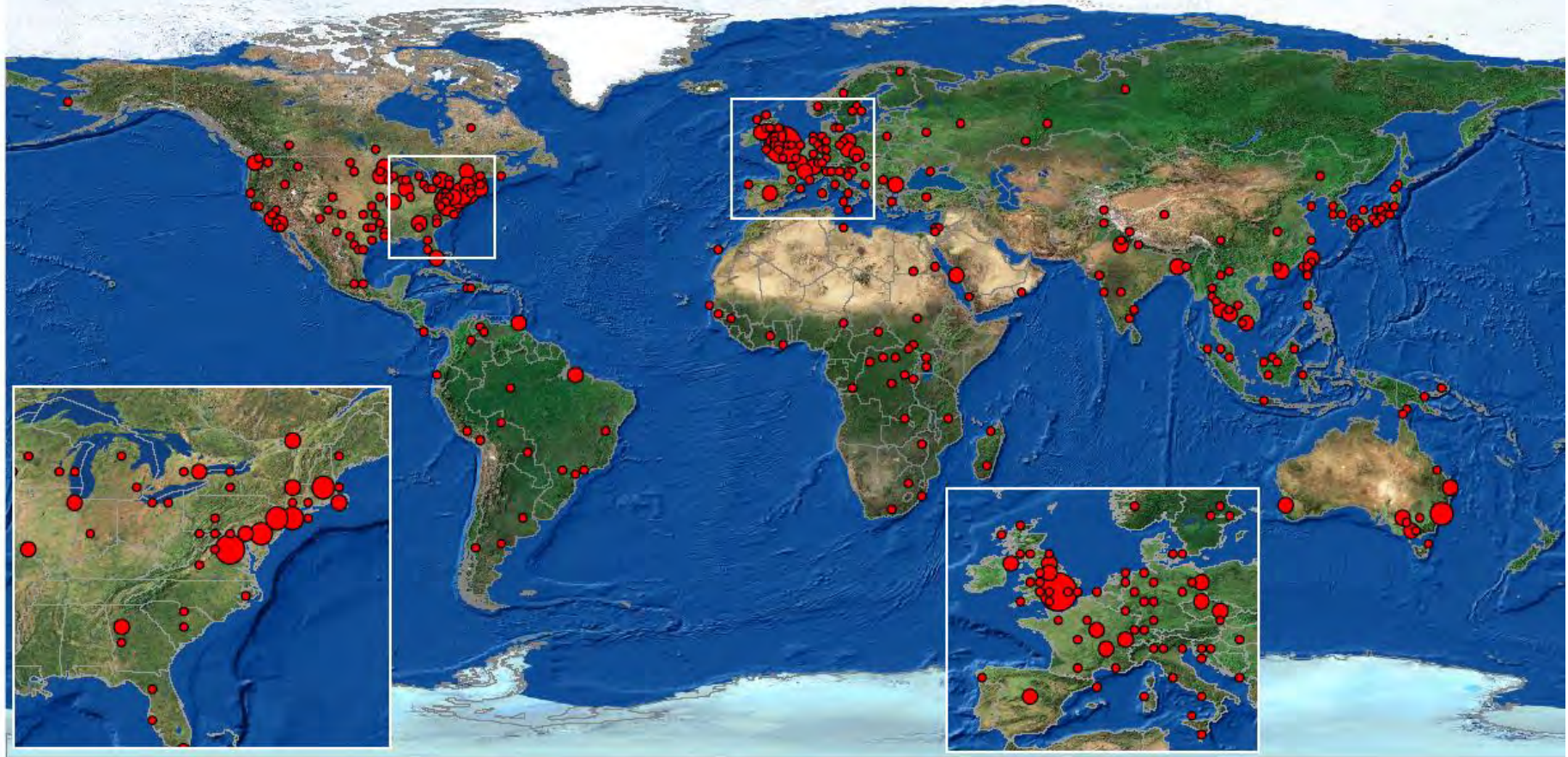
Temporal patterns in EID events



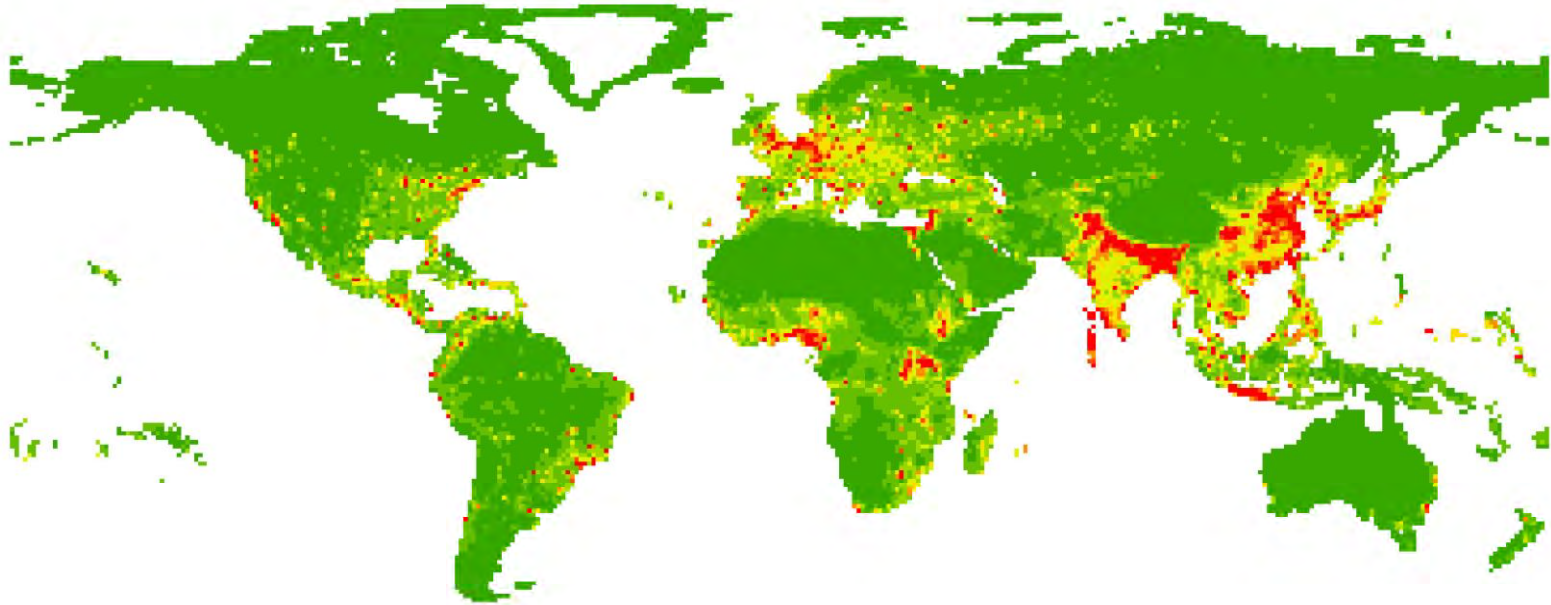
- EID events have increased over time, correcting for reporter bias (GLM_{P, JID} $F = 86.4$, $p < 0.001$, $d.f. = 57$)
- ~5 new EIDs each year
- ~3 new Zoonoses each year
- Zoonotic EIDs from wildlife reach highest proportion in recent decade

Spatial patterns in EID events

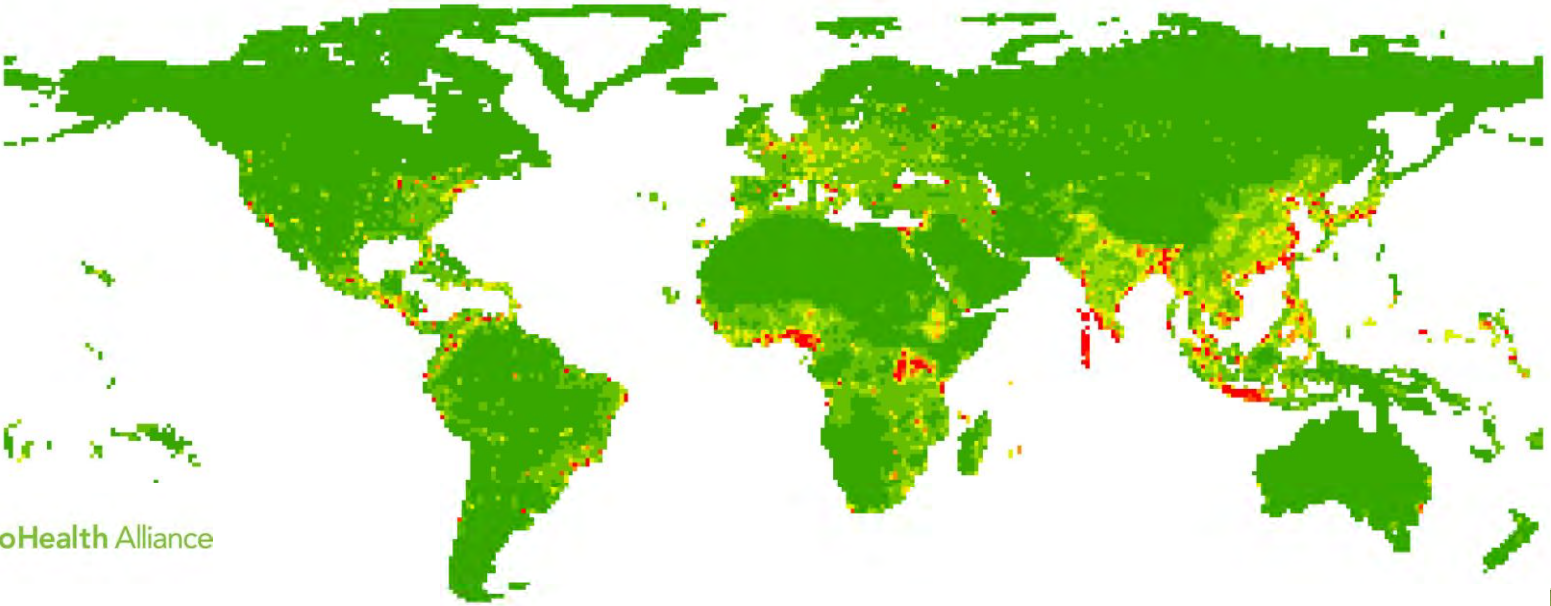
Total EID events ● 1 ● 2-3 ● 4-5 ● 6-7 ● 8-11



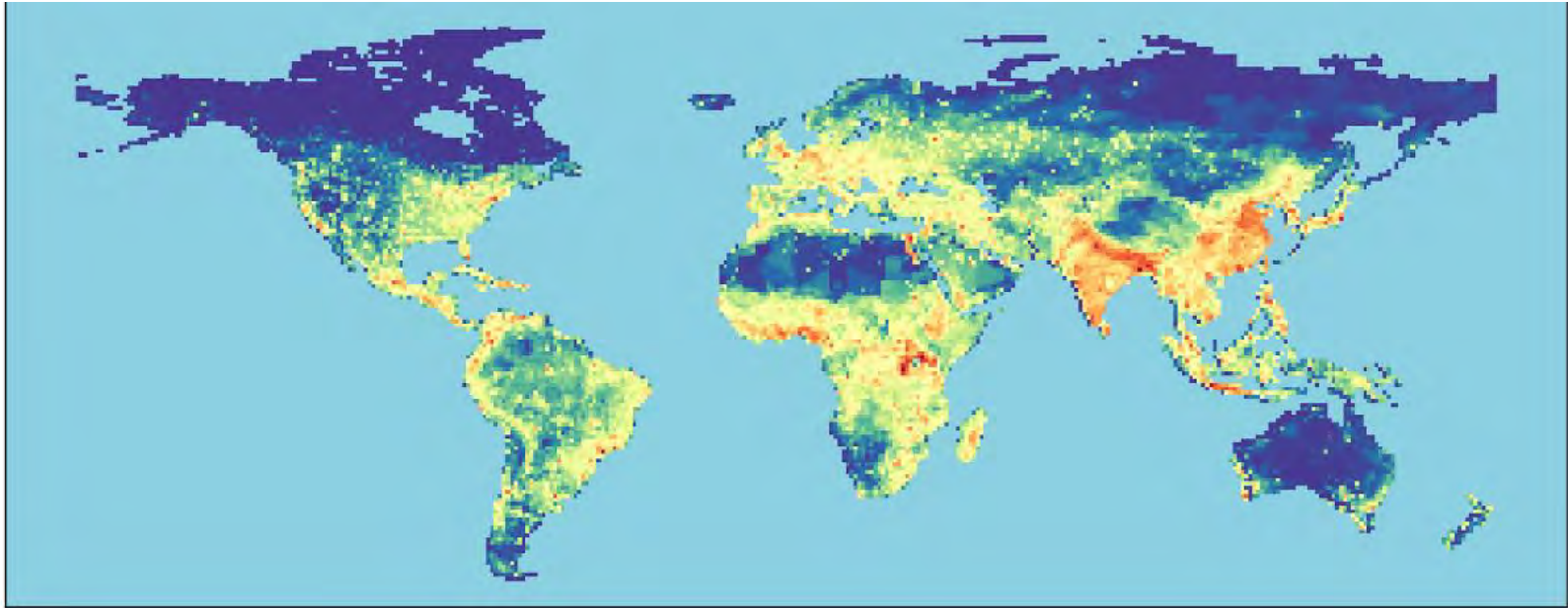
EID Hotspots – Jones 2008 Nature Model



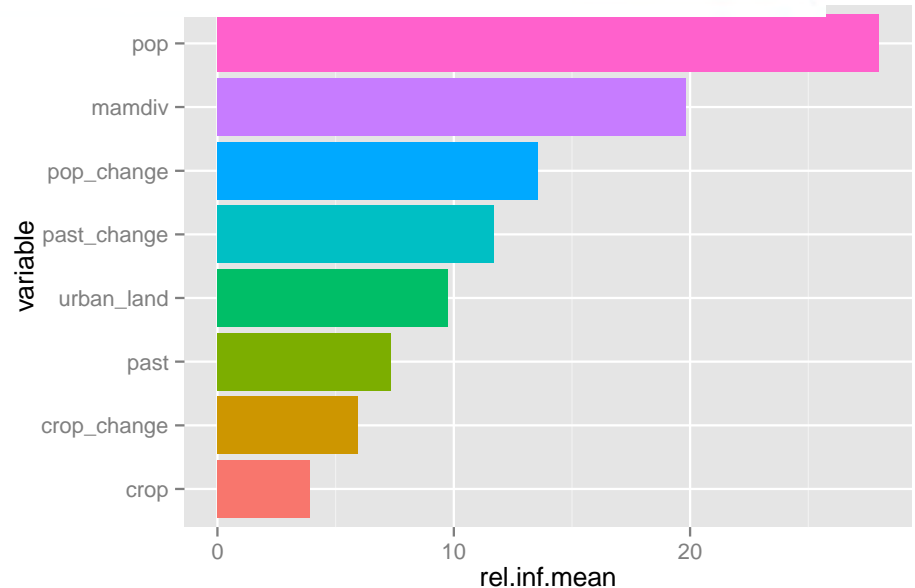
EID Hotspots – New Model with Land Use Change and Livestock



Relative risk of a new zoonotic EID



	relative influence (%)	std. dev.
population	27.99	2.99
mammal diversity	19.84	3.30
change: pop	13.54	1.54
change: pasture	11.71	1.30
urban extent	9.77	1.62
...



