Analysis of dog serologic data reveals critical insights into the epidemiology of human coccidioidomycosis, 2012-2023

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This presentation contains preliminary data that will undergo peer-review for publication.

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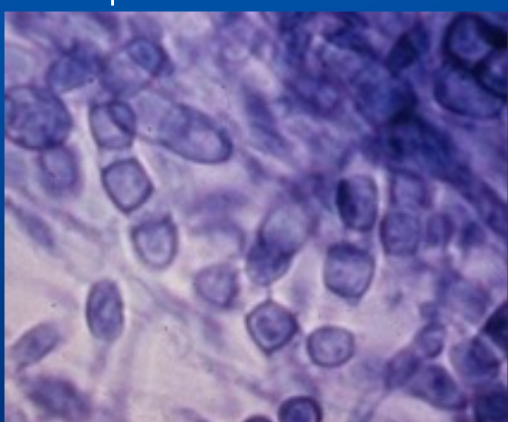
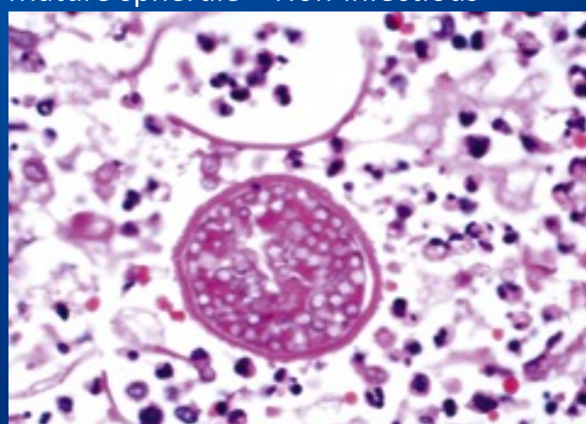
Background
Coccidioidomycosis

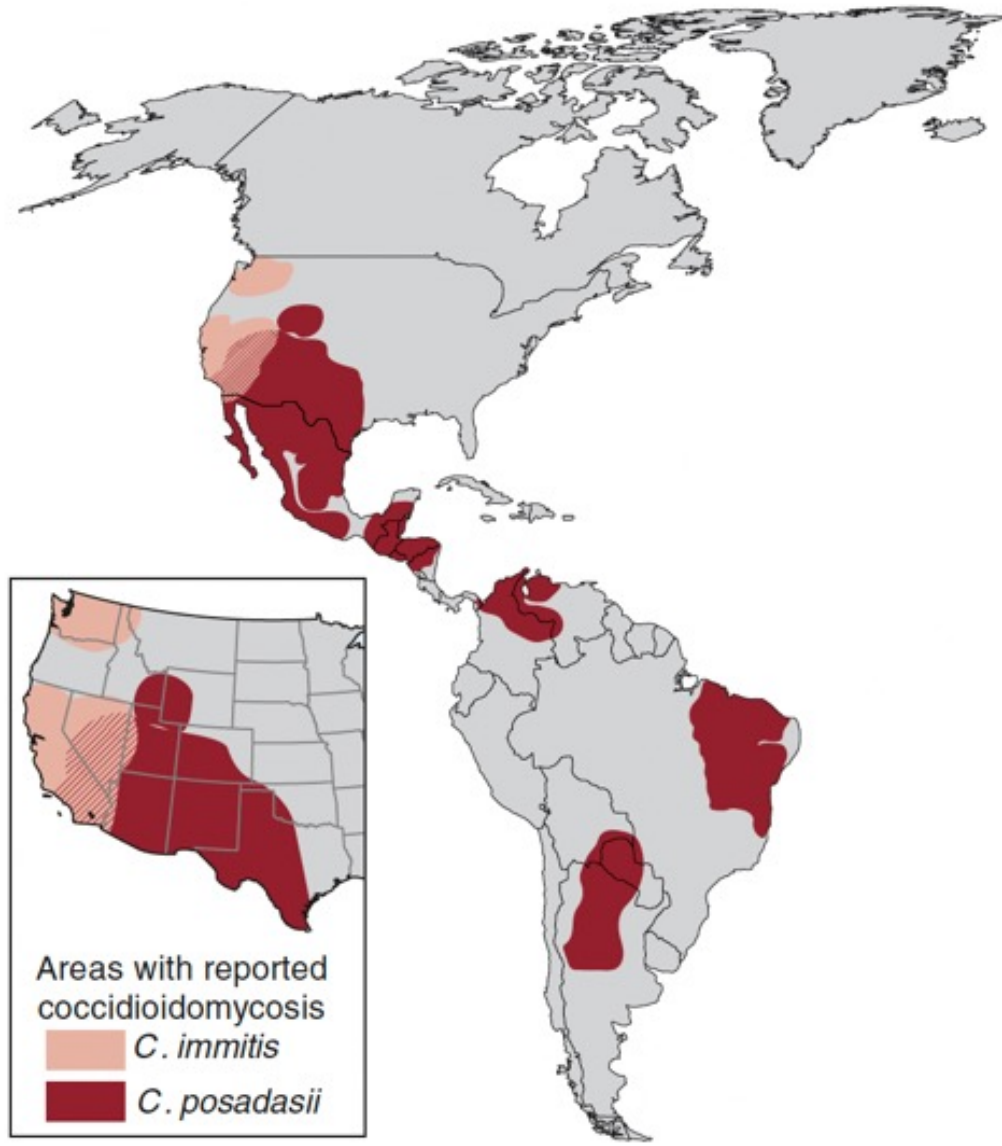
- Systemic fungal disease of humans and animals[1,2]
  - *Coccidioides immitis* and *Coccidioides posadasii*
  - Soil-borne, dimorphic fungi
  - Humans, dogs, horses, camelids, marine mammals
  - Other domestic animals, wildlife

Arthrospores – Infectious



Mature spherule – Non-infectious





Background Epidemiology

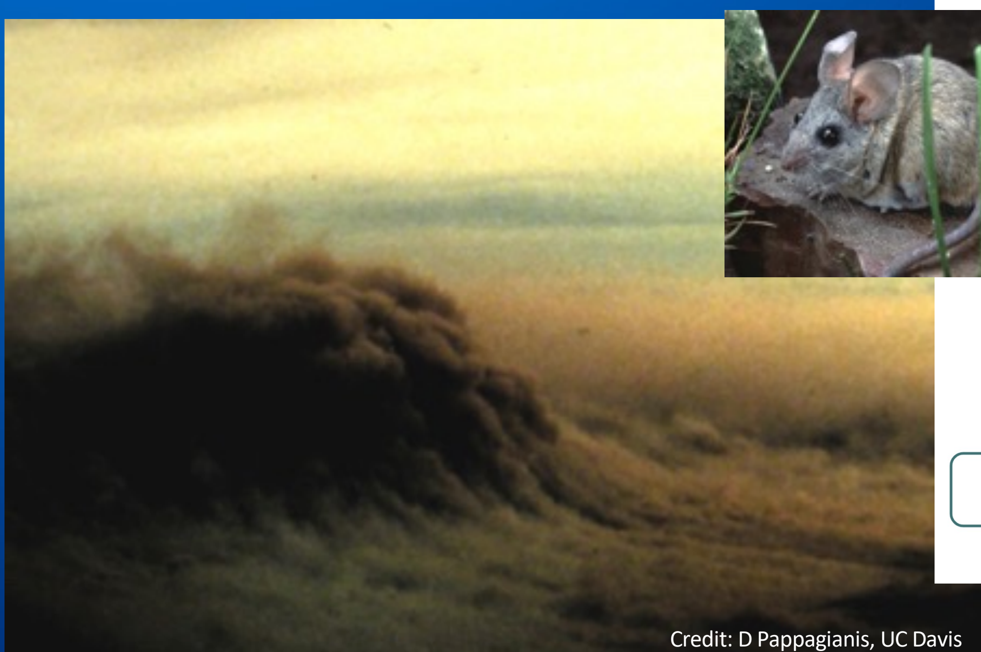
- Mexico, parts Central and South America
- Southwestern United States
  - AZ, TX, CA; also NM, UT, NV
  - San Joaquin Valley (“Valley fever”)
  - Phoenix and Tucson hyperendemic
- Lower Sonoran life zone
  - Hot summers
  - Low elevation
  - Semi-arid to arid soil

Ref 2

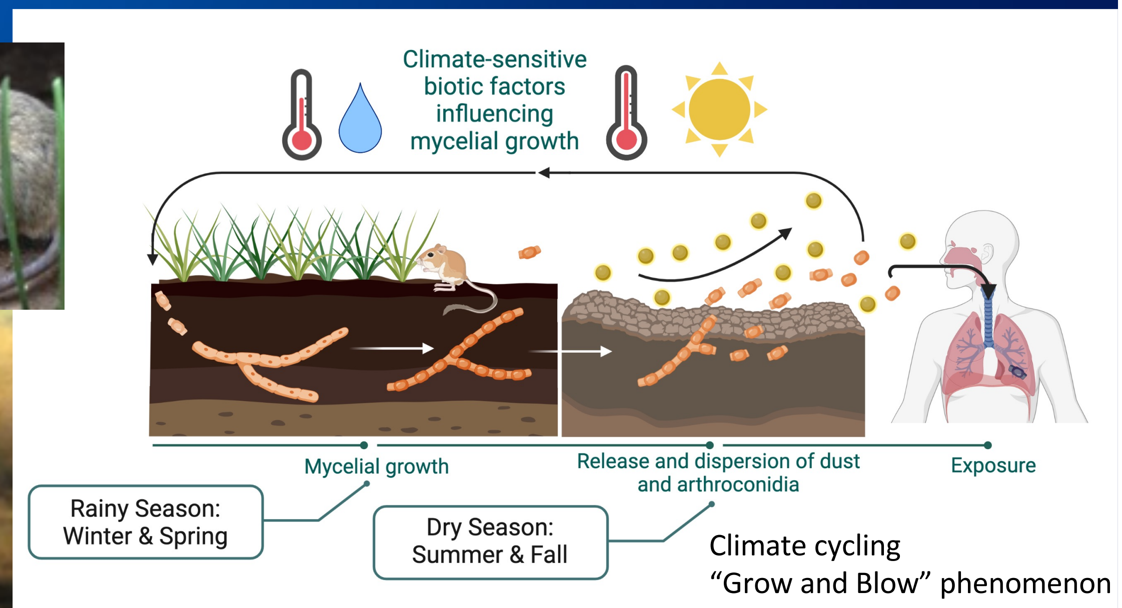
Background
Epidemiology

The “Dust Devil”

– Dust storms, haboobs, earthquakes, heavy rains, construction, agriculture, other soil disturbance



Credit: D Pappagianis, UC Davis



Credit: A Weaver, UC Berkeley

Background
Epidemiology

- Severe disease/dissemination
  - Adults 60+
  - Males
  - Pregnancy
  - Diabetes
  - HIV/AIDS
  - Organ transplant recipients
  - Pharmacologic immunosuppression
  - African Americans and Filipinos
    - Genetic variations in *CLEC7A* and *PLCG2* genes[4]
    - Encode DECTIN-1 and PLCγ2
    - Fungal β-glucan pattern recognition

Coccidioidomycosis outbreak among inmate wildland firefighters: California, 2017

Background Epidemiology

Research | Article

Climate Factors Influencing Coccidioidomycosis Seasonality and Outbreaks

Andrew C. Comrie

Department of Geography and Regional Development, University of Arizona, Tucson, Arizona, USA

Peak Valley fever incidence

Environ Health Perspect. 2005 Jun; 113(6): 688–692.

Published online 2005 Mar 3. doi: 10.1289/ehp.7786

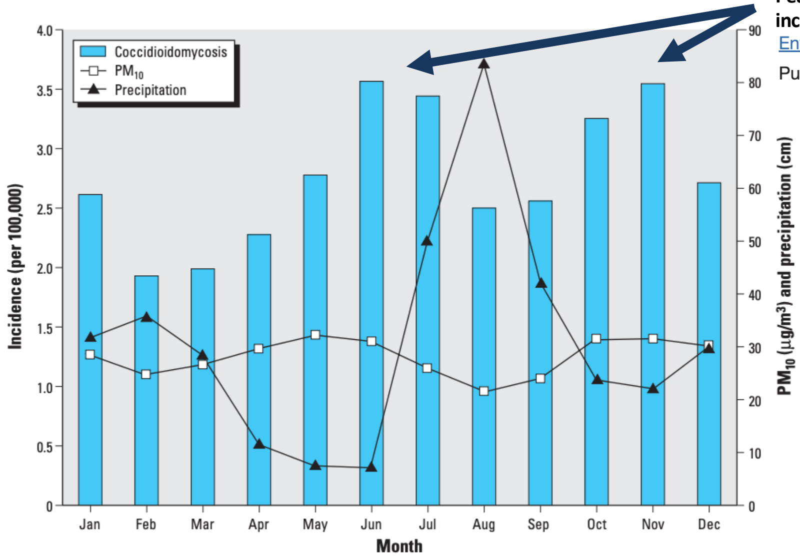


Figure 2. Mean monthly coccidioidomycosis incidence in Pima County, Arizona, based on estimated exposure date, with mean monthly precipitation and mean monthly PM_{10} concentrations, 1992–2003.