Natural Versus Unnatural

*“The emergence of zoonoses, both recent and historical, can be considered as a logical consequence of pathogen ecology and evolution, as microbes exploit new niches and adapt to new **hosts...***

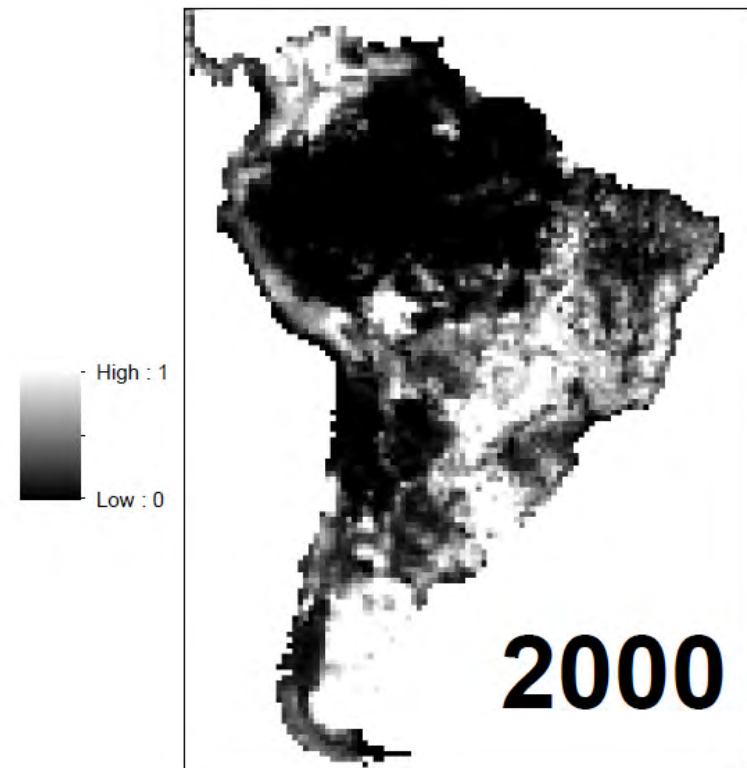
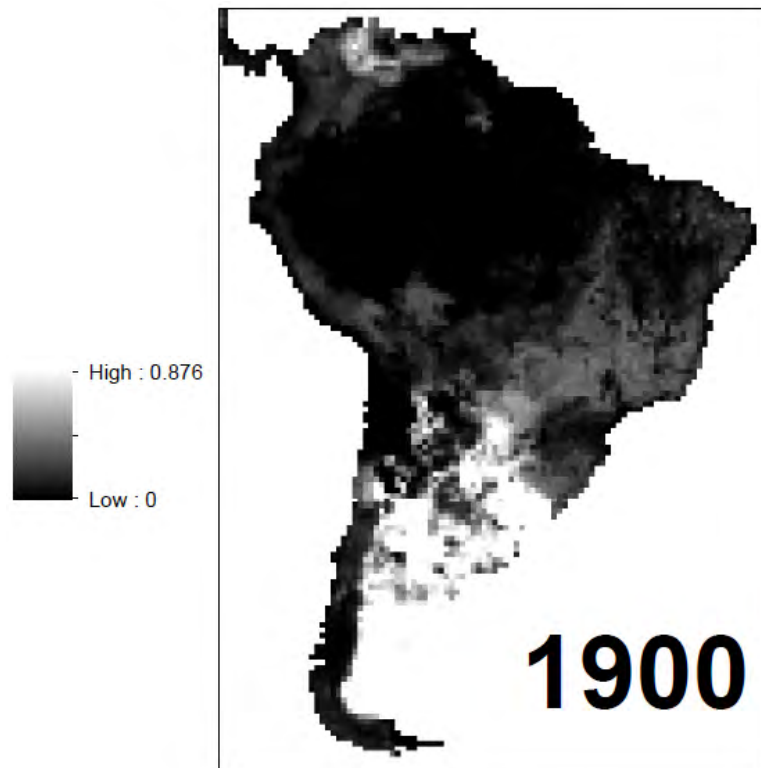
*Although underlying ecological principles that shape how these pathogens survive and change have remained similar, people have changed the environment in which these principles **operate.**”*

Pasture Data

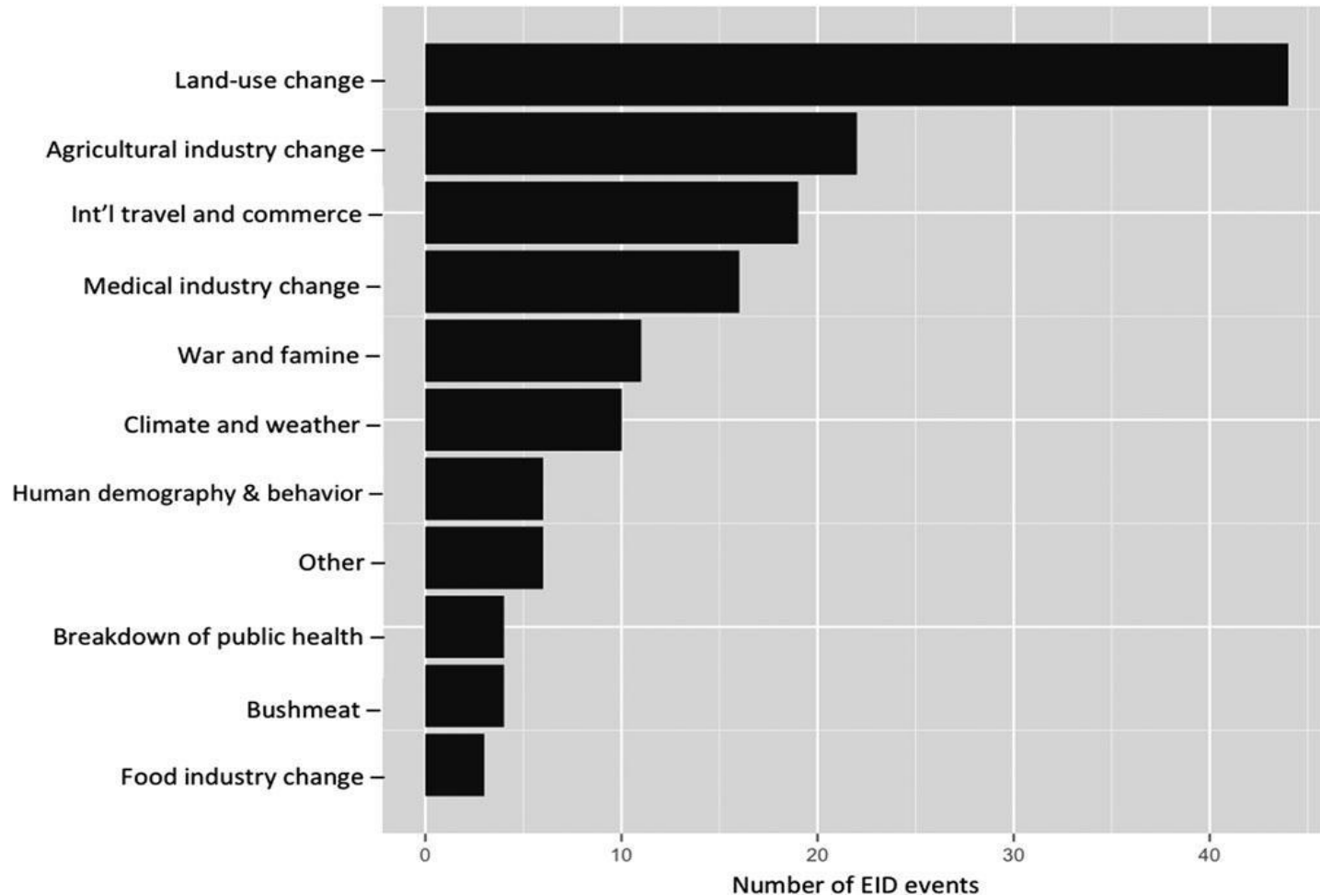
Source: Ramankutty and Foley, Department of Geography, McGill University

Description: Global historical pasture dataset, available at an annual timescale from 1700 to 2007 and at 0.5 degree resolution.

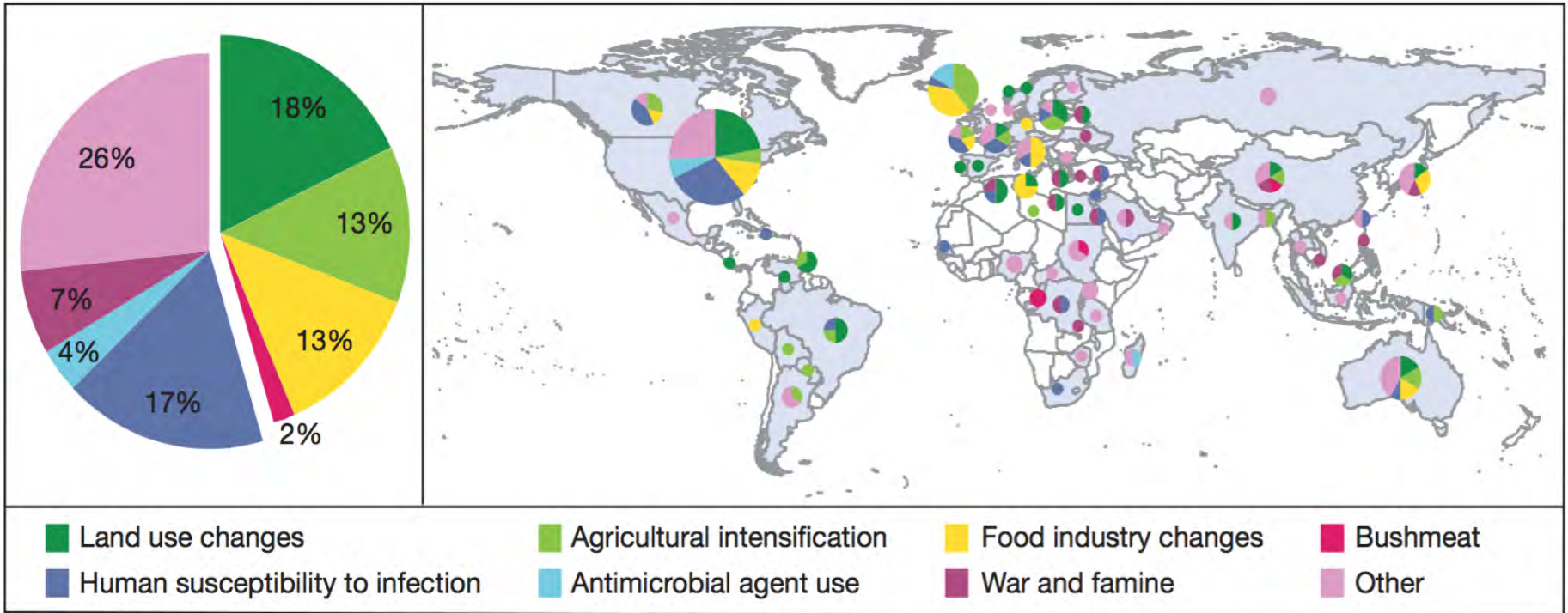
Proportion of land devoted to pasture, 1900 vs 2000



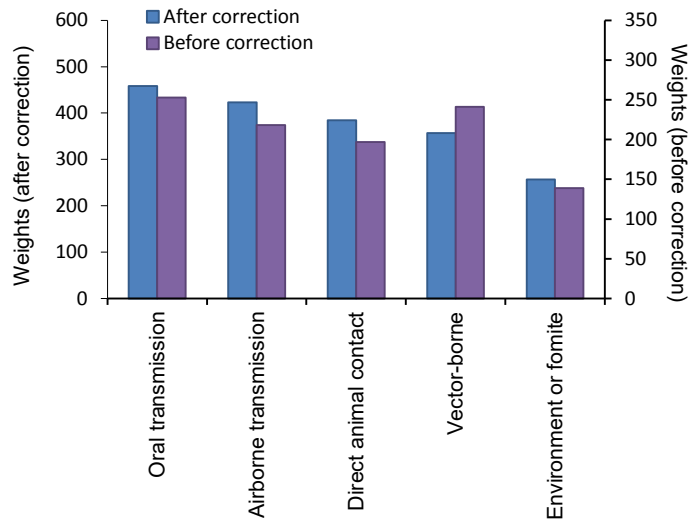
Drivers of Disease Emergence in Humans



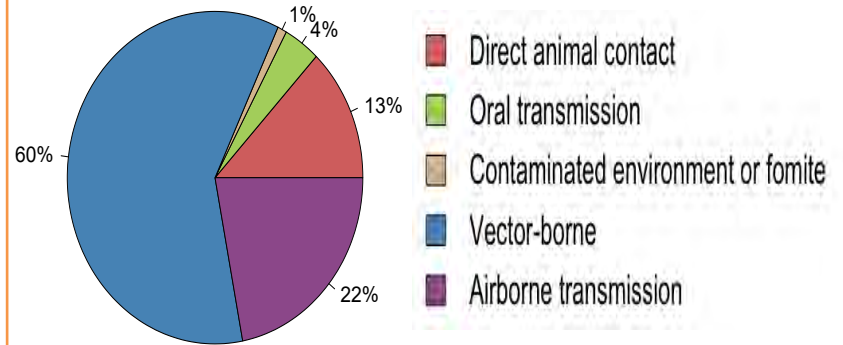
Country-Level Drivers of Disease Emergence