Refs 5, 6

EcoHealth 15, 840–852, 2018
https://doi.org/10.1007/s10393-018-1375-9

ECOHEALTH CrossMark

Original Contribution

Investigating the Relationship Between Climate and Valley Fever (Coccidioidomycosis)

Elizabeth A. Weaver[1] and Korine N. Kolivras[1]

[1] *Virginia Polytechnic Institute and State University, 115 Major Williams Hall, Blacksburg, VA 4061*

Peak Valley fever incidence

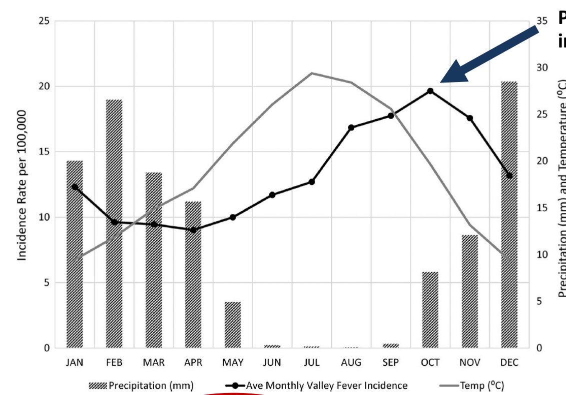


Figure 3. Disease and climate seasonality based on 2000–2015 monthly averages with the incidence having a single peak in the month of October, precipitation having a single peak in the month of February, and temperature having a single peak in July.

Credit: A Weaver, UC Berkeley

Background
Impact of Climate Change

Expansion of Coccidioidomycosis Endemic Regions in the United States in Response to Climate Change

Morgan E. Gorris[1], Kathleen K. Treseder[2], Charles S. Zender[1], and James T. Randerson[1]

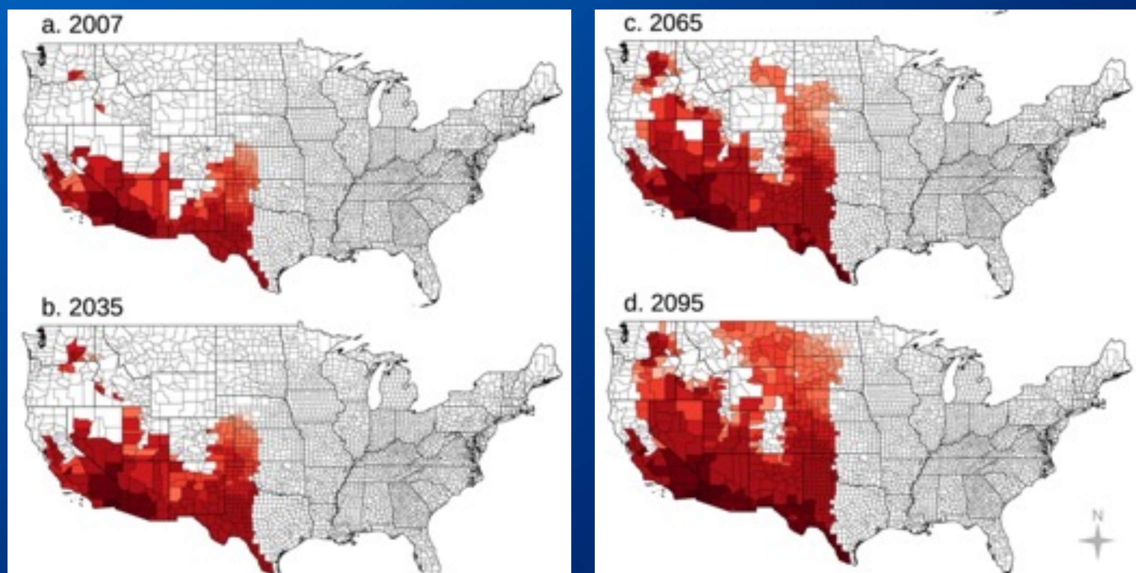
Economic Valuation of Coccidioidomycosis (Valley Fever) Projections in the United States in Response to Climate Change

Morgan E. Gorris[a], James E. Neumann[b], Patrick L. Kinney[c], Megan Sheahan[b], Marcus C. Sarofim[d]

GeoHealth

RESEARCH ARTICLE
10.1029/2019GH000209

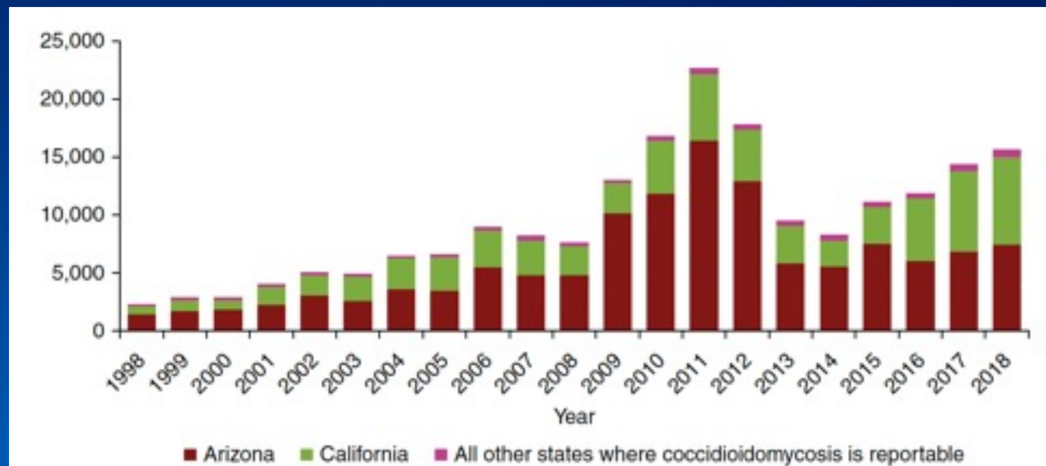
Key Points:
- We created a niche model to estimate climate limits on the spatial extent of Valley fever endemicity in the United States
- For a high warming scenario, the area of climate-limited endemicity will more than double by 2100, expanding northward into dry western states
- Our predictive model of Valley fever endemic regions may help mitigate disease impacts as the disease spreads into new regions



Time Period	Cost
2005-2019	\$3.9B/yr
End 21st century	\$18.5B/yr

Refs 7, 8

Background
Human Surveillance



Ref 9

Just One Breath

Valley fever cases reach epidemic levels, but harm remains hidden

Reporting on Health Collaborative

Saturday, September 8, 2012

By Kellie Schmitt, Rebecca Plevin and Tracy Wood

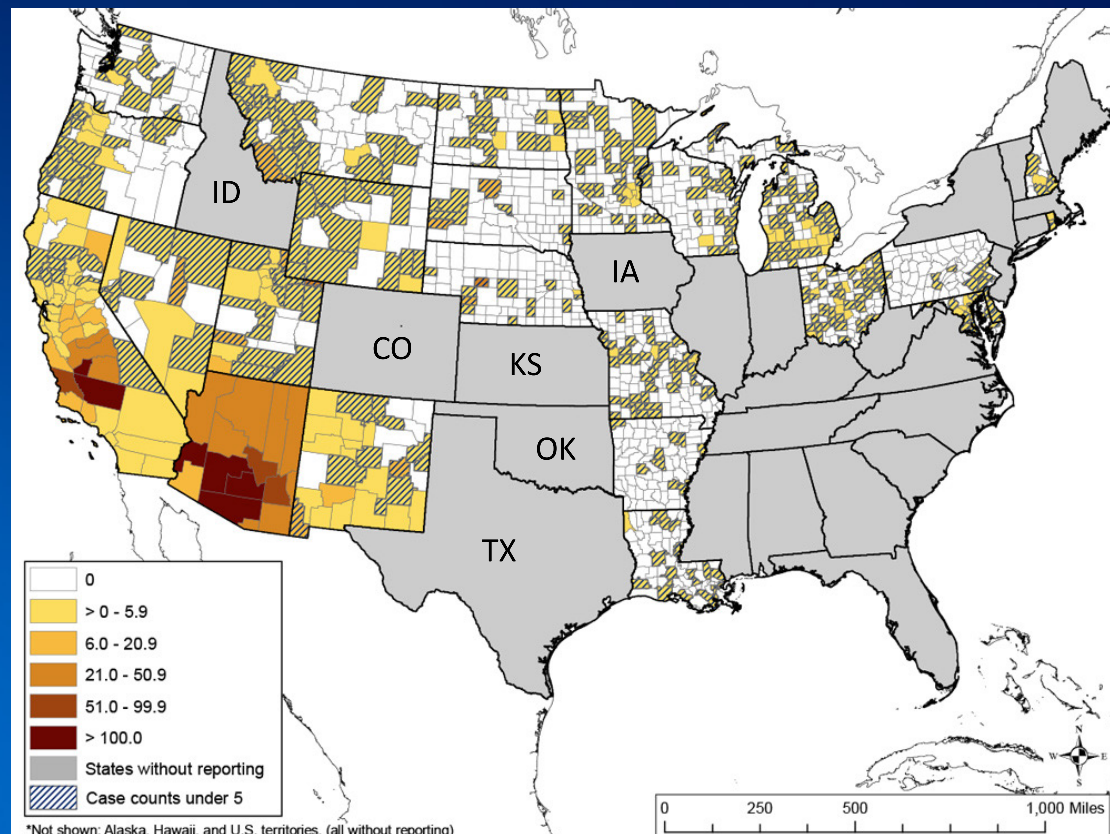
Valley fever starts with the simple act of breathing.

Ref 10

One of only two nationally notifiable fungal diseases

Reportable to local health jurisdictions in 26 states (including KS) and District of Columbia

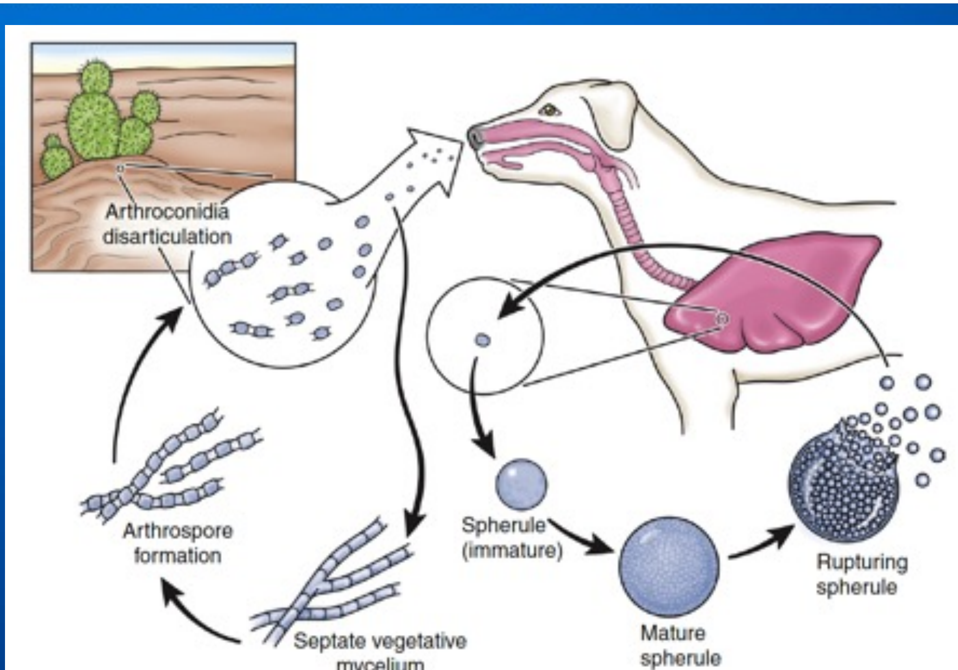
Background
Human Surveillance



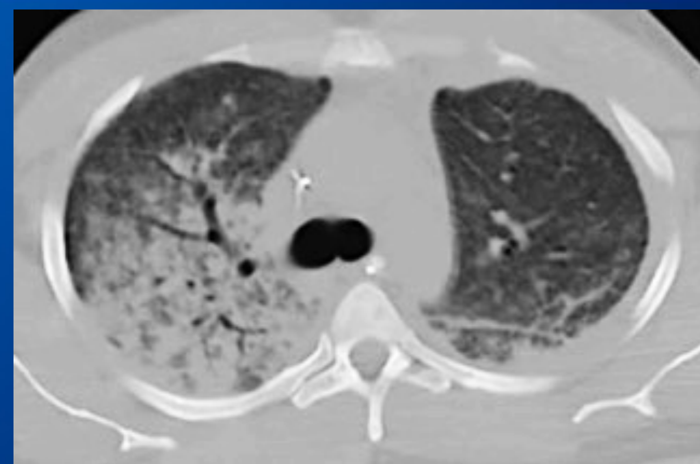
Average annual incidence (per 100,000), 2011-2017 (CDC)