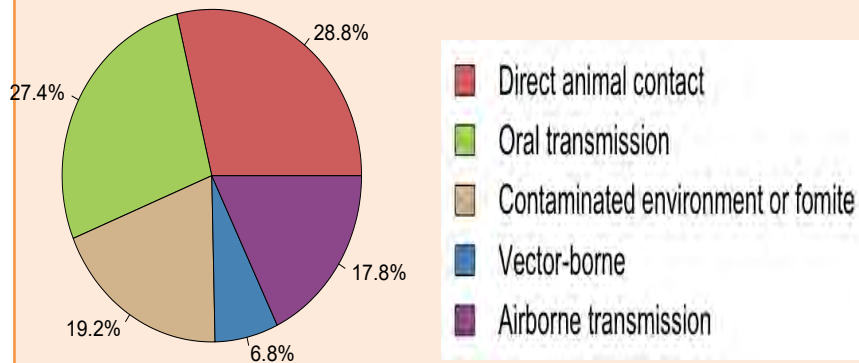
Actionable information to target surveillance and prevention



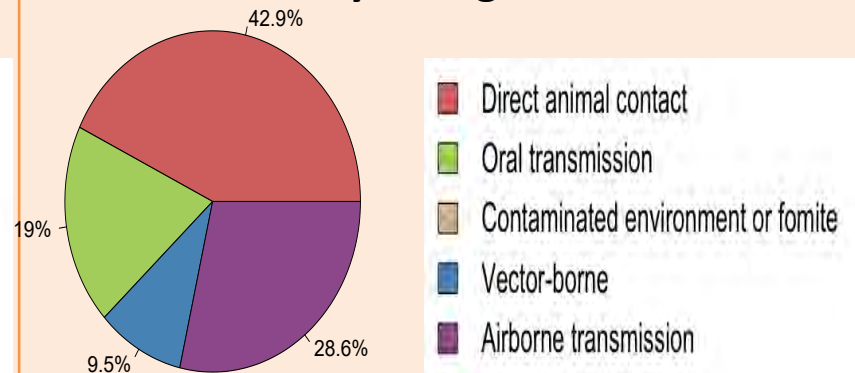
Land use change n= 39



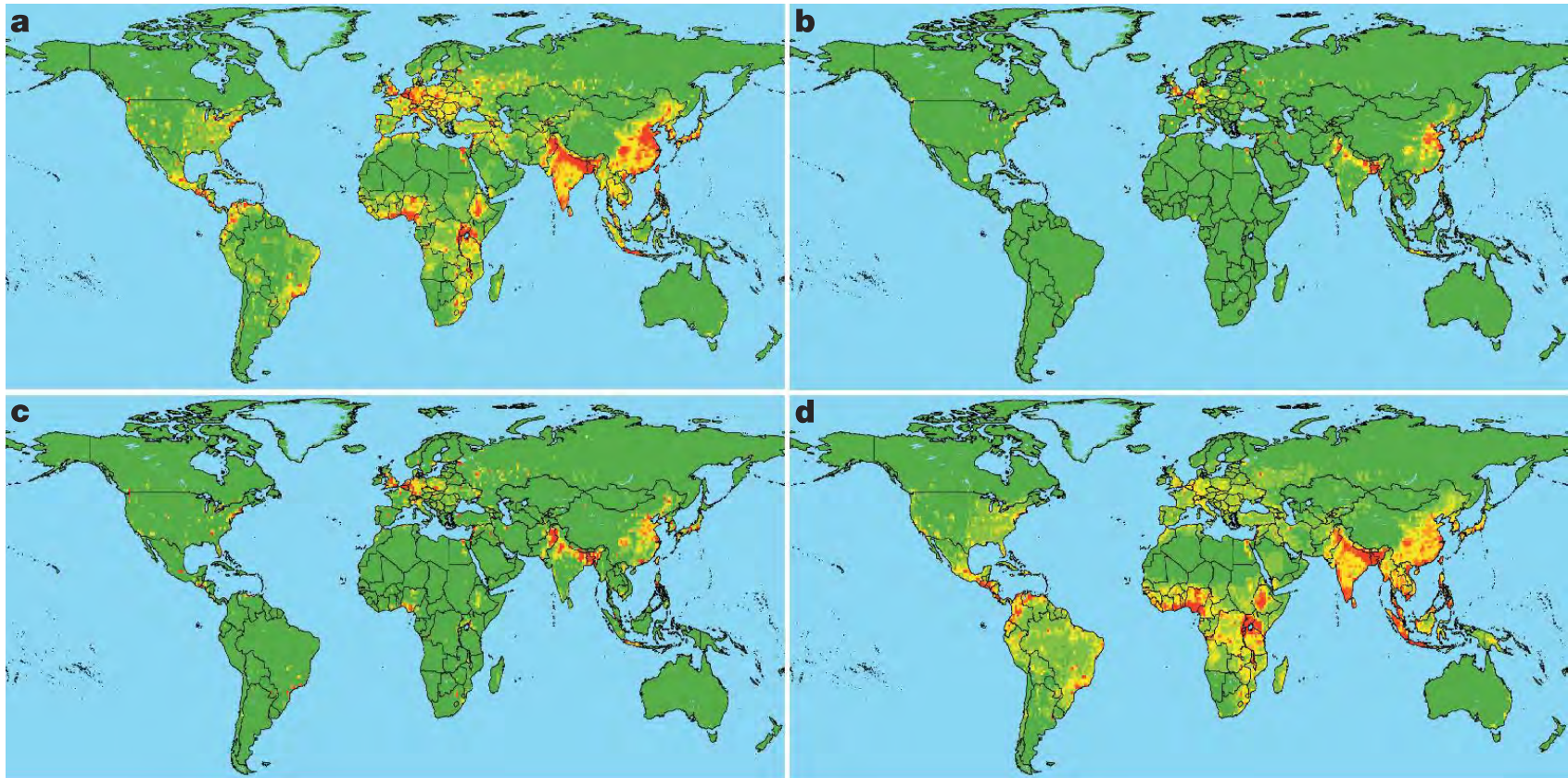
Agricultural industry change n=27



Medical industry change n=11



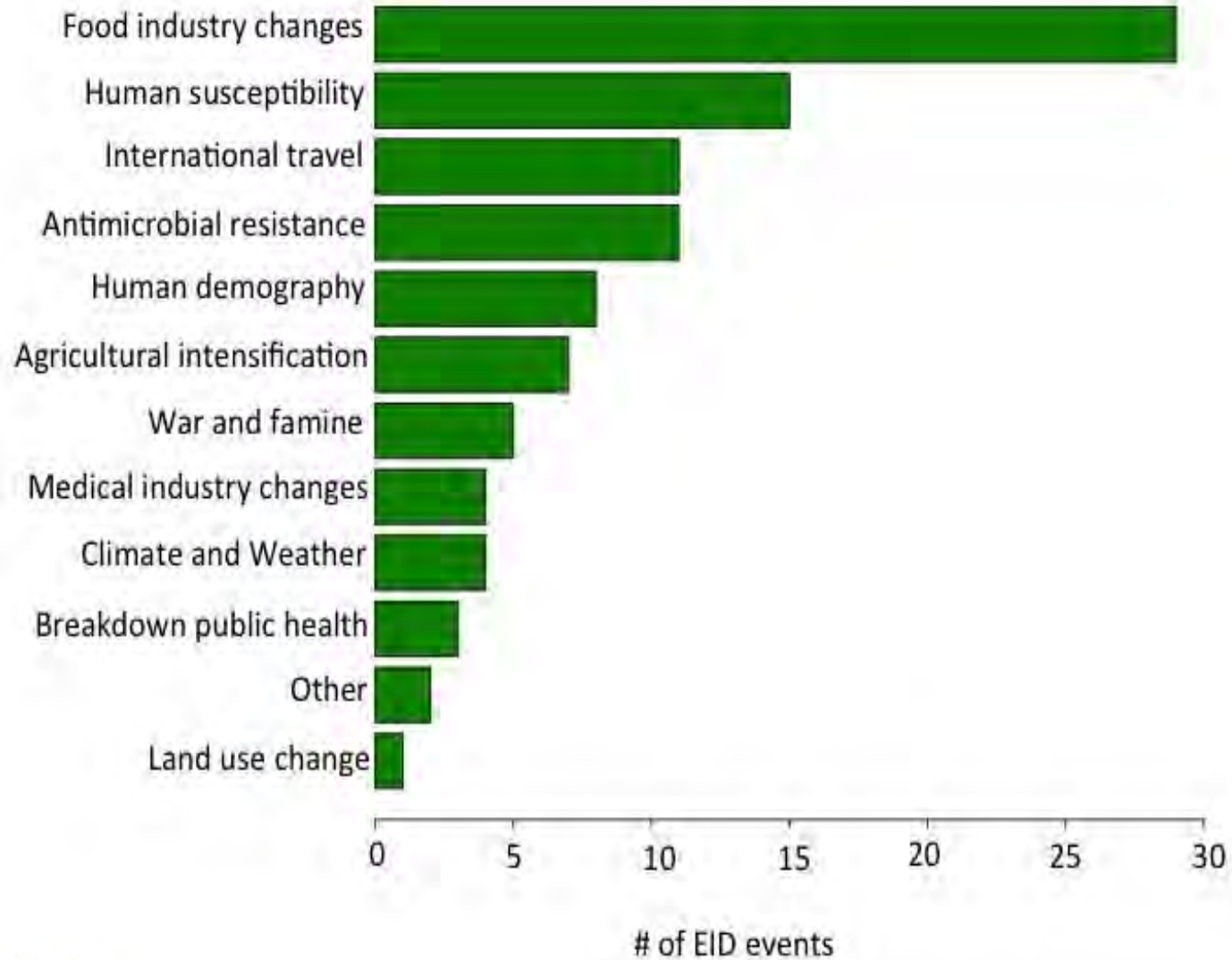
Global Distribution of relative risk of EID events



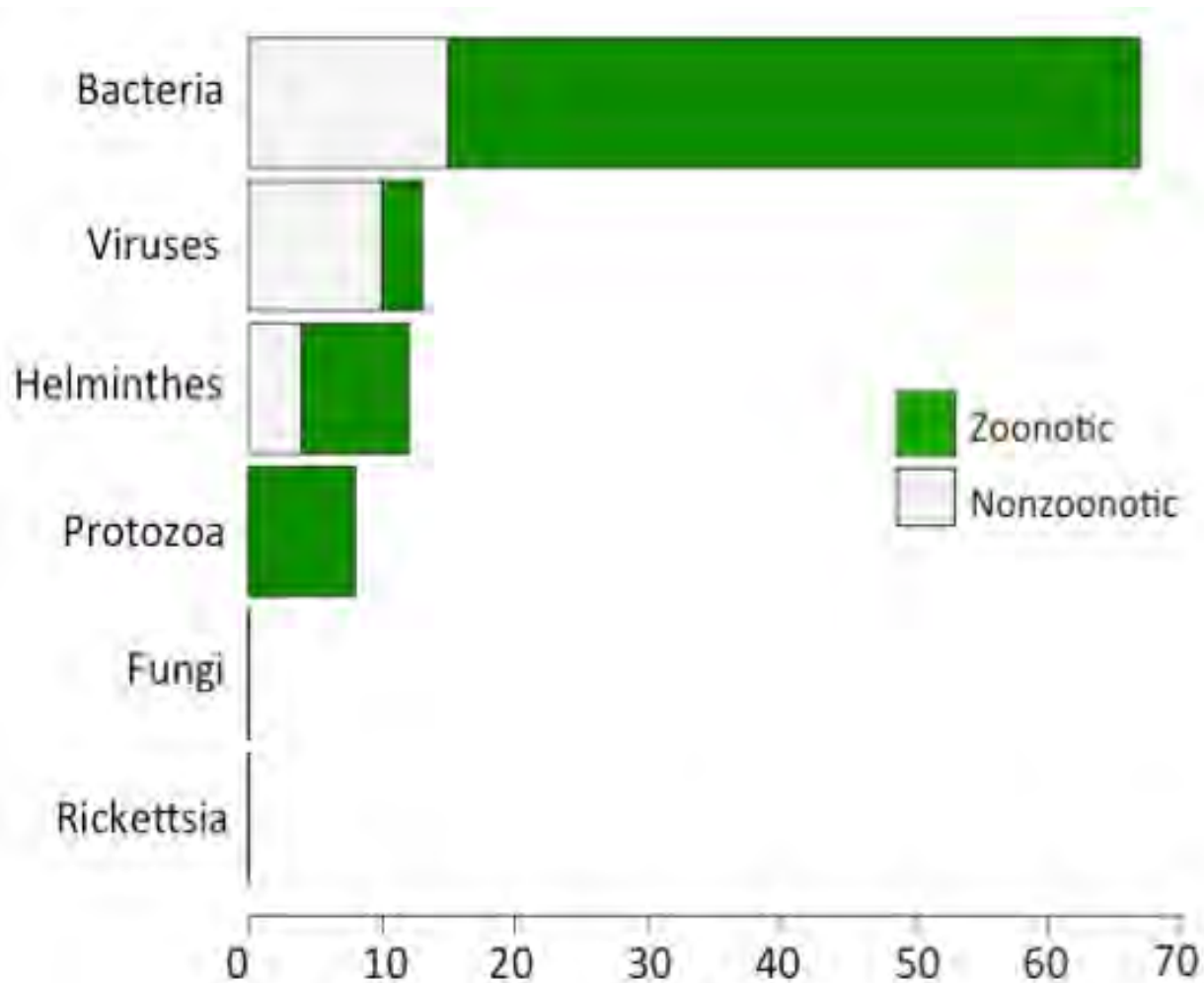
a) Zoonotic pathogens from wildlife
c) Drug resistance pathogens

b) Zoonotic pathogens from domestic animals
d) Vector-borne pathogens

Drivers of Foodborne EID events



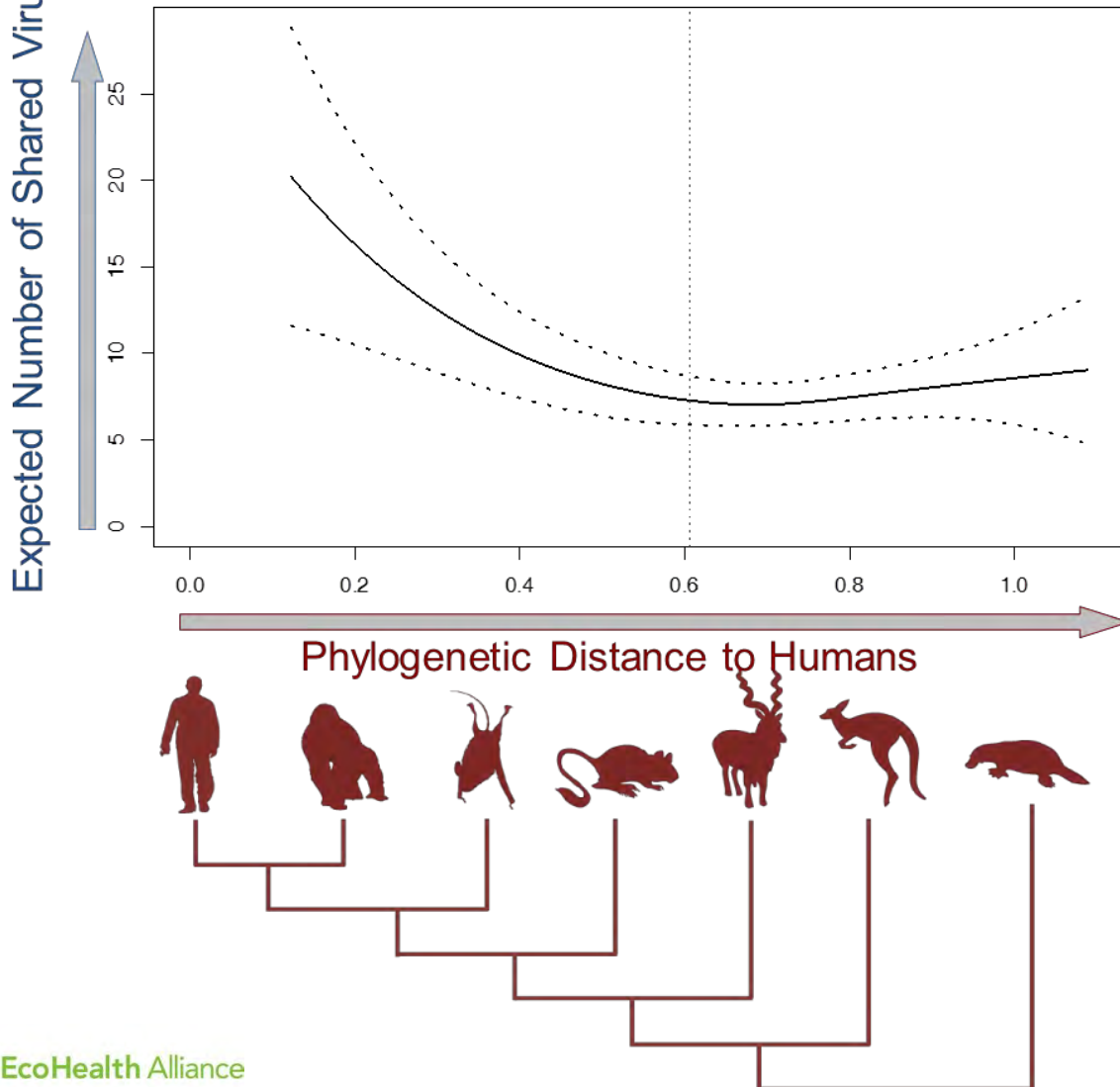
Foodborne EID events 1940-2004 (n=100)



A Day in a Food Market



Phylogenetic Distance to Humans Significant Predictor of the Number of Shared Viruses



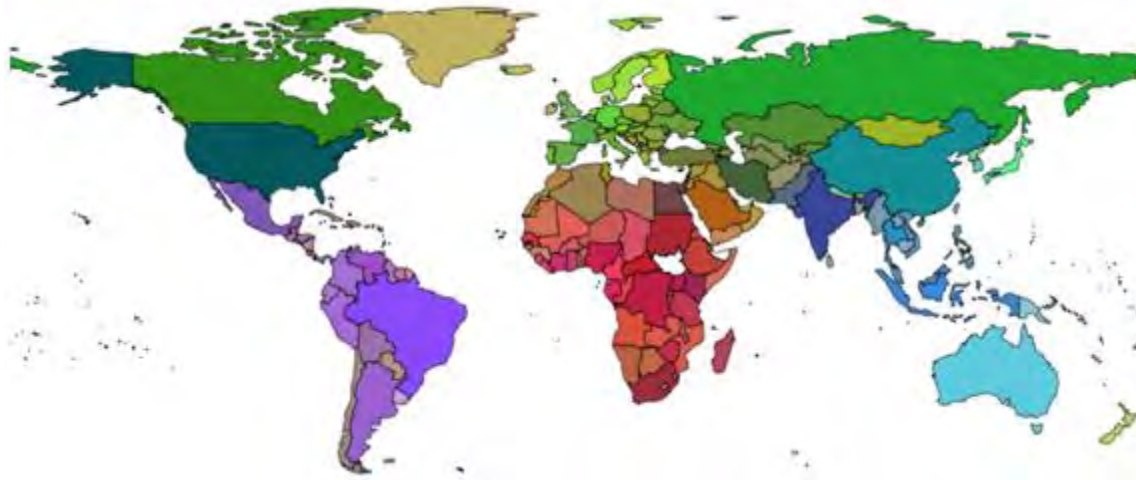




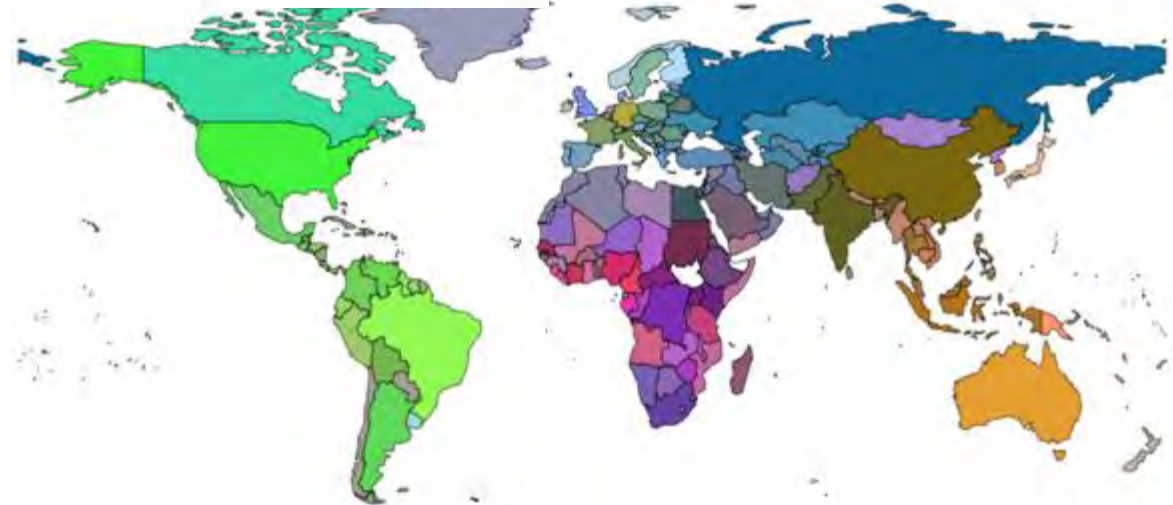
1,000,000,000 Kgs / Year
(Central Africa)



BioGeography of Human Infectious Diseases



**Zoonotic disease
biogeographic zones**



**Viral disease
biogeographic zones**

Based on similarity analysis of zoonotic human infectious disease assemblages at country level.

Global vulnerability index

- Calculating index

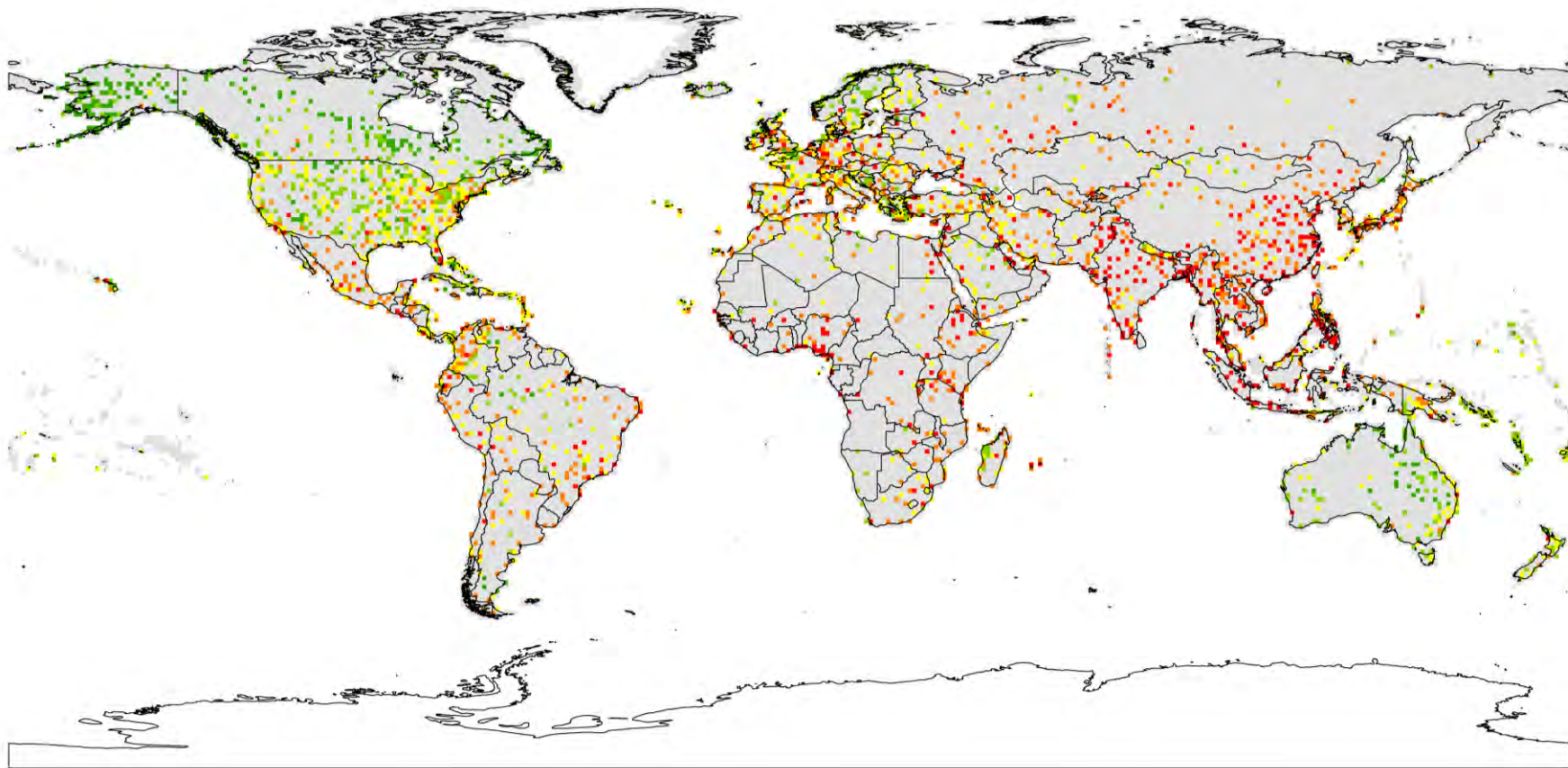
- E_i = Jones et al. hotspots
- C_{ij} = Est. Number of passengers
- H_i = Healthcare spending per capita
 - i = source of risk
 - j = destination of risk

$$\phi_j = \sum_{all\ i} \frac{C_{ij} \cdot E_i}{H_i}$$

- We then interpolate risk out from airport locations globally
- Using Inverse Distance Weighted interpolation