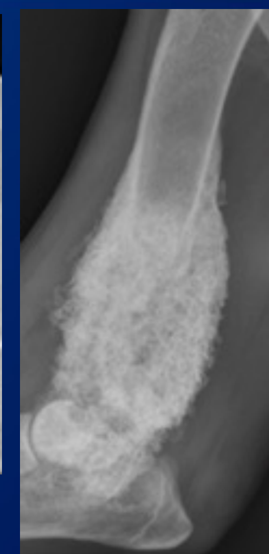
Background

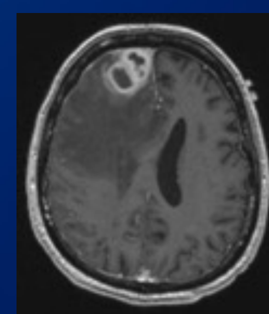
Dogs as a Model



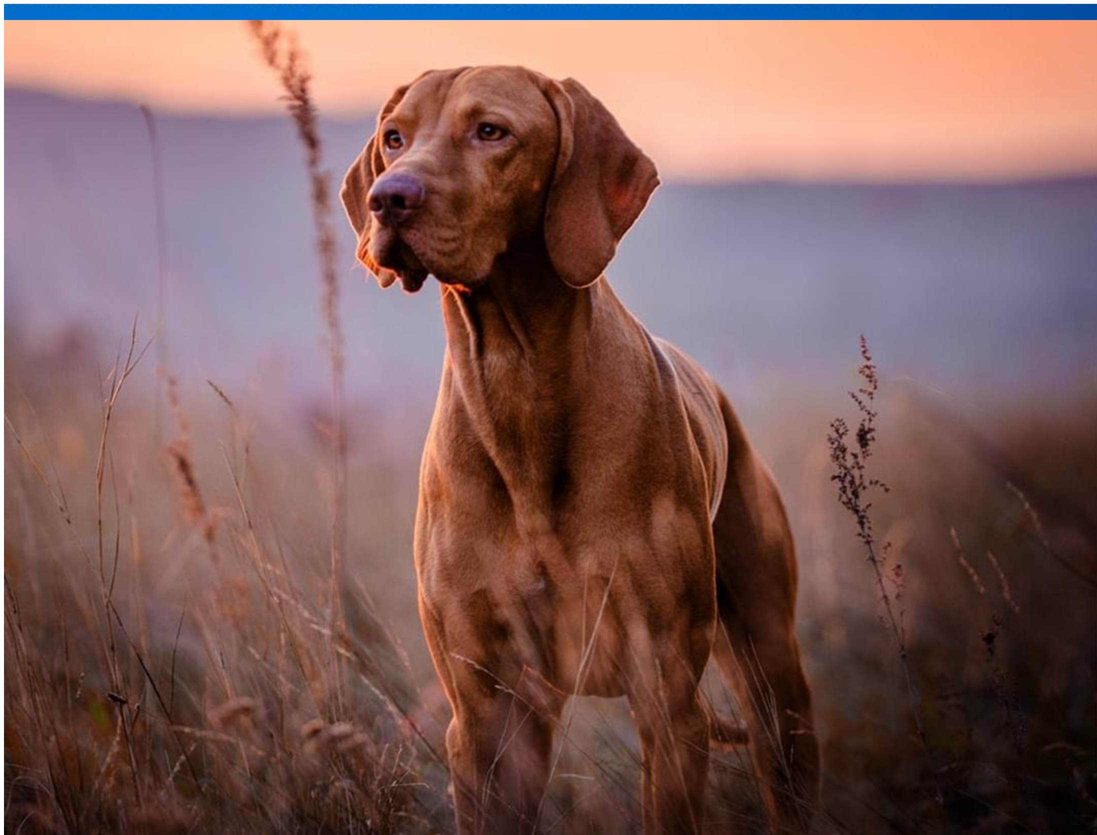
Ref 3



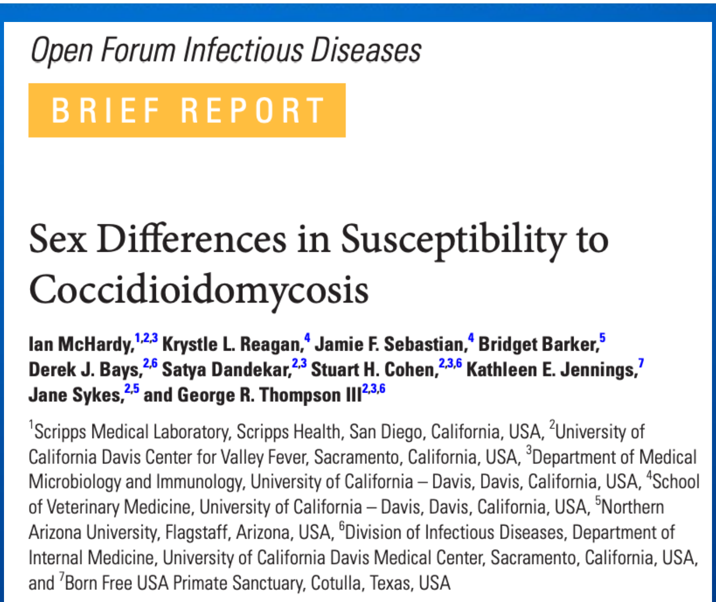




Background
Dogs as a Model



Background
Dogs as a Model



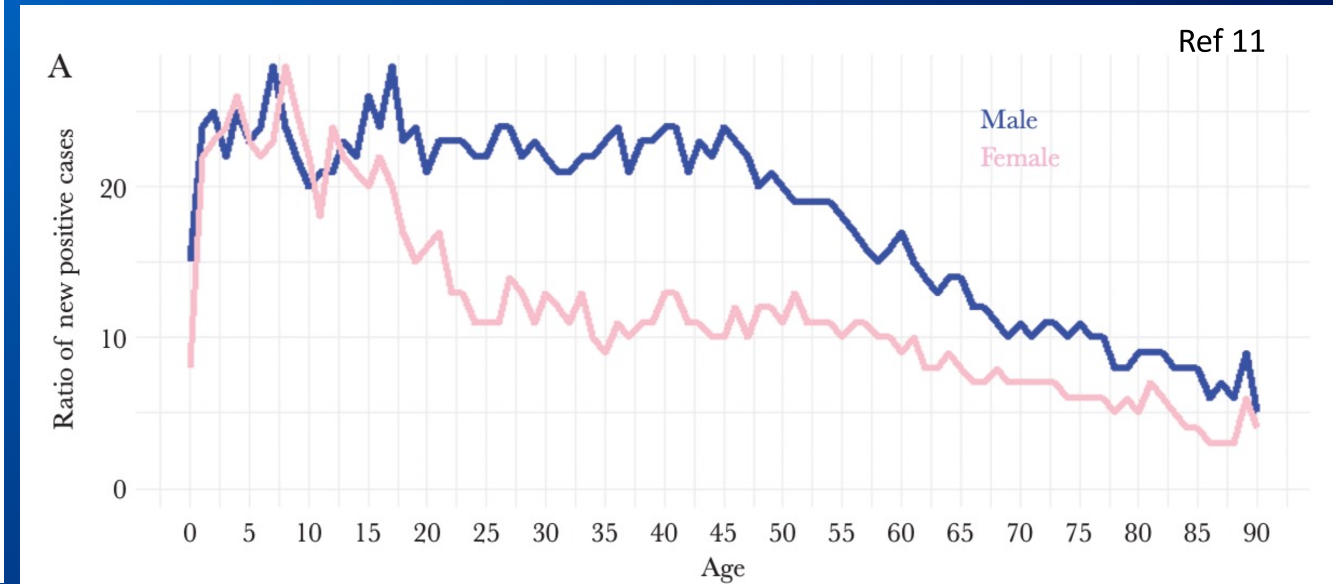
Open Forum Infectious Diseases

BRIEF REPORT

Sex Differences in Susceptibility to Coccidioidomycosis

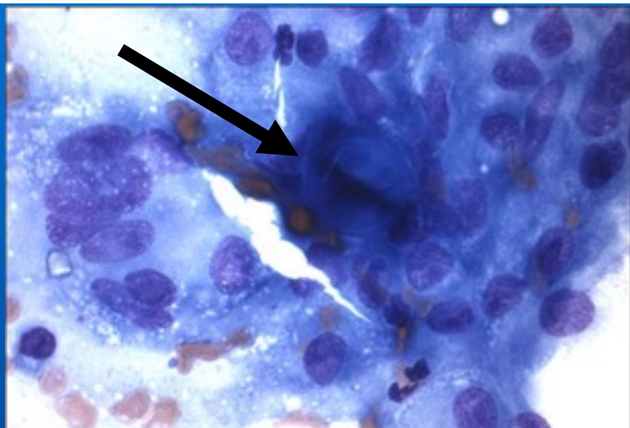
Ian McHardy,[1,2,3] Krystle L. Reagan,[4] Jamie F. Sebastian,[4] Bridget Barker,[5] Derek J. Bays,[2,6] Satya Dandekar,[2,3] Stuart H. Cohen,[2,3,6] Kathleen E. Jennings,[7] Jane Sykes,[2,5] and George R. Thompson III[2,3,6]

[1]Scripps Medical Laboratory, Scripps Health, San Diego, California, USA, [2]University of California Davis Center for Valley Fever, Sacramento, California, USA, [3]Department of Medical Microbiology and Immunology, University of California – Davis, Davis, California, USA, [4]School of Veterinary Medicine, University of California – Davis, Davis, California, USA, [5]Northern Arizona University, Flagstaff, Arizona, USA, [6]Division of Infectious Diseases, Department of Internal Medicine, University of California Davis Medical Center, Sacramento, California, USA, and [7]Born Free USA Primate Sanctuary, Cotulla, Texas, USA

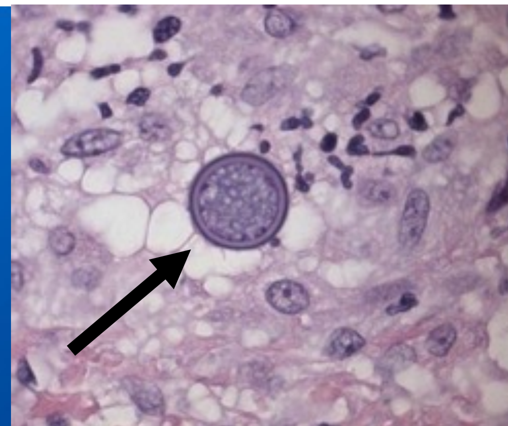


- 220,240 human cases; significant differences in risk between males and females only apparent between 19 and 80 (OR 1.8, P < 0.00001)
- 82961 male dogs, 80390 female dogs, 2000-2020
- 99 male dog cases, 60 female dog cases (OR 1.6, P = 0.0041); risk abolished for male neutered dogs

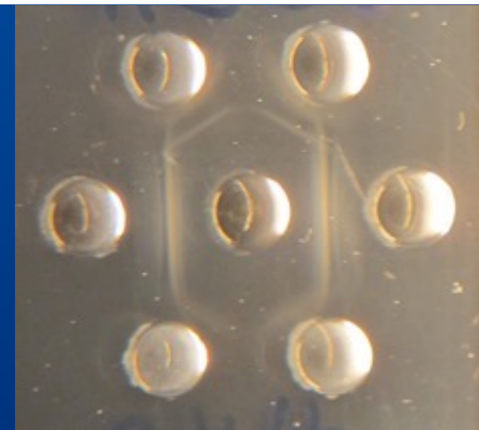
Background
Diagnosis



Cytology



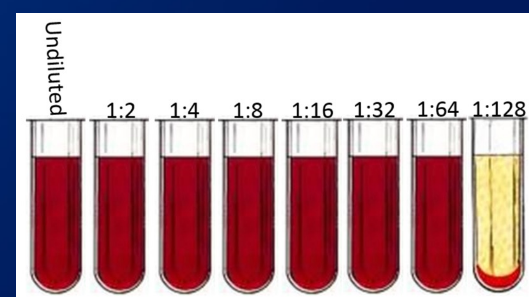
Histopathology



Serology (immunodiffusion)

Serology (lateral flow immunoassay)