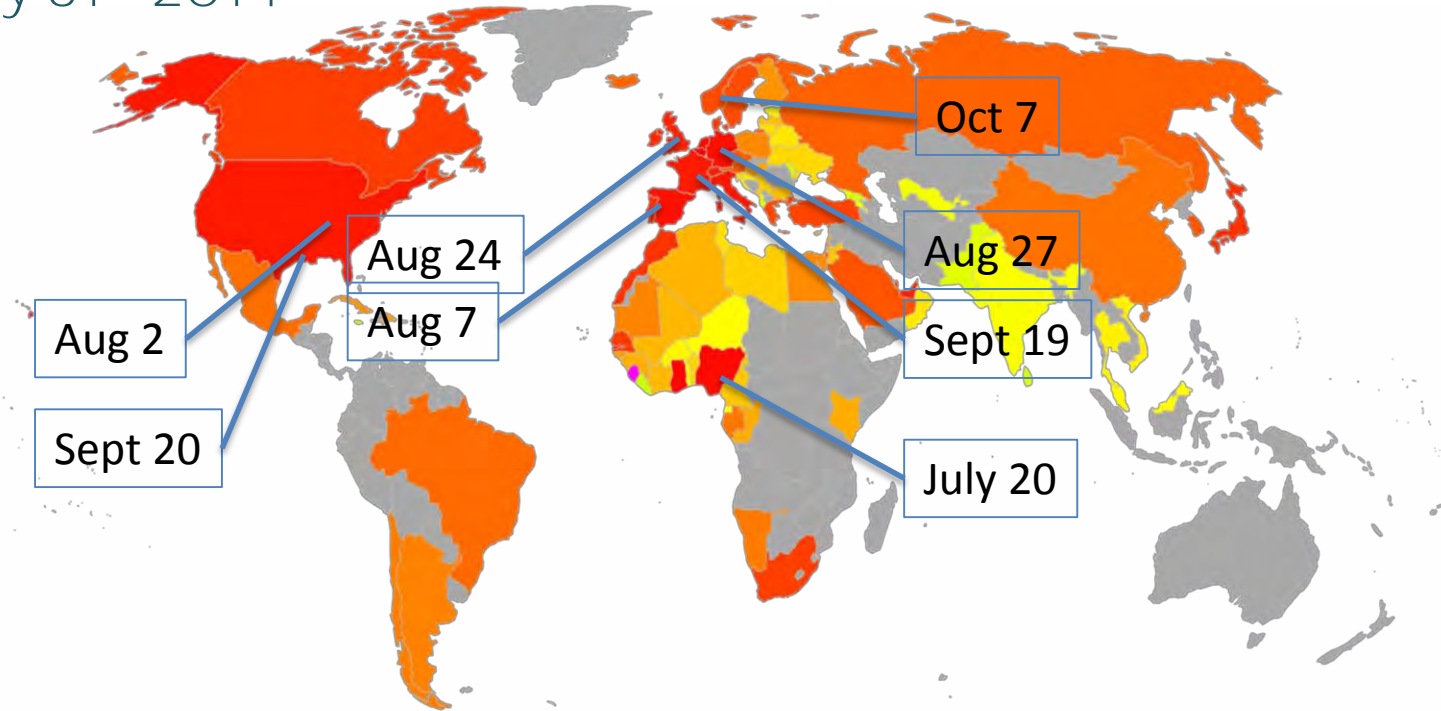
EID risk per airport



Hosseini *et al.* (in review)

Our prediction of which countries were at risk for Ebola spread

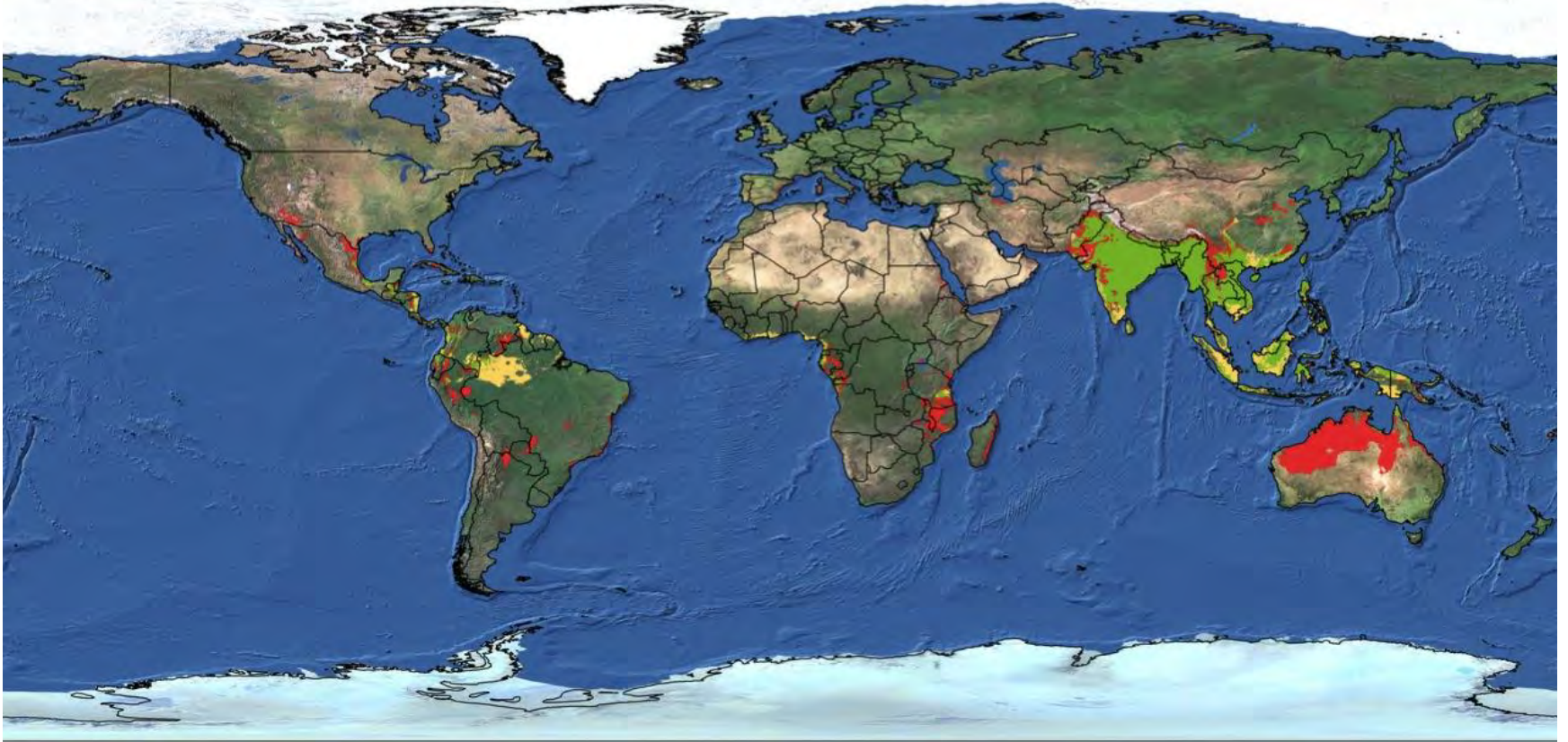
July 31st 2014



Red = earliest arrival; Green = last arrival. Grey = countries that can't be reached in 2 legs or less.

There are 10 countries that can be arrived at via direct flights, and 95 that can be reached by flights of two legs or less.

Climate Change and Emerging Diseases



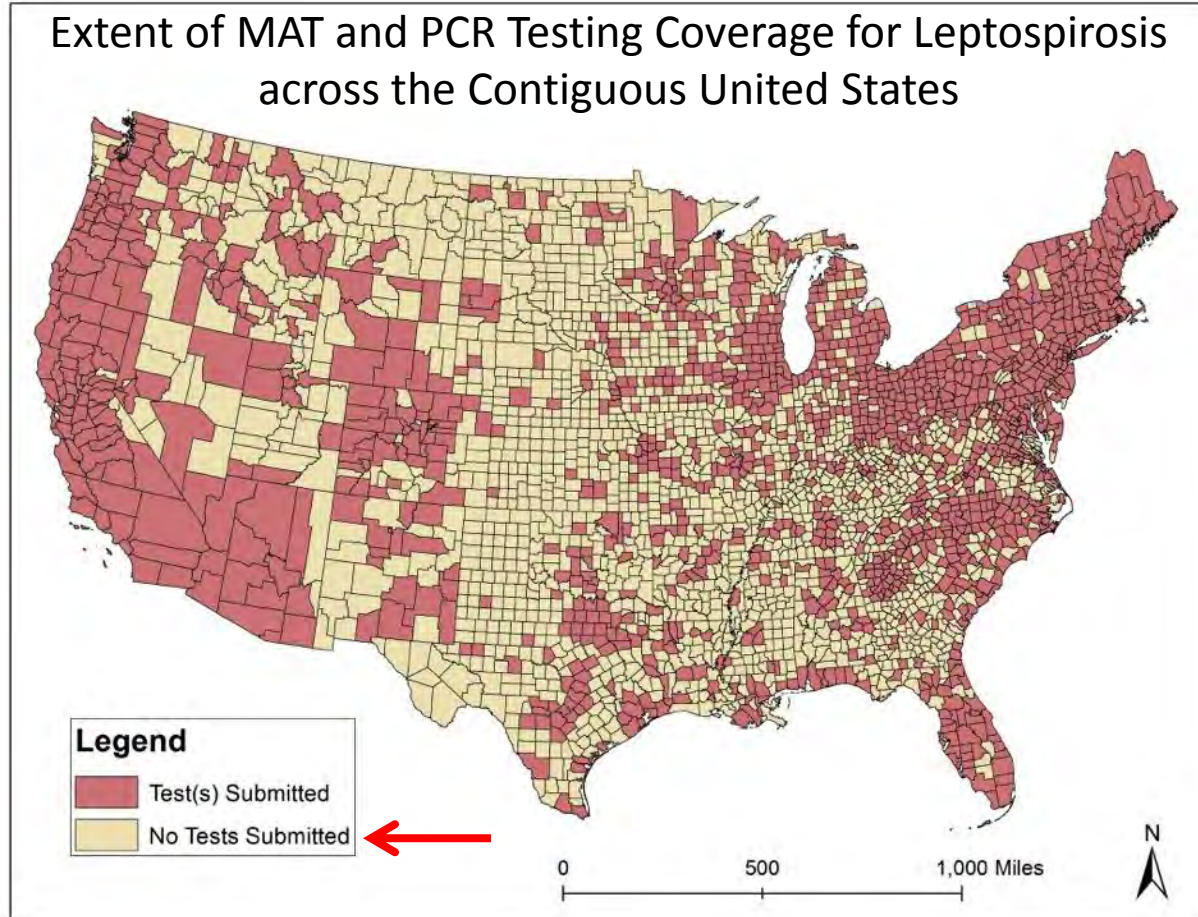
Future Climate Change Scenario for the distribution of Nipah virus. Year 2050, optimistic scenario (B2). Red areas show new potential areas for virus spread.

Background on Leptospirosis

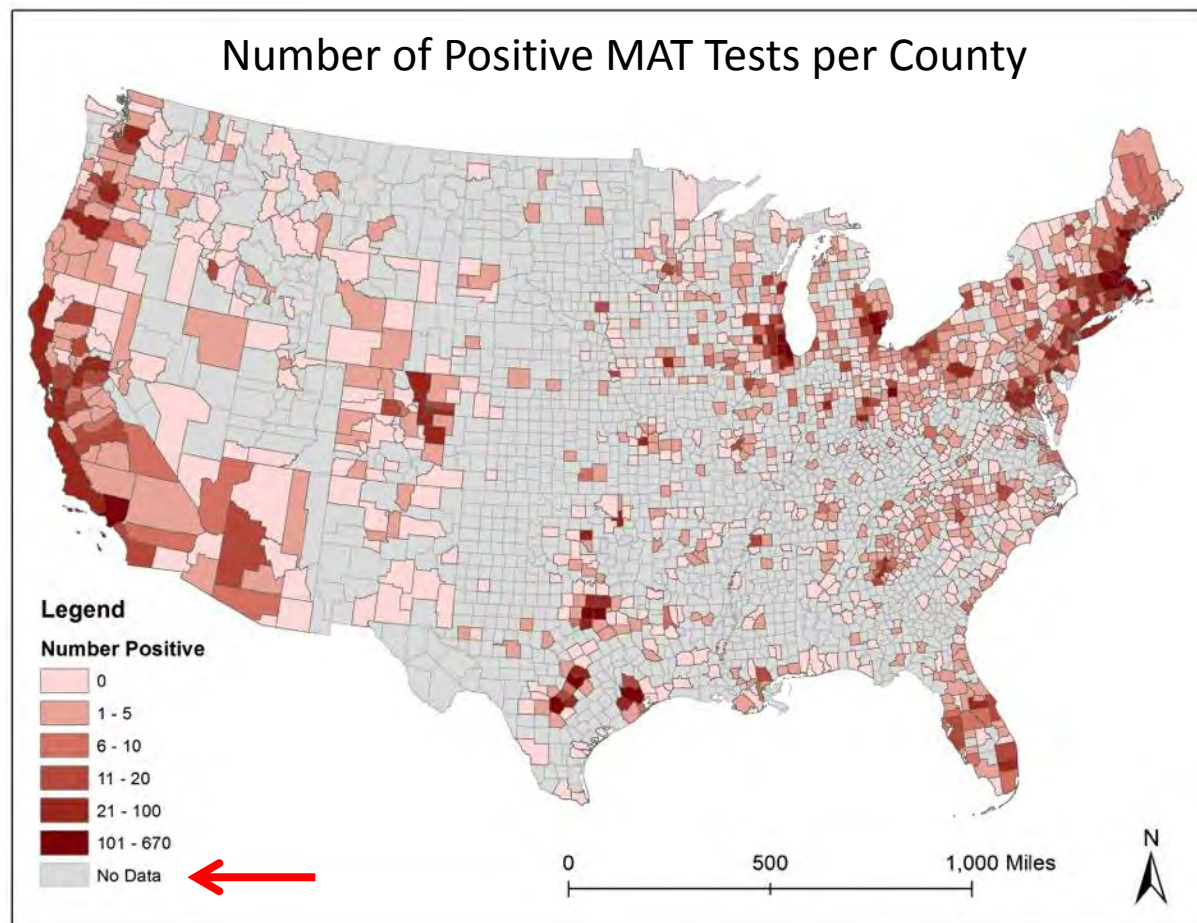
- Leptospirosis is a widespread zoonotic disease
 - Can affect a wide variety of domestic animals and wildlife, as well as humans
- Caused by *Leptospira*, an anaerobic spirochete



IDEXX Data Overview

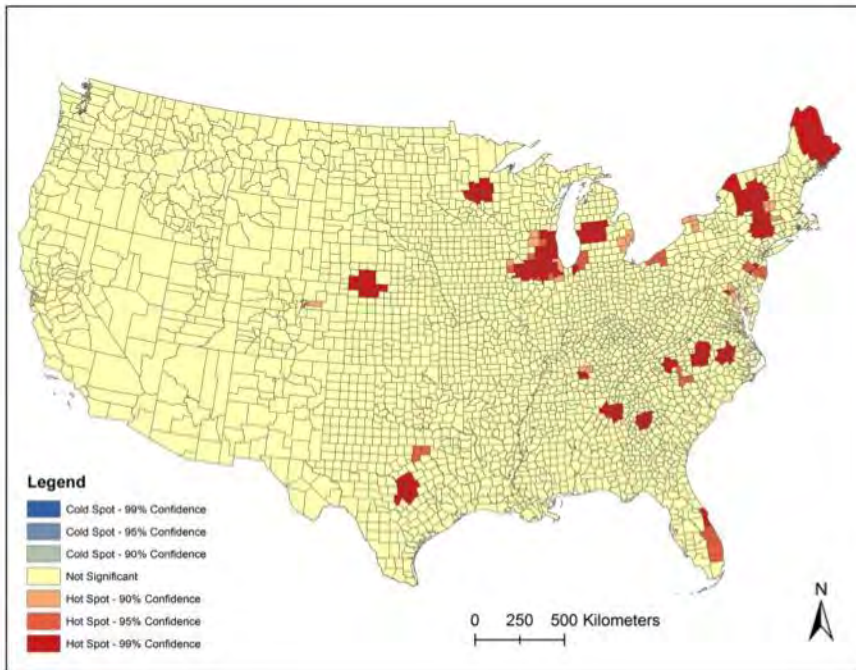


MAT Results

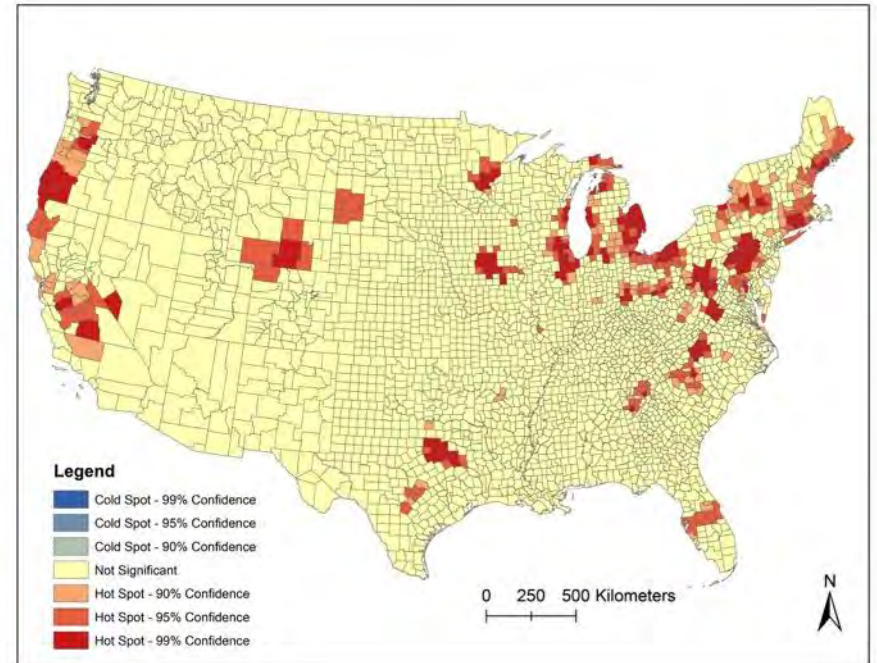


Spatial Clusters: Percent of Tests Positive

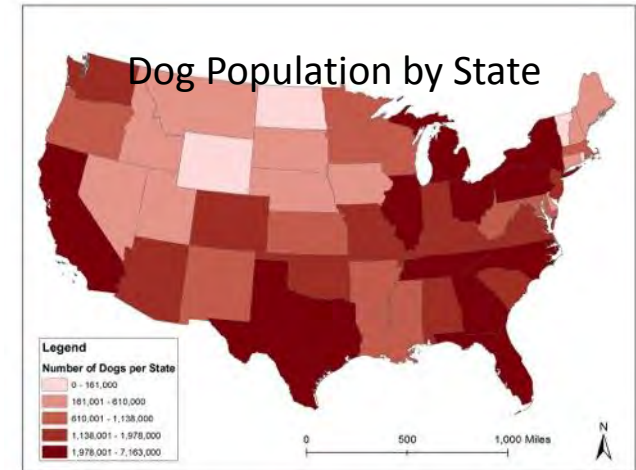
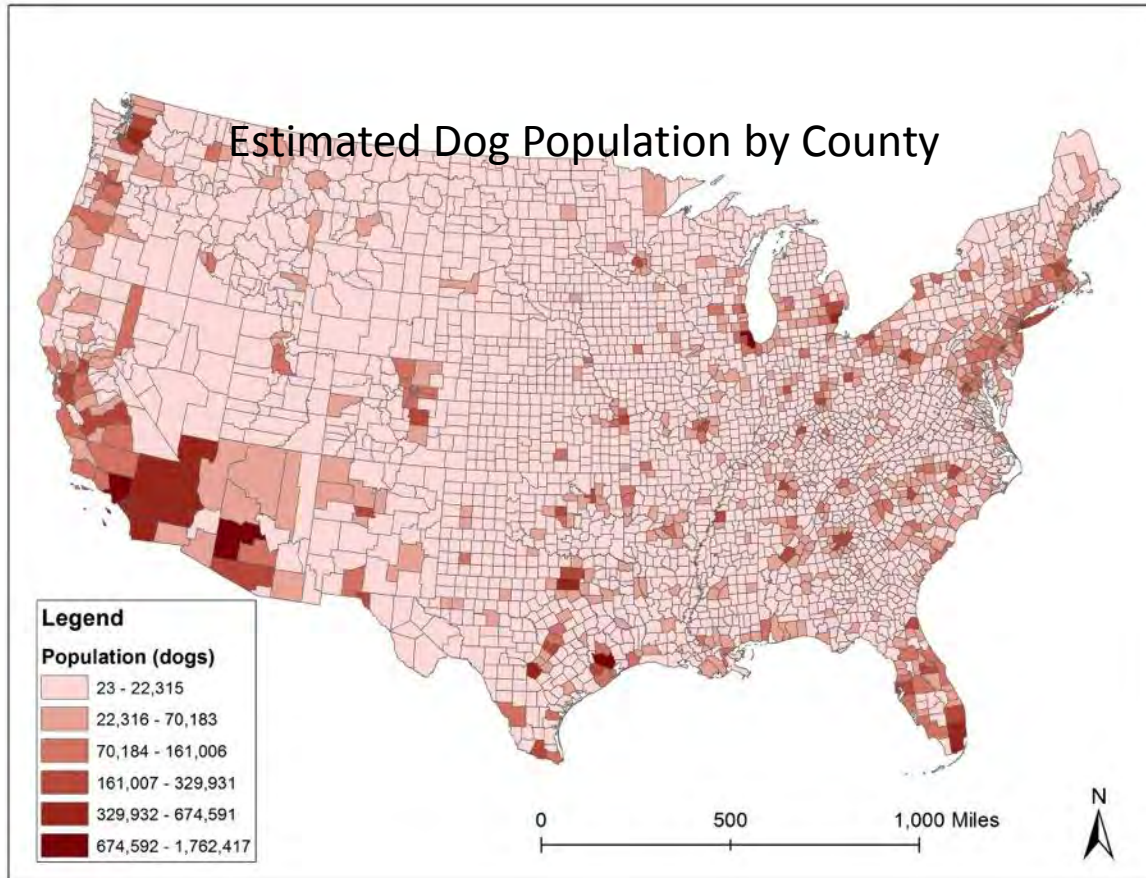
Clusters of Positive PCR Results:
Proportion of Positive Results to
Total Tests



Clusters of Positive MAT Results:
Proportion of Positive Results to
Total Tests



Dog Population Data

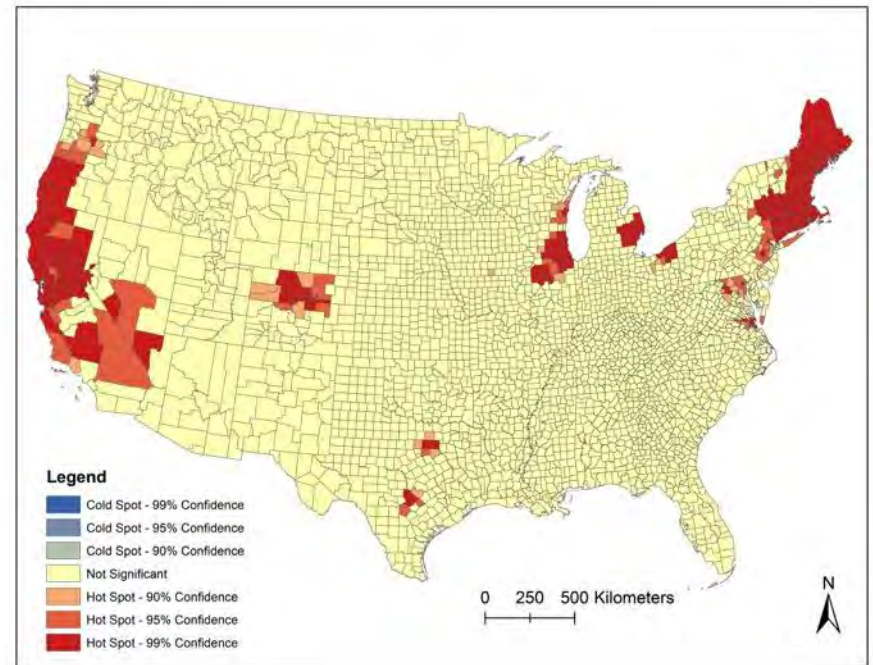
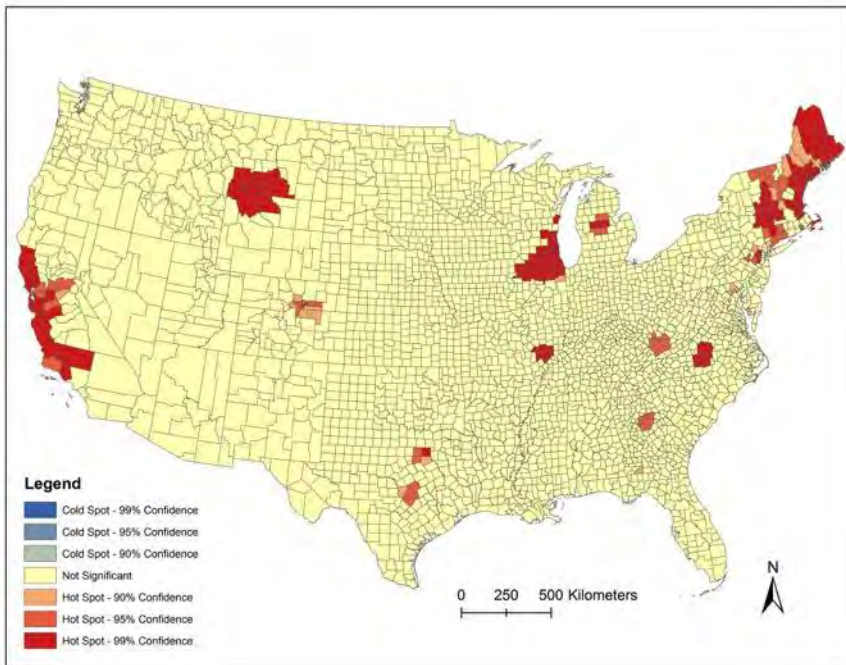


- Human population data from US Census
- State-level data for dogs from AVMA US Pet Demographics Sourcebook 2012
- Used county-level human population census data to estimate population of dogs per county
- Assuming that within each state, dogs are distributed within the state similar to humans

Spatial Clusters: Positive Tests per Estimated County Dog Population

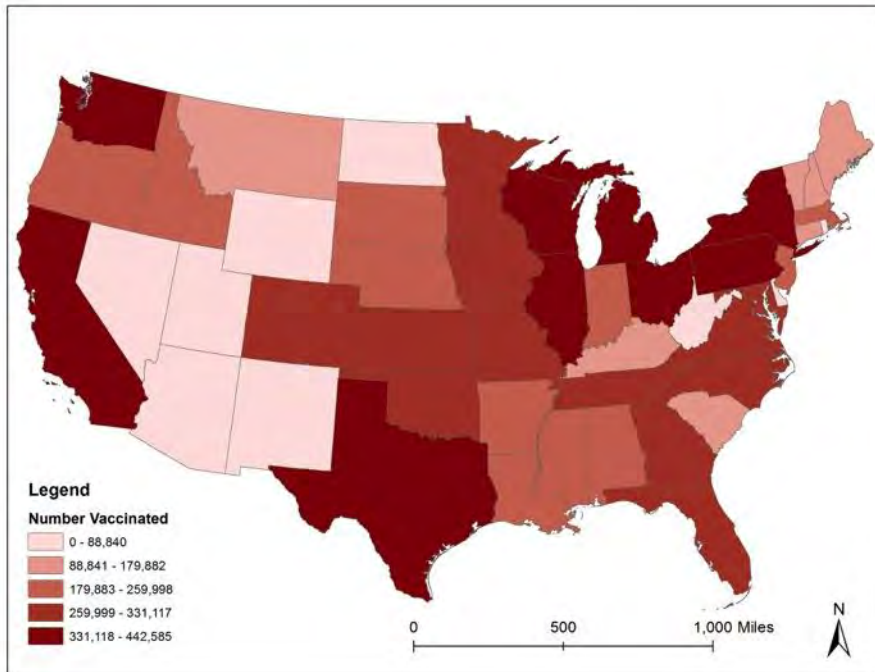
Clusters of Positive PCR Results:
Positive Tests per Estimated Dogs