Serology (EIA)



Serology (complement fixation)

Background
Dogs as Sentinels

Transboundary and Emerging Diseases

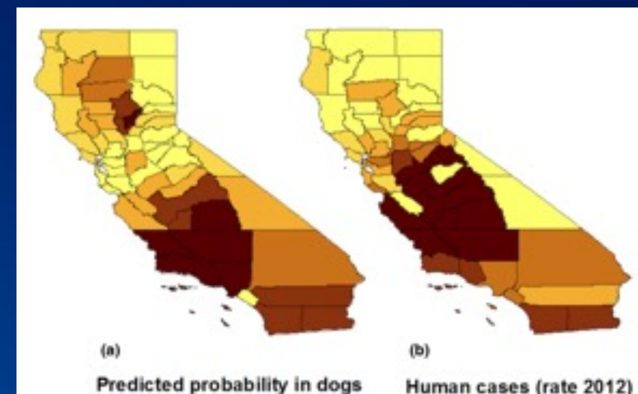
ORIGINAL ARTICLE

Risk Factors and Spatial Distribution of Canine Coccidioidomycosis in California, 2005–2013

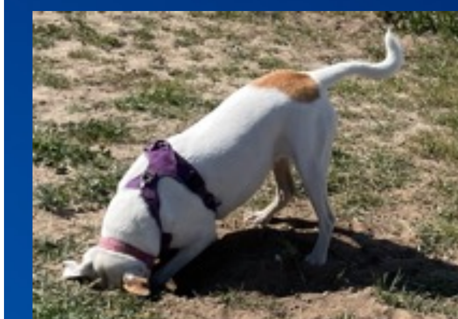
S. E. Grayzel[1], B. Martínez-López[2] and J. E. Sykes[2]

Table 1. Association between dog demographic and environmental variables and coccidioidomycosis occurrence in dogs in California as a result of a multivariable logistic regression model

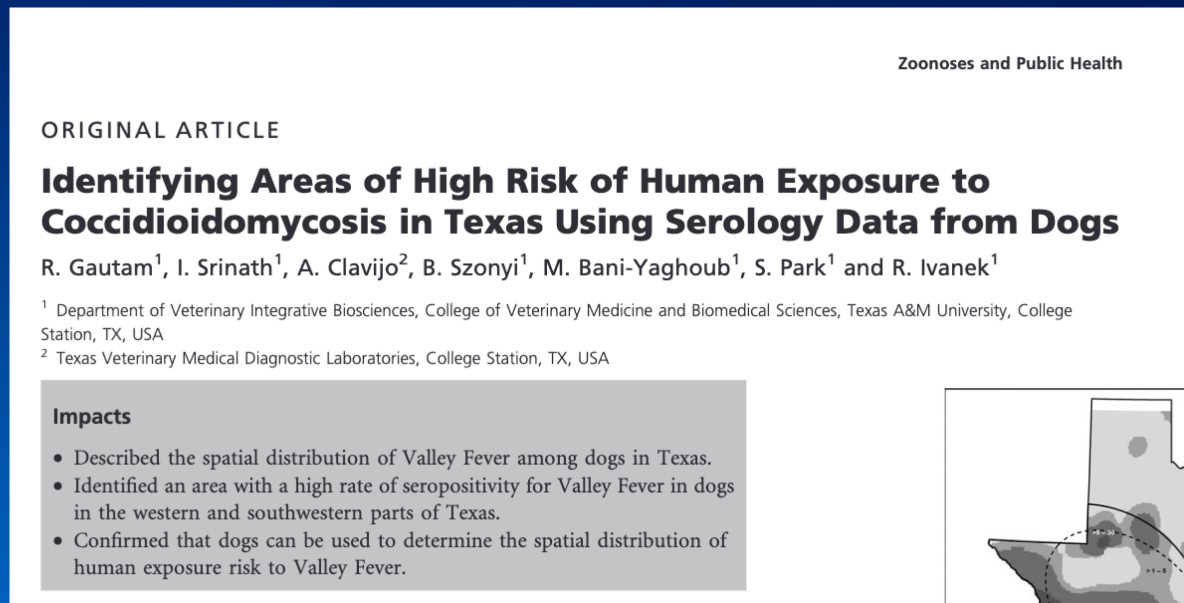
Variable	Descriptive statistics: Cases	Descriptive statistics: Controls	Odds ratio (95% confidence interval)	*P* value[a]
Age in months (mean ± SD)[b]	64 ± 36	99 ± 44	0.3 (0.16–0.56)	<0.001
Digging behavior				
No[c]	16	59	6.68 (2.47–18.06)	<0.001
Yes	25	20		
Travel to Arizona or California central valley				
No[c]	14	39	4.42 (1.46–13.38)	0.005
Yes	27	40		



Ref 12



Background



Zoonoses and Public Health

ORIGINAL ARTICLE

Identifying Areas of High Risk of Human Exposure to Coccidioidomycosis in Texas Using Serology Data from Dogs

R. Gautam[1], I. Srinath[1], A. Clavijo[2], B. Szonyi[1], M. Bani-Yaghoub[1], S. Park[1] and R. Ivanek[1]

[1] Department of Veterinary Integrative Biosciences, College of Veterinary Medicine and Biomedical Sciences, Texas A&M University, College Station, TX, USA
[2] Texas Veterinary Medical Diagnostic Laboratories, College Station, TX, USA

Impacts

- Described the spatial distribution of Valley Fever among dogs in Texas.
- Identified an area with a high rate of seropositivity for Valley Fever in dogs in the western and southwestern parts of Texas.
- Confirmed that dogs can be used to determine the spatial distribution of human exposure risk to Valley Fever.

Ref 13. Gautam R, et al. Zoonoses Public Health 2013;60:174-181

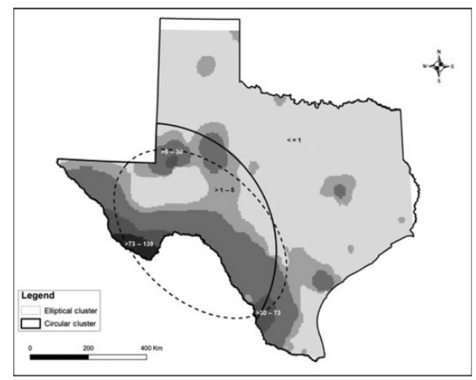


Fig. 3. Isopleth map obtained through kriging of the empirical Bayesian-smoothed seropositive rates of VF among dogs in Texas over the study period (July 1999–December 2009). The seropositive rate distribution is represented by graduated scale of shading in which rate decreases as the shade becomes lighter. The map is overlaid with the identified spatio-temporal cluster that spans the period from August 2004 to October 2009 and from September 2003 to November 2008, based on the cylindrical and ellipsoidal scanning windows, respectively.

July 1999 – December 2009
Seroprevalence 2,547/5,871 (43%)

Background
Dogs as Sentinels

Ref 14

Coccidioidomycosis Acquired in Washington State

Nicola Marsden-Haug,[1] Marcia Goldoft,[1] Cindy Ralston,[2] Ajit P. Limaye,[4] Jimmy Chua,[3] Heather Hill,[2] Larry Jecha,[2] George R. Thompson III,[5] and Tom Chiller[6]

[1]Office of Communicable Disease Epidemiology, Washington State Department of Health, Shoreline, [2]Communicable Disease Program, Benton-Franklin Health District, and [3]Infectious Diseases Department, Kennewick General Hospital, Kennewick, and [4]Division of Allergy and Infectious Diseases, University of Washington, Seattle, Washington; [5]Coccidioidomycosis Serology Laboratory, University of California, Davis; and [6]Mycotic Diseases Branch, Centers for Disease Control and Prevention, Atlanta, Georgia

- Acute disease, three unrelated people from SE WA, no travel
  - 2010: 12-year-old boy with pneumonia, biked, dug in canyon
  - 2010: 15-year-old boy with knee cellulitis after ATV crash
  - 2011: 58-year-old man with pneumonia, construction excavator

Background
Dogs as Sentinels

Journal of *Fungi*

Review

Coccidioidomycosis in Brazil: Historical Challenges of a Neglected Disease

Rossana Cordeiro [1,*,†], Santiago Moura [1,†], Débora Castelo-Branco [1,*], Marcos Fábio Rocha [1,2], Reginaldo Lima-Neto [3] and José Júlio Sidrim [1]

"The international scientific community turned its attention to coccidioidomycosis in Brazil after an outbreak…
In August 1991, three individuals and eight of their dogs who went on an armadillo hunt developed severe pneumonia; three dogs died a few days later"

Ref 15

Hypothesis and Study Goals

- Serosurveillance efforts in dogs will provide insight into the epidemiology of coccidioidomycosis in humans
- Spatial analysis of serologic test data will correlate with that found for humans and reveal emerging regions of endemicity
- The inter-annual and seasonal pattern of seroreactivity in dogs will match those known for people
- Inter- and intra-annual variation in seroreactivity will correlate with climatic variables
- Overarching goal: demonstrate value of dogs as a sentinel

Learning Objectives

- Develop an in-depth understanding regarding epidemiology of coccidioidomycosis
- Understand value and limitations of surveillance efforts
- Learn how software platforms (R, Excel) can be used to analyze a large set of health data
- Know steps required to manipulate data and create maps in ArcGIS Pro
- Interpret results to inform public health interventions
- Refine writing and oral presentation skills

Methods

- Gathered ‘big’ serologic data
  - 7 different laboratories
  - January 2012 to August 2023
  - AGID, IgM and IgG, positive and negative; EIA accepted
  - Initially CA, AZ, OR, WA, NV, NM, UT, and TX; then all U.S. states
  - Dog ID, age, breed, sex, owner/practice zip code, county, state, test date (month, year), lab number, test result
- Data clean-up (R)
  - Raw 2,141,055 visits
  - Removed non-dogs, serially tested dogs, non-serologic data
  - Final 887,764 dogs
  - Harmonized location data

Methods
Statistical Analysis

- Risk factors: breed, body size, sex, age
  - Breed categories
    - Closely-related breeds (n = 155)
    - Behavior-associated groups (n = 53)
    - American Kennel Club (AKC) breed groups (n = 9) (e.g., working, sporting, herding, mixed breed, hound, toy)
    - AKC breed size groupings (n = 5)
  - Sex categories
    - MI, FI, MN, FS, MU, FU
  - Age by year (continuous), groups
  - Chi square test (GraphPad Prism), unpaired t-test (Excel)

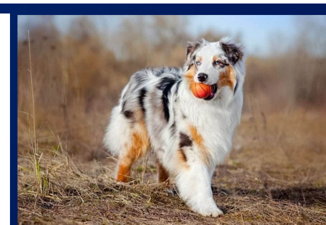
iScience
CellPress OPEN ACCESS
Article

Breed, age, and social environment are associated with personality traits in dogs

Milla Salonen,[1,2,3,4,*] Salla Mikkola,[1,2,3] Julia E. Niskanen,[1,2,3] Emma Hakanen,[1,2,3] Sini Sulkama,[1,2,3] Jenni Puurunen,[1,2,3] and Hannes Lohi[1,2,3,5,*]

Table S1. Breeds and breed groups, related to STAR Methods.

Australian Shepherd	**Belgian shepherd dogs**	**Bernese Mountain Dogs**	**Bichon type dogs**
Australian Shepherd	Groenendael	Appenzell Cattle Dog	Bichon Frise
Miniature American Shepherd	Laekenois	Bernese Mountain Dog	Bolognese
	Malinois	Entlebucher Mountain Dog	Coton de Tulear
	Tervueren	Greater Swiss Mountain Dog	Havanese
			Löwchen
			Maltese
			Russian Tsvetnaya Bolonka
Brachycephalic dogs	**Bull type terriers**	**Dachshunds**	**English herders**
Boston Terrier	Bull Terrier	Miniature Longhaired	Australian Cattle Dog
Bulldog	Miniature Bull Terrier	Miniature Shorthaired	Australian Kelpie
French Bulldog	Staffordshire Bull Terrier	Miniature Wirehaired	Australian Koolie
Olde English Bulldogge		Rabbit Longhaired	Bearded Collie
Pug		Rabbit Shorthaired	Lancashire Heeler
		Rabbit Wirehaired	Old English Sheepdog
		Standard Longhaired	Welsh Sheepdog
		Standard Shorthaired	
		Standard Wirehaired	
European sighthounds	**Fighting dogs**	**German spitz related breeds**	**Hunting terriers**
Borzoi	American Bulldog	Eurasier	Bedlington Terrier
Deerhound	American Bully	Giant Spitz	Border Terrier
Greyhound	American Pit Bull Terrier	Medium size Spitz	Cairn Terrier
Hungarian Greyhound	American Staffordshire Terrier	Miniature Spitz	Cesky Terrier
Irish Wolfhound	Cane Corso	Japanese Spitz	Dandie Dinmont Terrier
Italian Sighthound	Dogo Argentino	Keeshond	Fox Terrier Smooth
Polish Greyhound	Presa Canario	Pomeranian	Fox Terrier Wire
Silken Windhound		Volpino Italiano	German Hunting Terrier
Spanish Greyhound			Glen of Imaal Terrier
			Lakeland Terrier
			Norfolk Terrier
			Norwich Terrier
			Scottish Terrier
			Skye Terrier
			Welsh Terrier



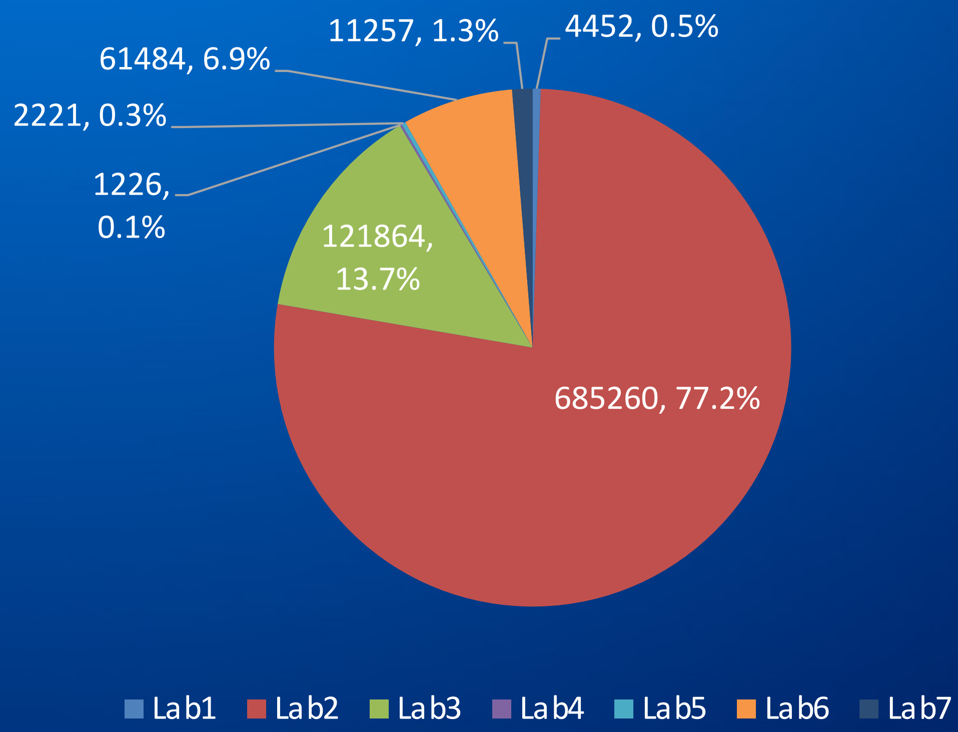
Ref 16

Methods
Statistical Analysis

- Examined total tests, test positivity, incidence/10,000 households – annual and seasonal
- Inter-annual and monthly/seasonal incidence compared with human data for CA and AZ
  - CA Department of Public Health (monthly county-level) and CA Department of Finance
  - AZ Department of Health Services (annual county-level; dog data aggregated)
  - Pearson's correlation coefficient (R)
- Spatial analysis (ArcGIS Pro)
  - Data joined with county shapefiles (US Census Bureau)
  - Choropleth mapping (tests, prevalence, incidence)
    - USA Albers Equal Area Conic projection
  - Spatial autocorrelation
    - Moran's I
  - Hot spot analysis
    - Getis Ord-Gi*, fixed distance band method

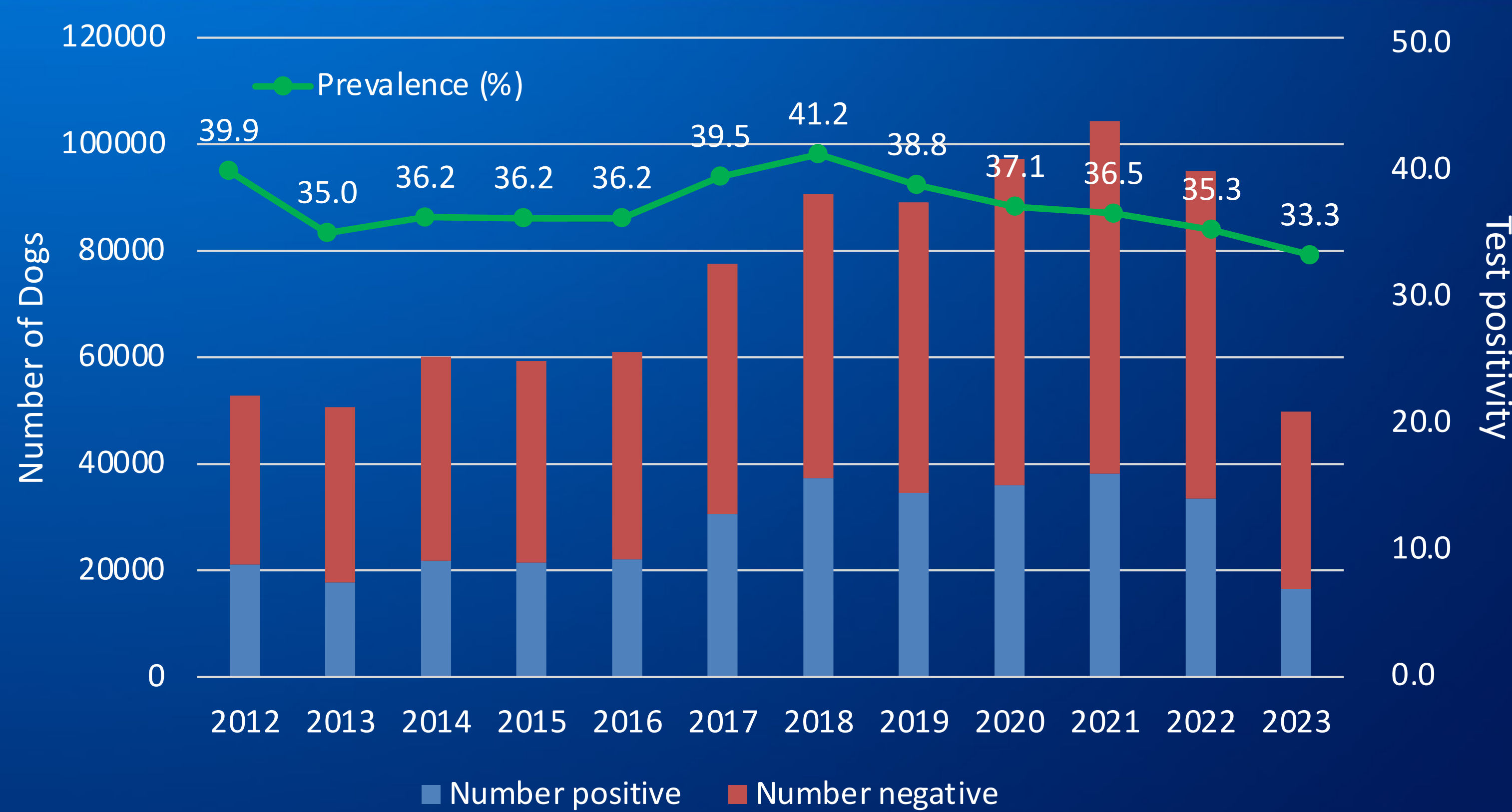
Results
Laboratories

Proportion of Samples by Laboratory, 2012-2023 (n = 887,764)



Test positivity 330,959/887,764 (37.3%)

Results
Total Tests and Test Positivity



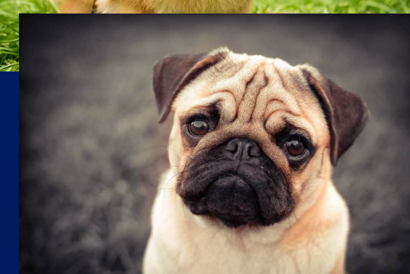
Results
Individual Breed Analysis: 682,078 dogs (77%)



Breed	Number positive	Number negative	Test Positivity	OR (95% CI)	P value
McNab	29	6	82.9%	7.62 (3.25 – 17.85)	< 0.0001
Spinone Italiano	71	41	63.4%	2.89 (1.96 – 4.26)	< 0.0001
Viszla	1852	1082	63.1%	2.87 (2.60 – 3.18)	< 0.0001
Polish Lowland sheepdog	22	15	59.5%	2.44 (1.27 – 4.67)	0.0094
Golden retriever mix	2834	1970	59.0%	2.41 (2.21 – 2.64)	< 0.0001
Scottish terrier	964	684	58.5%	2.37 (2.10 – 2.66)	< 0.0001
Weimaraner	2245	1877	54.5%	2.01 (1.83 – 2.20)	< 0.0001
Bull terrier	1014	856	54.2%	1.99 (1.78 – 2.23)	< 0.0001
Afghan hound	144	125	53.5%	1.93 (1.51 – 2.48)	< 0.0001
Saluki	73	68	51.8%	1.80 (1.29 – 2.52)	0.0005
Shetland sheepdog	432	1999	17.8%	0.36 (0.32 – 0.41)	< 0.0001
Pomeranian	1367	5913	18.8%	0.39 (0.35 – 0.42)	< 0.0001
Pug	1700	7258	19.0%	0.39 (0.36 – 0.42)	< 0.0001
Japanese Chin	84	340	19.8%	0.42 (0.33 – 0.53)	< 0.0001
Brussels Griffon	139	547	20.3%	0.43 (0.35 – 0.52)	< 0.0001
Maltese	1853	7282	20.3%	0.43 (0.39 – 0.46)	< 0.0001
Italian greyhound	240	919	20.7%	0.44 (0.37 – 0.51)	< 0.0001
French bulldog	1016	3558	22.2%	0.48 (0.44 – 0.53)	< 0.0001
Chihuahua	10419	36358	22.3%	0.48 (0.45 – 0.51)	< 0.0001
Cavalier King Charles Spaniels	884	2793	24.0%	0.53 (0.48 – 0.59)	< 0.0001

Reference group greyhounds, 1340/3589, prevalence 37.3%



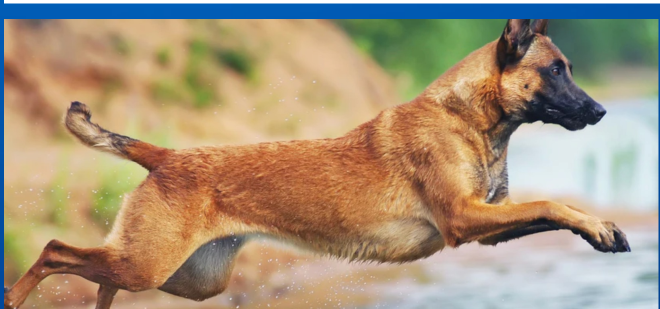


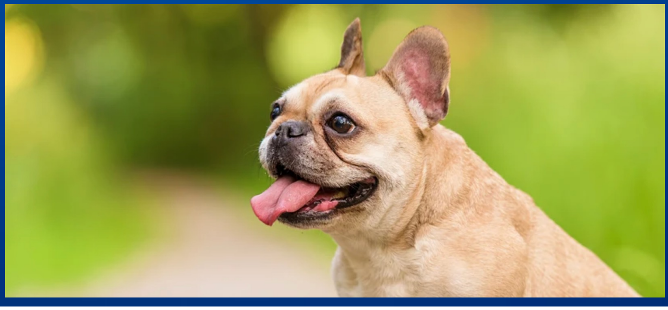
Results

American Kennel Club Size Group Analysis: 568,997 dogs (64%)

Body Size	Number positive	Number negative	Test Positivity	OR (95% CI)	P value
Large	78674	102693	43.4%	1.24 (1.21 – 1.27)	< 0.0001
Medium	58284	76478	43.2%	1.23 (1.20 – 1.26)	< 0.0001
Small	38315	86826	30.6%	0.71 (0.70 – 0.73)	< 0.0001
Toy	22004	68891	24.2%	0.51 (0.50 – 0.53)	< 0.0001

Reference group Giant dogs (14087/36832, prevalence 38.2%)