Clusters of Positive MAT Results:
Positive Tests per Estimated Dogs

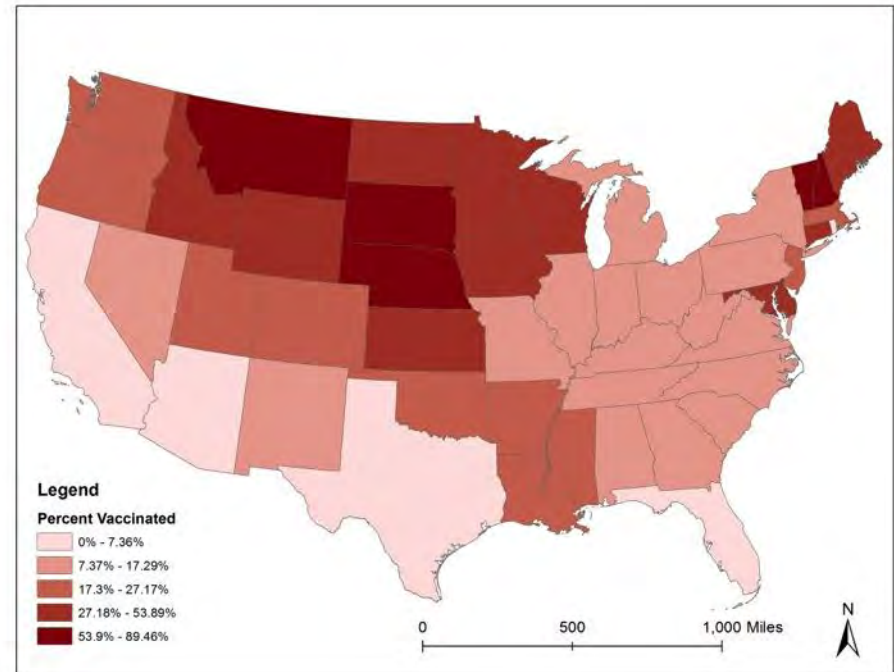


Leptospirosis Vaccination

Number of Dogs Vaccinated per State 2010-2014

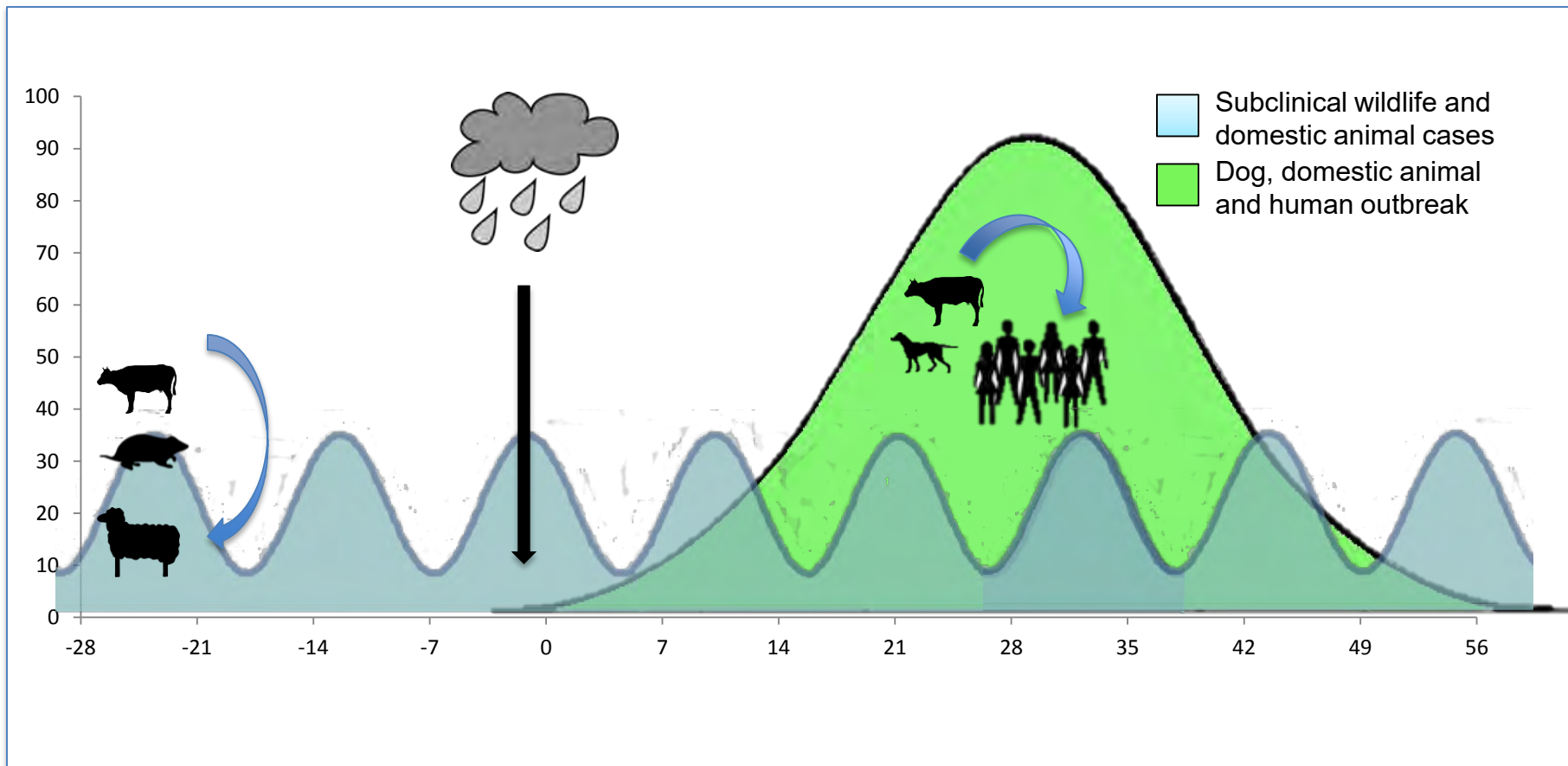


Four-Year Vaccination Numbers per Estimated Dog Population by State



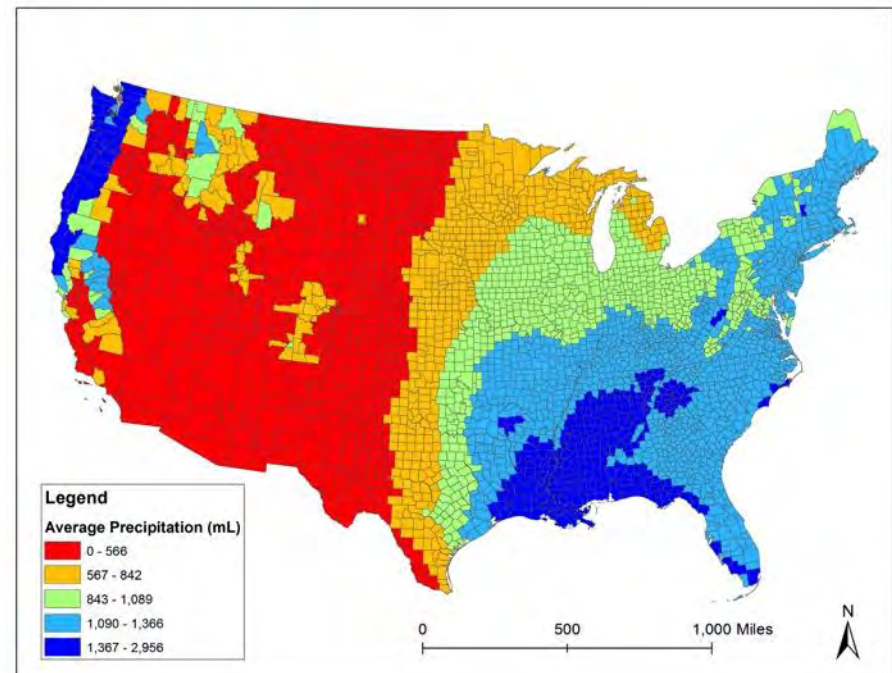
Possible Importance of Rainfall

Determine how other factors could affect transmission and support the ability to predict an outbreak



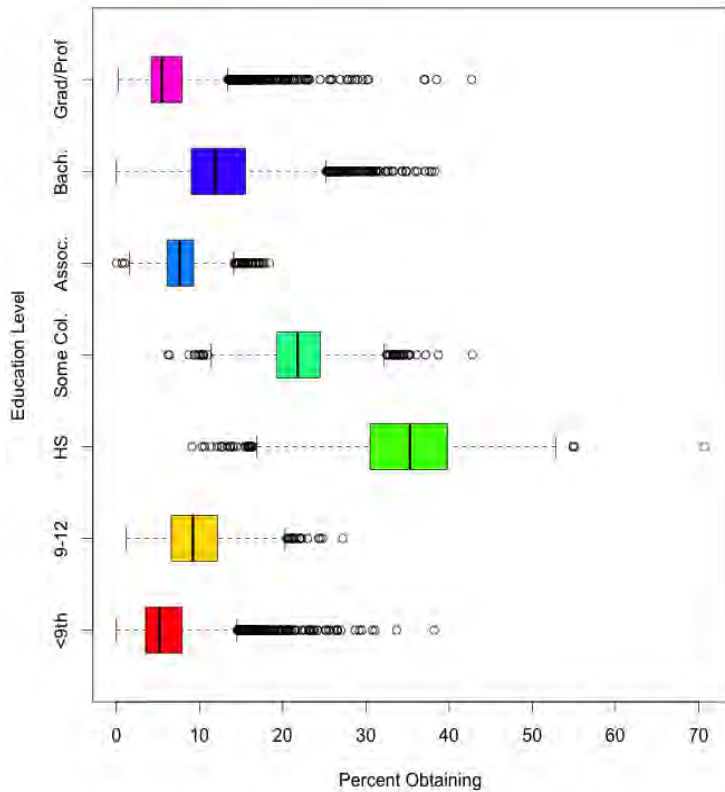
Climatic Variables

- Climate Data
 - Mean Precipitation
 - Mean Temperature
 - Bioclimate Data
 - Represents annual trends, seasonality, and extreme factors (e.g., temperature in coldest month)

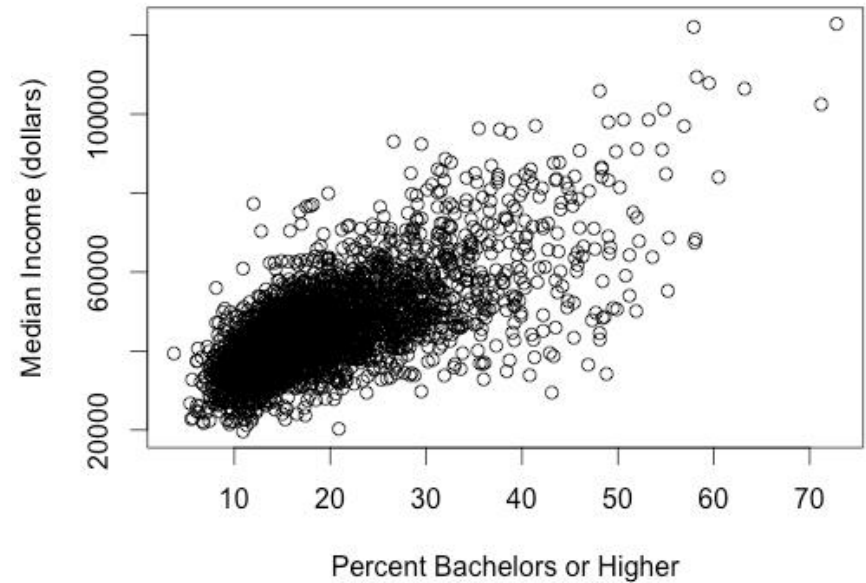


Income and Education Data

Distribution of Education Levels By County

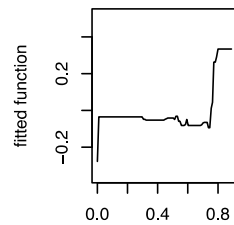


Scatterplot of Income and Education

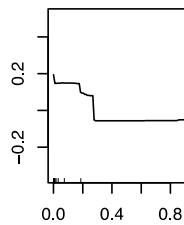
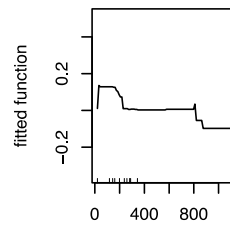


Partial Dependence Plots: MAT Results

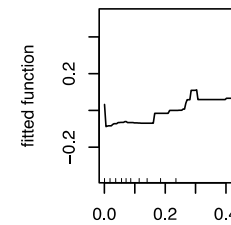
result – page 1



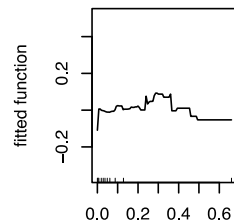
deciduous_forest_2011 (10.7%)



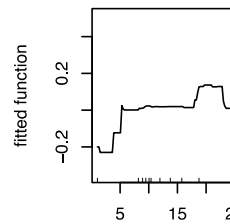
shrub_scrub_2011 (6.1%)



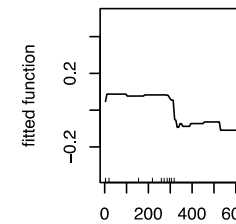
developed_low_intensity_2011 (5.0%)



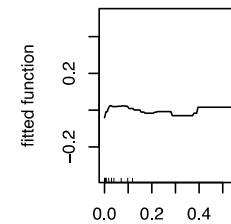
pasture_hay_2011 (4.9%)