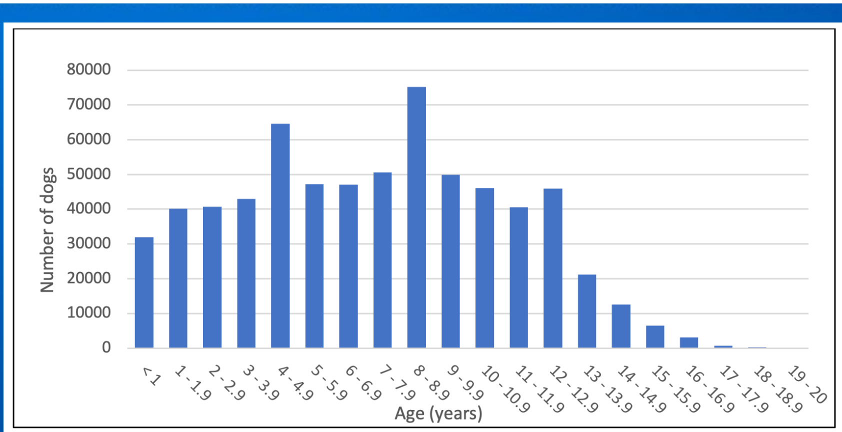
Results

Sex Analysis: 804,426 (91%)

Sex	Number positive	Number negative	Test Positivity	OR (95% CI)	P value
Male not stated	30318	43068	41.3%	1.16 (1.14 – 1.19)	< 0.0001
Male neutered	113705	178328	38.9%	1.1 (1.03 – 1.08)	< 0.0001
Female not stated	24730	40885	37.7%	1.00 (0.99 – 1.02)	0.98
Female neutered	108482	188595	36.5%	0.95 (0.93 – 0.97)	< 0.0001
Female intact	11122	20977	34.6%	0.88 (0.85 – 0.90)	< 0.0001

Reference group intact male dogs (16668/27548, prevalence 37.7%)

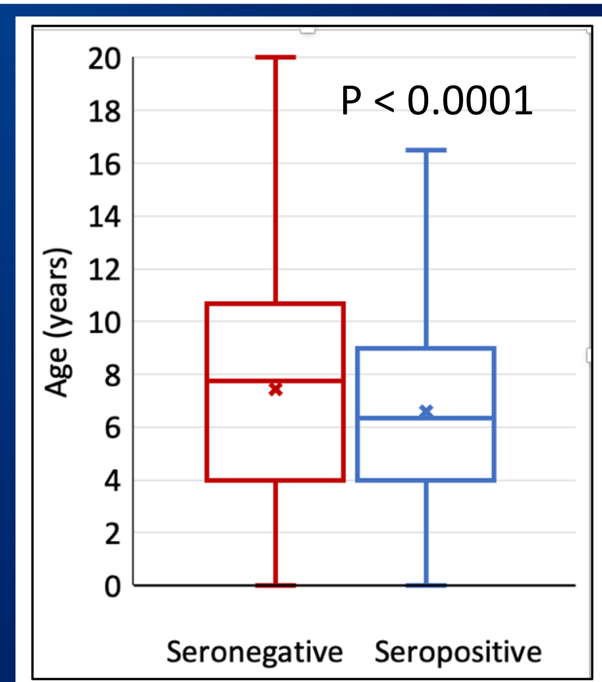
Results
Age Analysis: 667,279 (75%)



Distribution of age categories for dogs tested for *Coccidioides* spp. 2012-2023

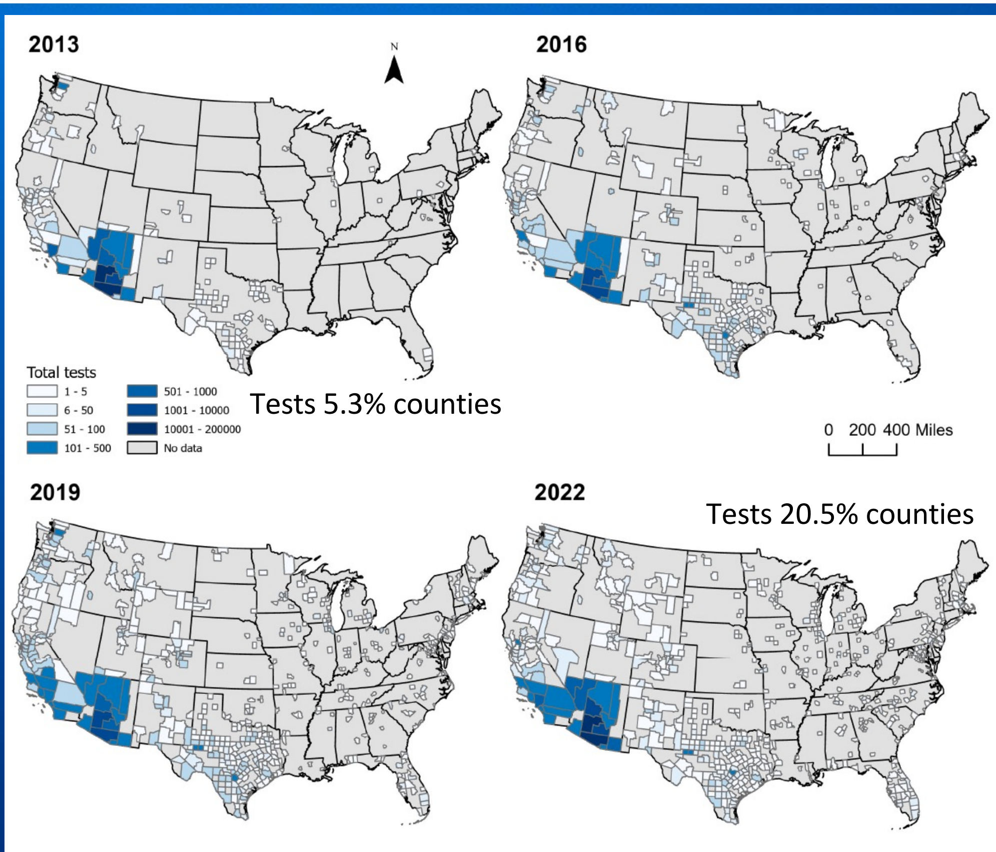
Age Group (years)	Number positive	Number negative	Test Positivity	OR (95% CI)	P value
Less than 1	8836	23102	27.7%	0.63 (0.61 – 0.65)	< 0.0001
1 to 3	33857	46944	41.9%	1.19 (1.17 – 1.21)	< 0.0001
3 to 6	70356	84296	45.5%	1.36 (1.36 – 1.40)	< 0.0001
6 to 8	42075	55605	43.1%	1.25 (1.23 – 1.27)	< 0.0001
10 to 15	47928	118419	28.8%	0.67 (0.66 – 0.68)	< 0.0001
15 to 20	1940	8688	18.3%	0.37 (0.35 – 0.39)	< 0.0001

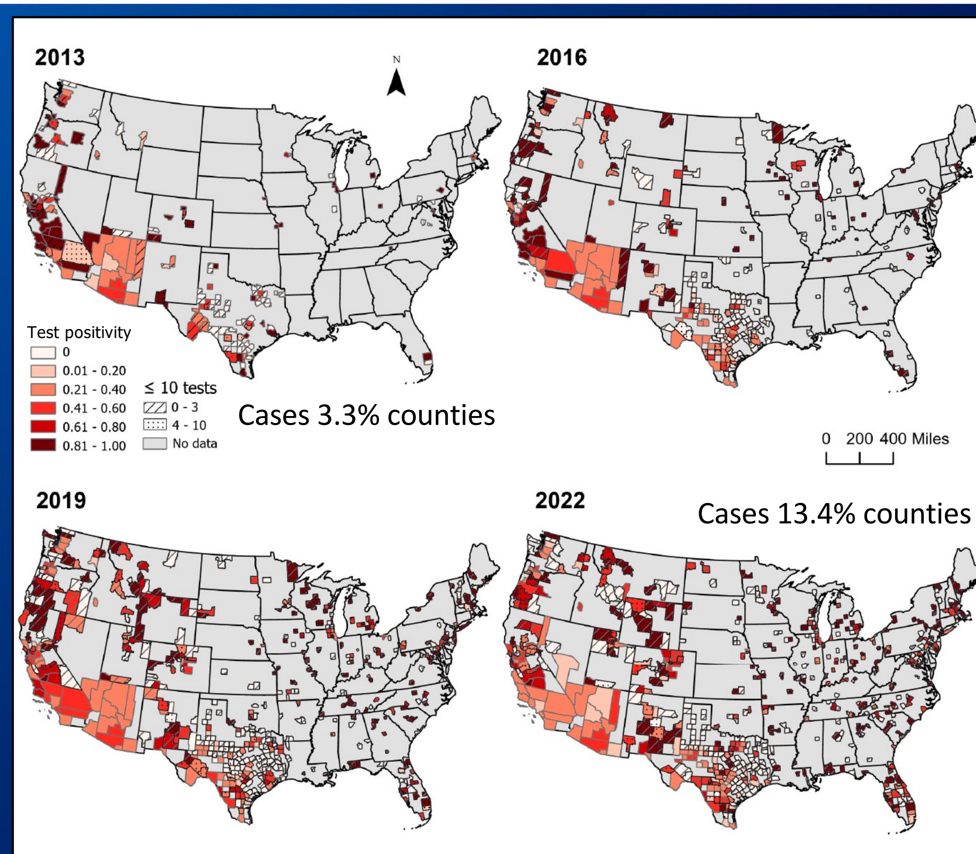
Reference group dogs 8 to 10 years of age (47239/125123, prevalence 37.8%)



Comparison of age distributions in dogs seronegative and seropositive for *Coccidioides* spp. antibodies

Results
Total Tests and %Test Positivity Maps





Results
Overall Test Positivity, 2012-2023

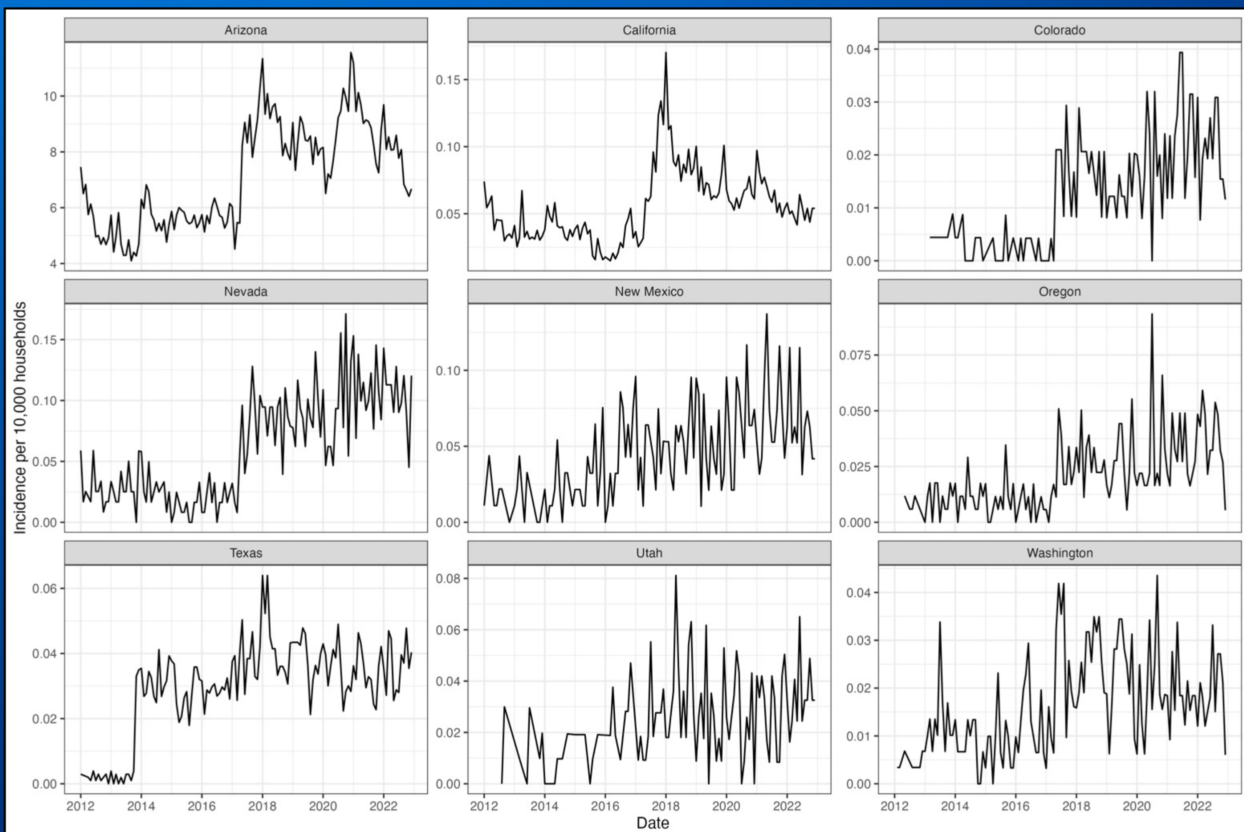
State	Number positive	Number negative	Test Positivity	OR (95% CI)
Texas	4998	10776	31.7%	0.87 (0.84 – 0.90)
Washington	695	1145	37.8%`	1.14 (1.04 – 1.26)
Nevada	526	747	41.3%	1.33 (1.19 – 1.48)
New Mexico	780	807	49.1%	1.82 (1.65 – 2.01)
California	8528	8464	50.2%	1.90 (1.84 – 1.96)
Oregon	612	424	59.1%	2.72 (2.40 – 3.08)
Utah	300	149	66.8%	3.79 (3.12 – 4.62)
Colorado	869	256	77.2%	6.39 (5.56 – 7.35)