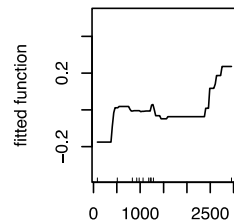
temp_average (4.8%)



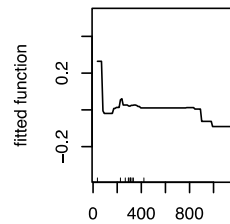
18_precip_warmest_quarter_average (4.7%)



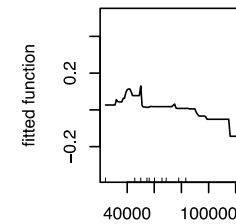
woody_wetlands_2011 (4.1%)



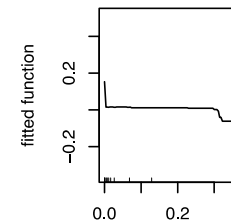
precip_average (3.8%)



16_precip_wettest_quarter_average (3.7%)



median_income (3.2%)



mixed_forest_2011 (3.1%)

Boosted Regression Tree Results

PCR Model: Top 5 Predictors

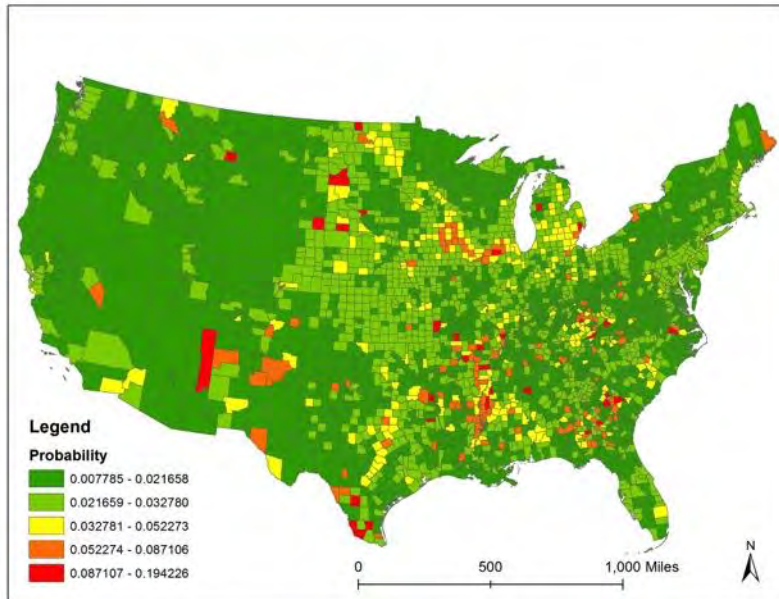
Variable	Relative Influence
Evergreen Forest Cover	12.24919776
Shrub/Scrub Cover	9.887439268
Grassland/ Herbaceous Cover	7.161191081
Developed Open Space Cover	6.195173737
Median Income	5.81007611

MAT Model: Top 5 Predictors

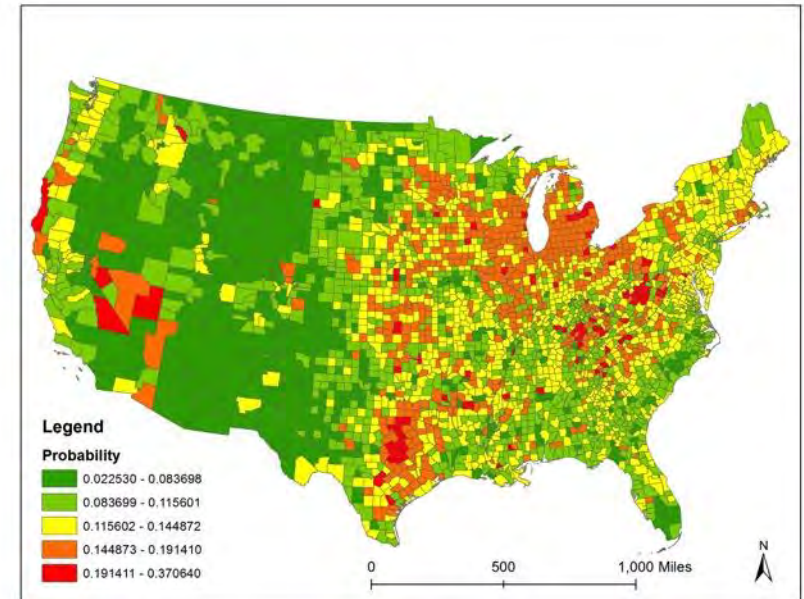
Variable	Relative Influence
Deciduous Forest Cover	10.6624204
Average Precipitation in Coldest Quarter	8.622065784
Shrub/Scrub Cover	6.067515302
Developed Low Intensity Cover	5.785643682
Pasture/Hay Cover	4.897024777

Predictive Modeling Results by County

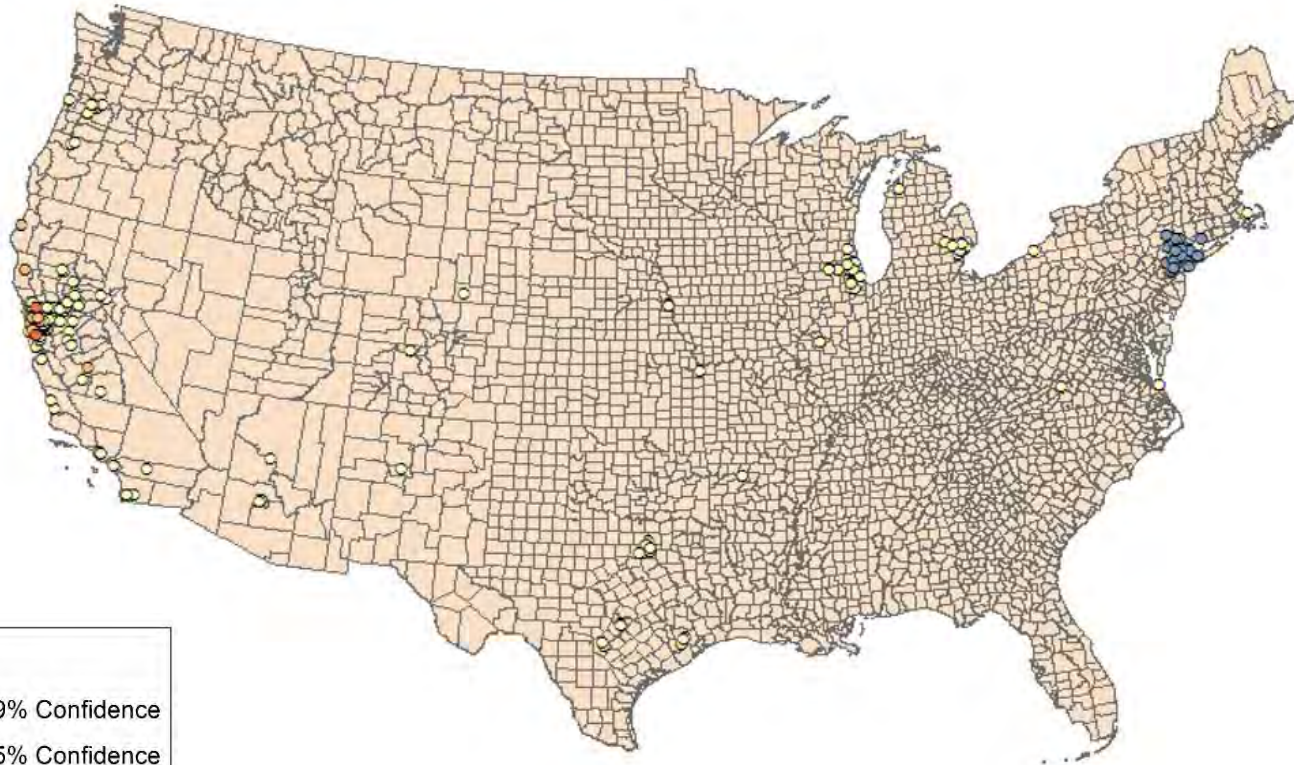
Inverse Logit Transformed Prediction by County: PCR










Inverse Logit Transformed Prediction by County: MAT



Date: 01/06/00 to 04/06/00

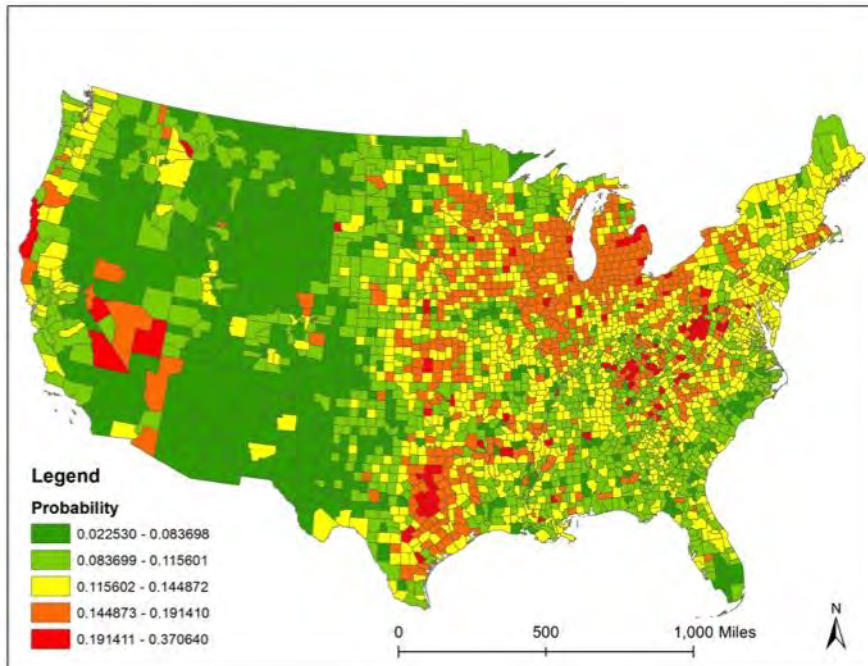


Legend

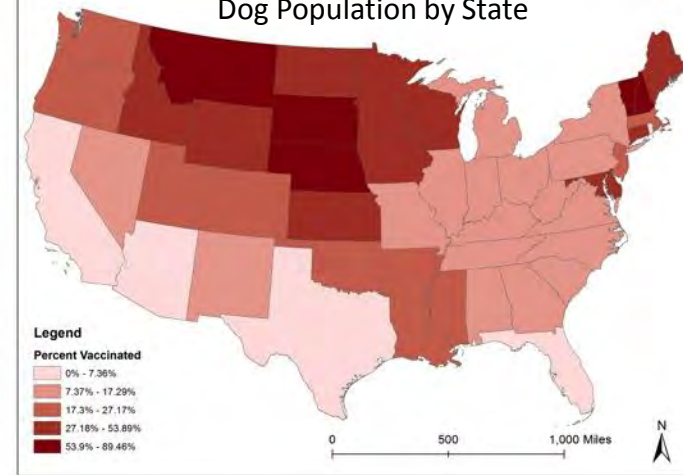
-  Cold Spot - 99% Confidence
-  Cold Spot - 95% Confidence
-  Cold Spot - 90% Confidence
-  Not Significant
-  Hot Spot - 90% Confidence
-  Hot Spot - 95% Confidence
-  Hot Spot - 99% Confidence

Summary of Final Results: MAT

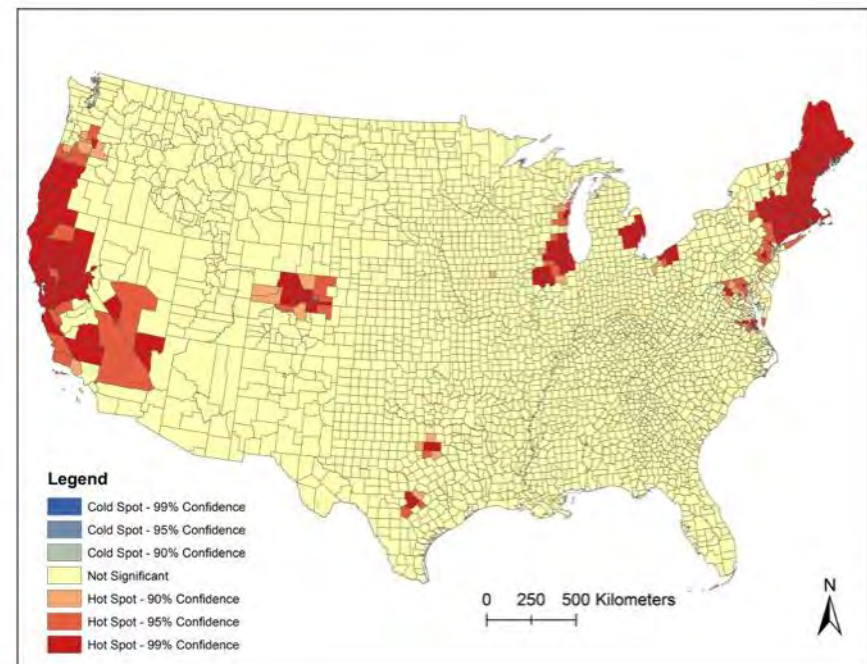
Inverse Logit Transformed
Prediction by County: MAT

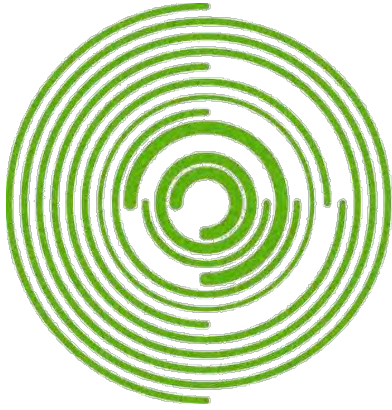


Four-year Vaccination Numbers per Estimated
Dog Population by State



Clusters of Positive MAT Tests Relative to
the Estimated County Dog Population





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Local conservation.
Global health.