/ith 95% CI

Reference group AZ, 248987/717930, test positivity 34.7%; all P values < 0.0001

Results

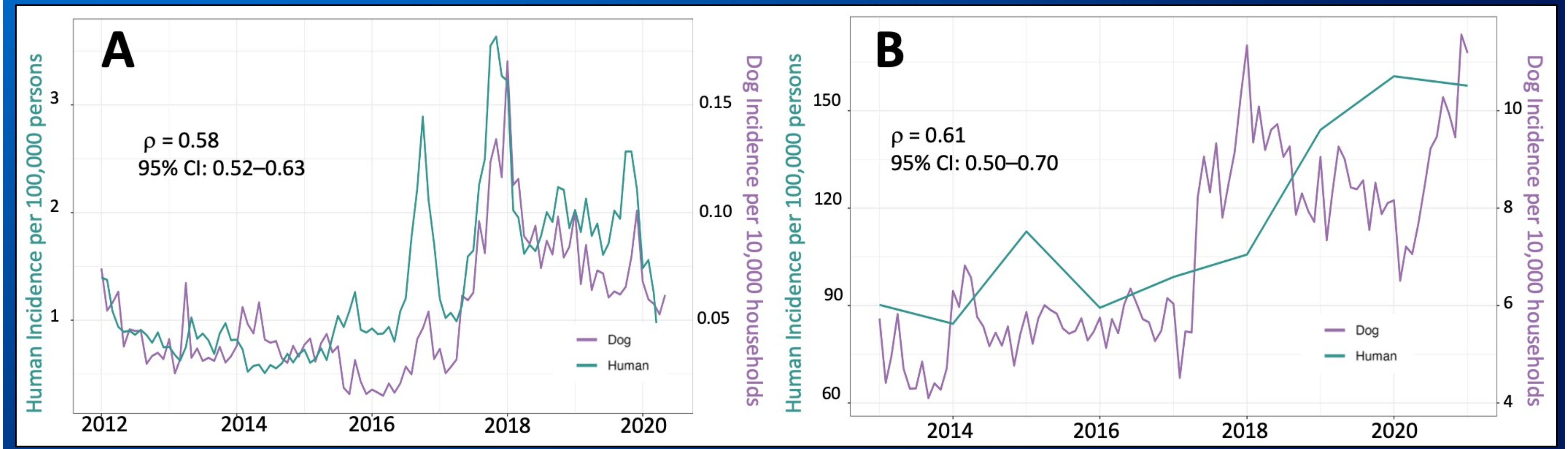
Incidence Curves, 2012-2023

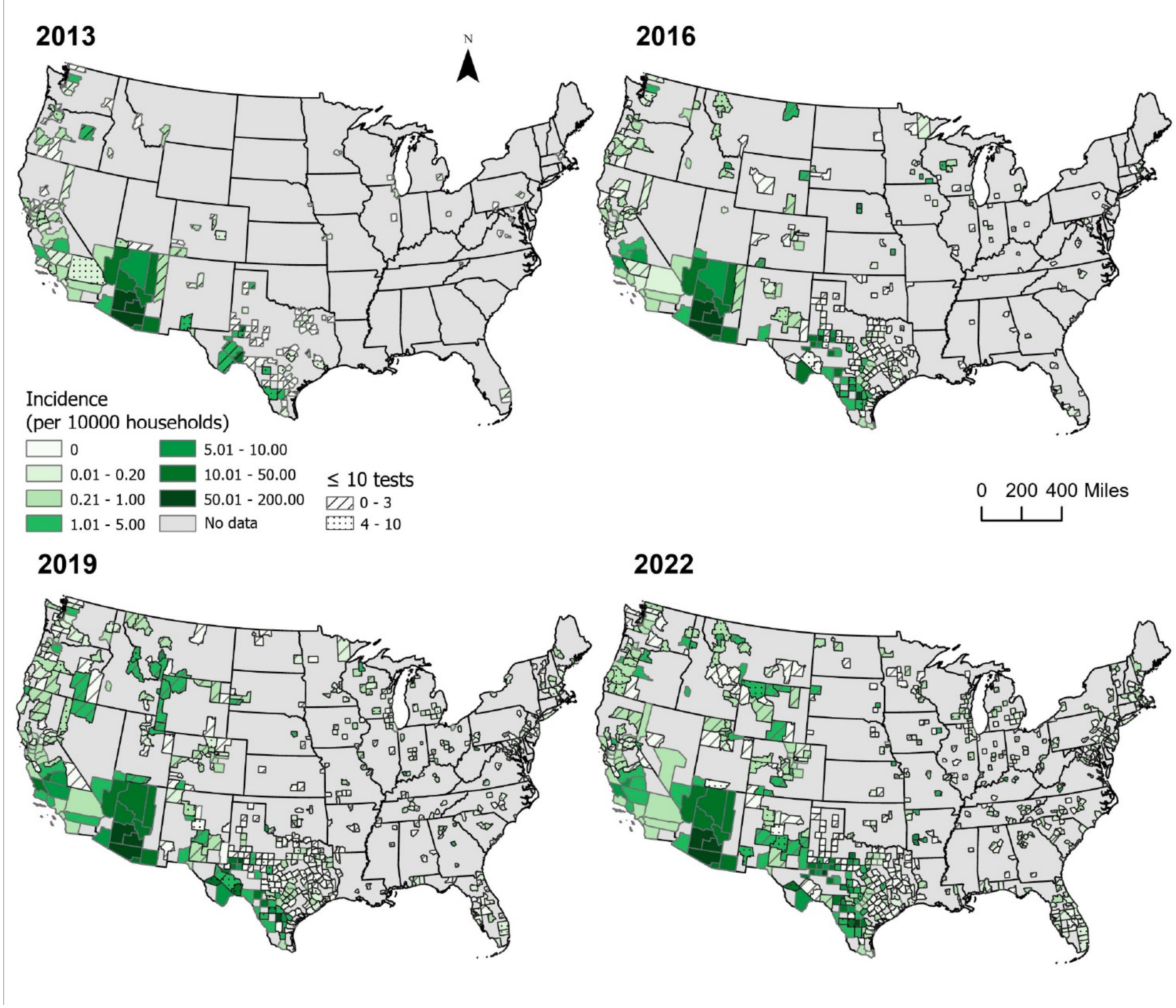


- AZ incidence rates 80 to 100-fold higher than CA, 100- to 1000-fold other SW states
- 2018 peak in AZ, CA, TX
- Incidence rates in NV and NM exceeded CA 2019-2023
- Rates in WA, OR, UT, TX low

Results

Dog vs. Human Incidence Curves, 2012-2023





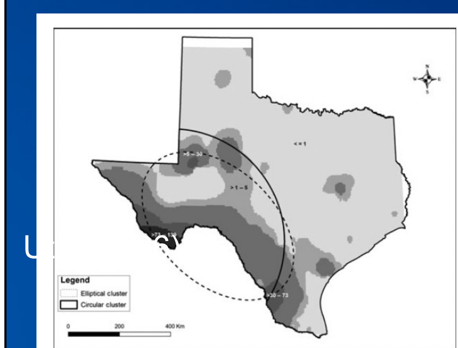
Results
Incidence Maps (Annual)

Overall Incidence:

Arizona (87.1)
Nevada (0.78)
California (0.67)
New Mexico (0.53)
Montana (0.35)
Texas (0.34)
Oregon (0.29)

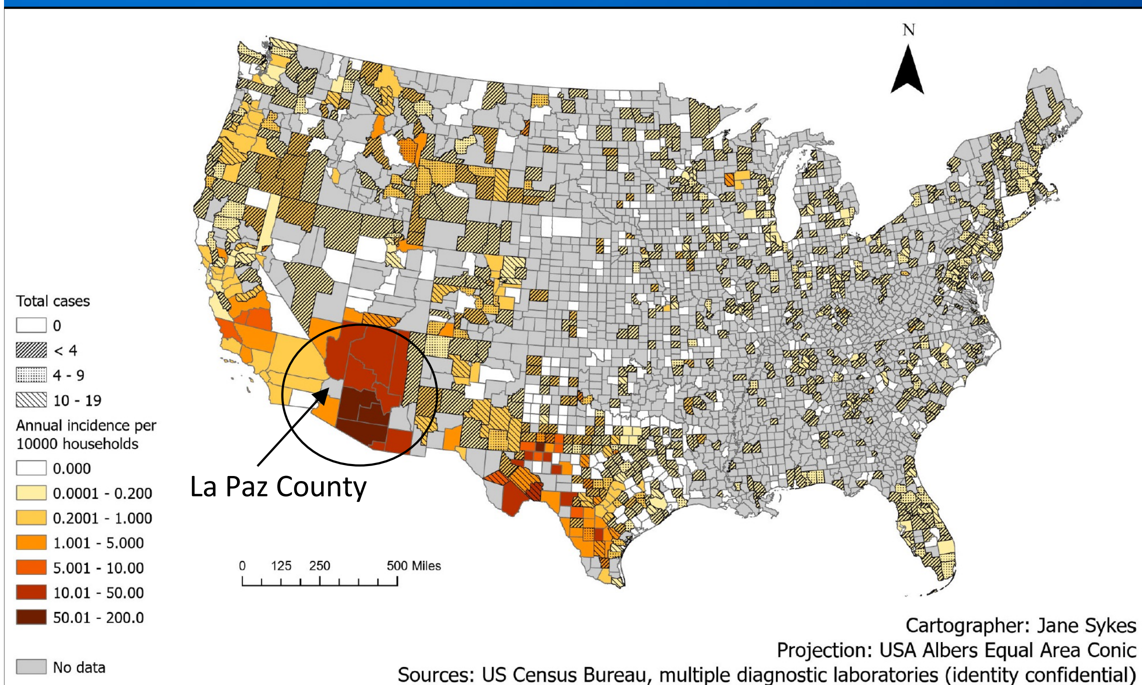
Colorado (0.26)
Washington (0.20)
Wyoming (0.19)
Idaho (0.17)

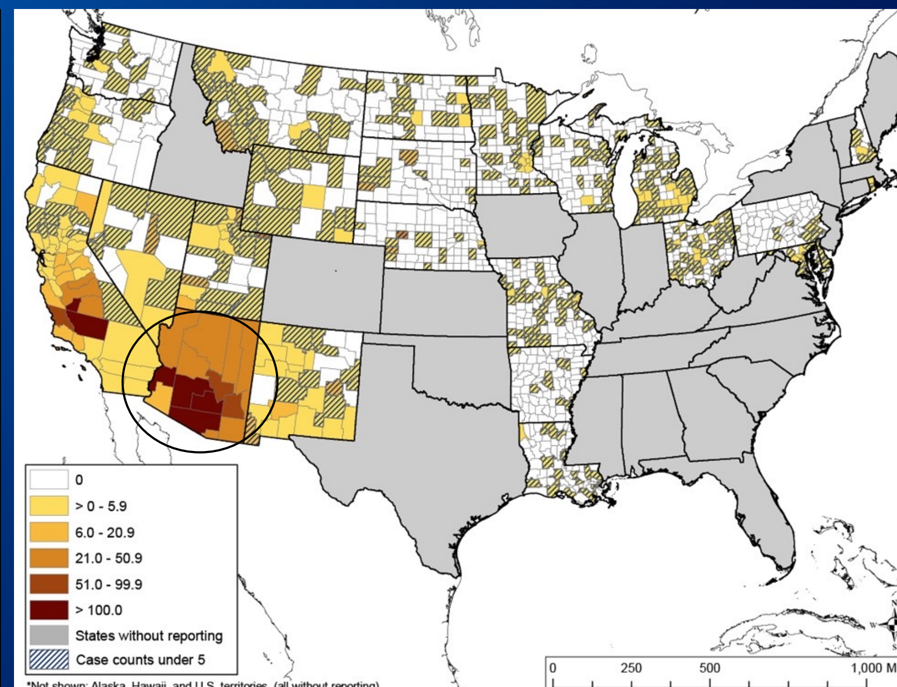
Remaining:
0.007 (AL) to 0.09 (KS)



Gautam et al. 2013

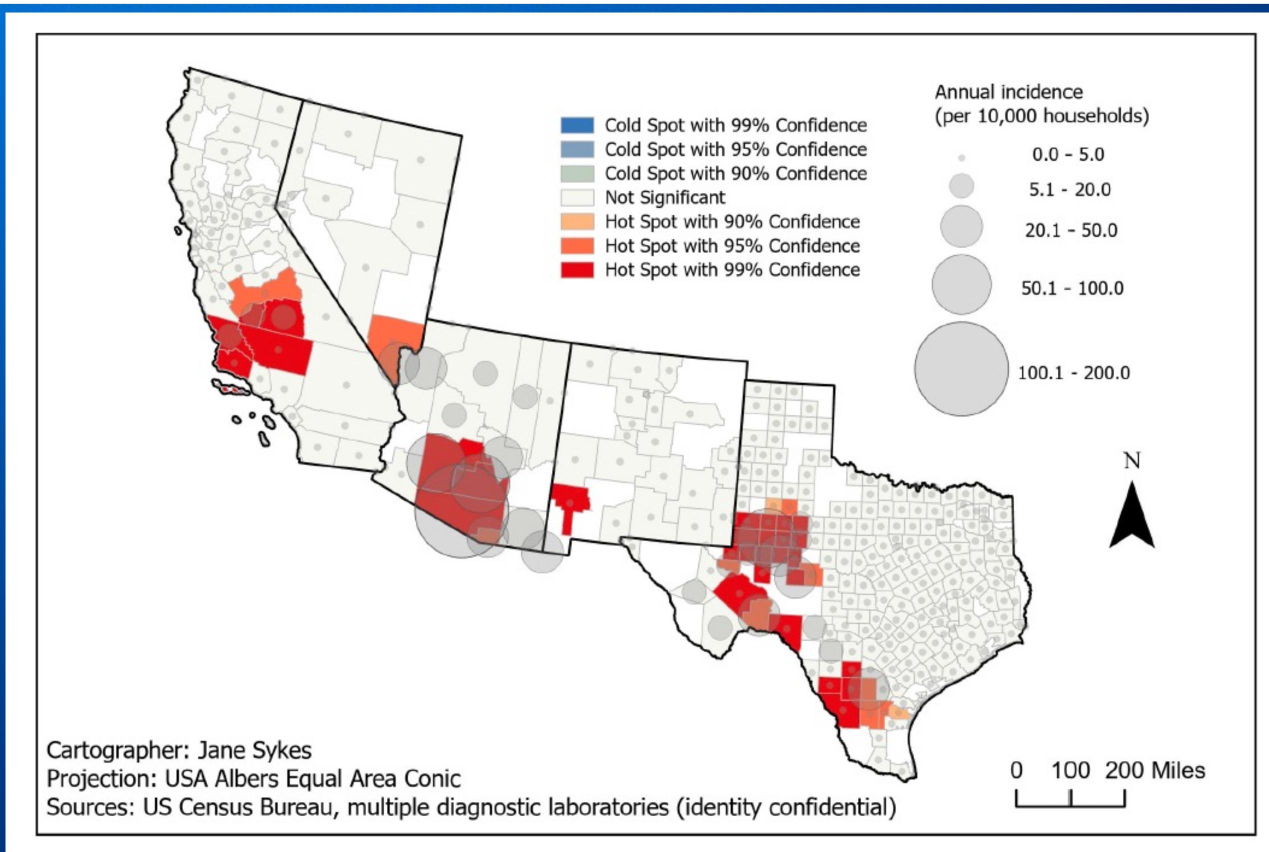
Results
Dog vs. Human Incidence Maps, 2012-2023





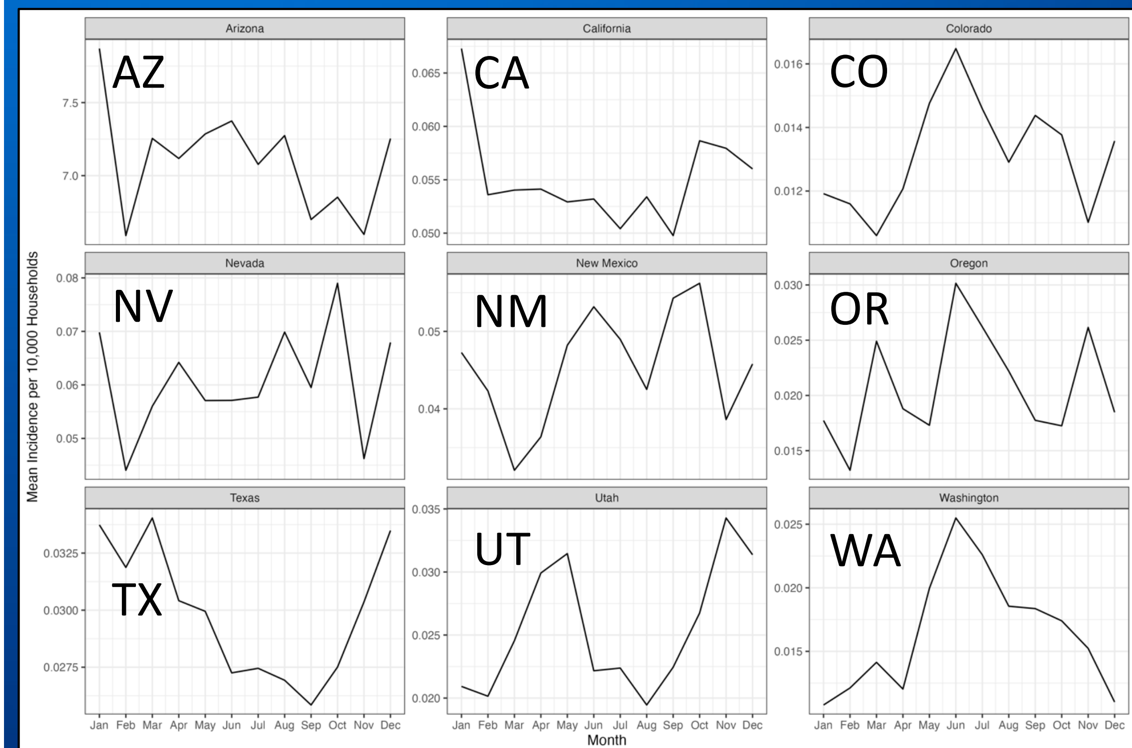
La Paz County population 16,557 (Maricopa 4.6 million)
Largest city, Parker, 3,417 people
Cases from Parker listed as Mohave county

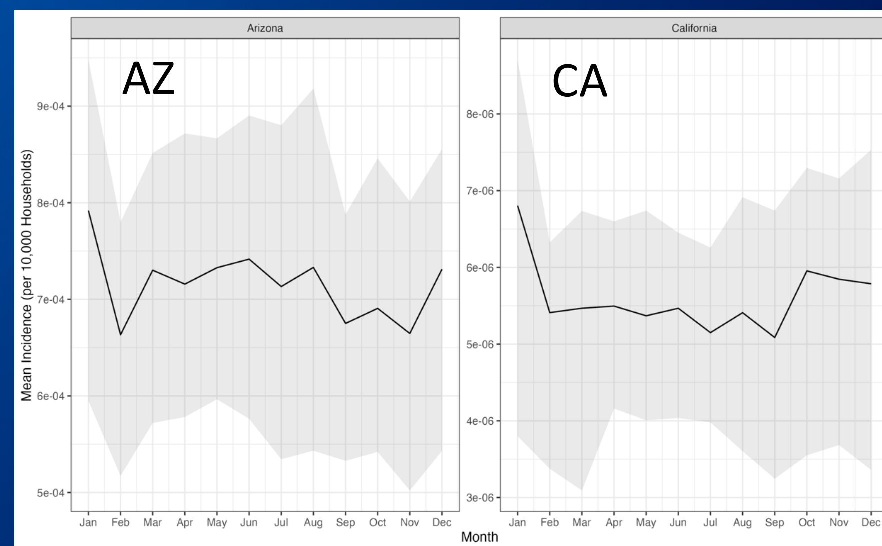
Results
Hot Spot Analysis, 2012-2023



Spatial autocorrelation (Moran’s I), $p < 0.0001$

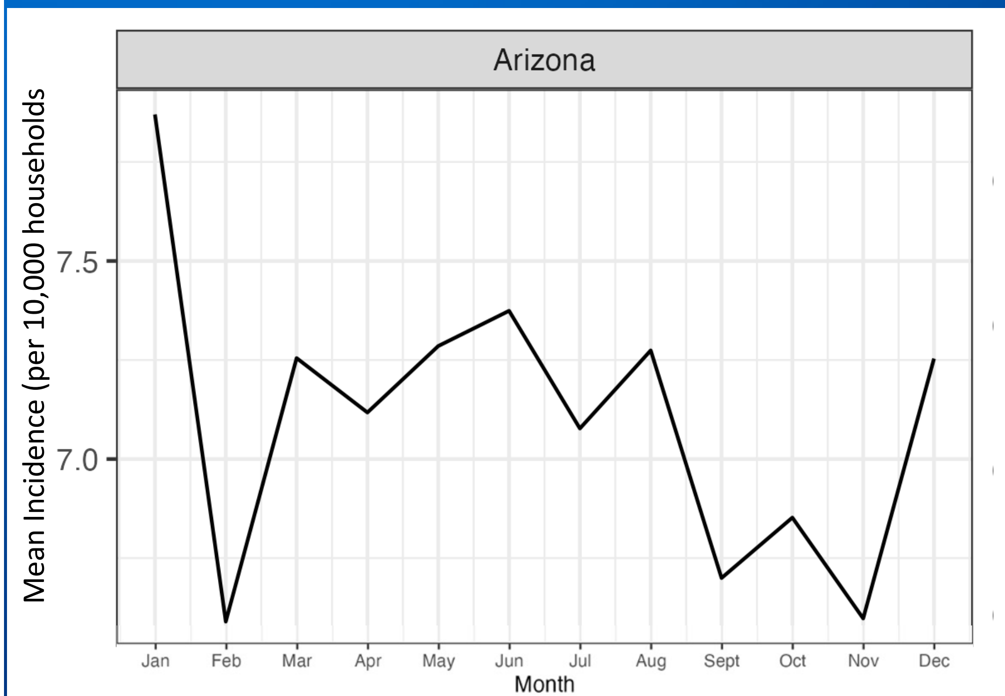
Results
Seasonal Incidence Curves, 2012-2023

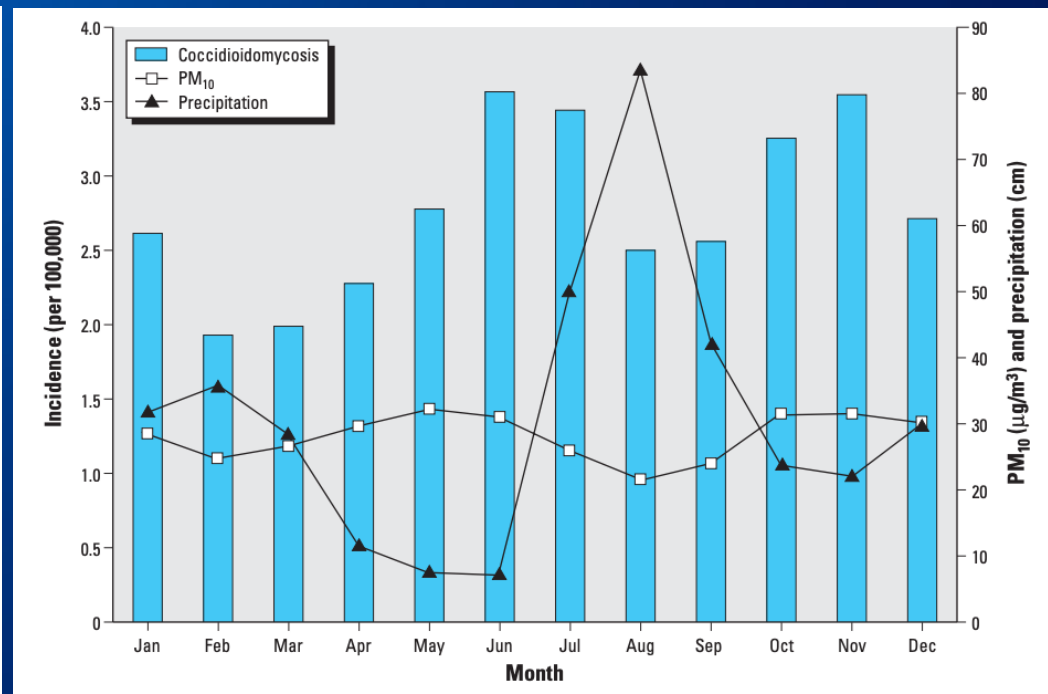




AZ and CA shown with interquartile ranges
Wide variation in annual incidence

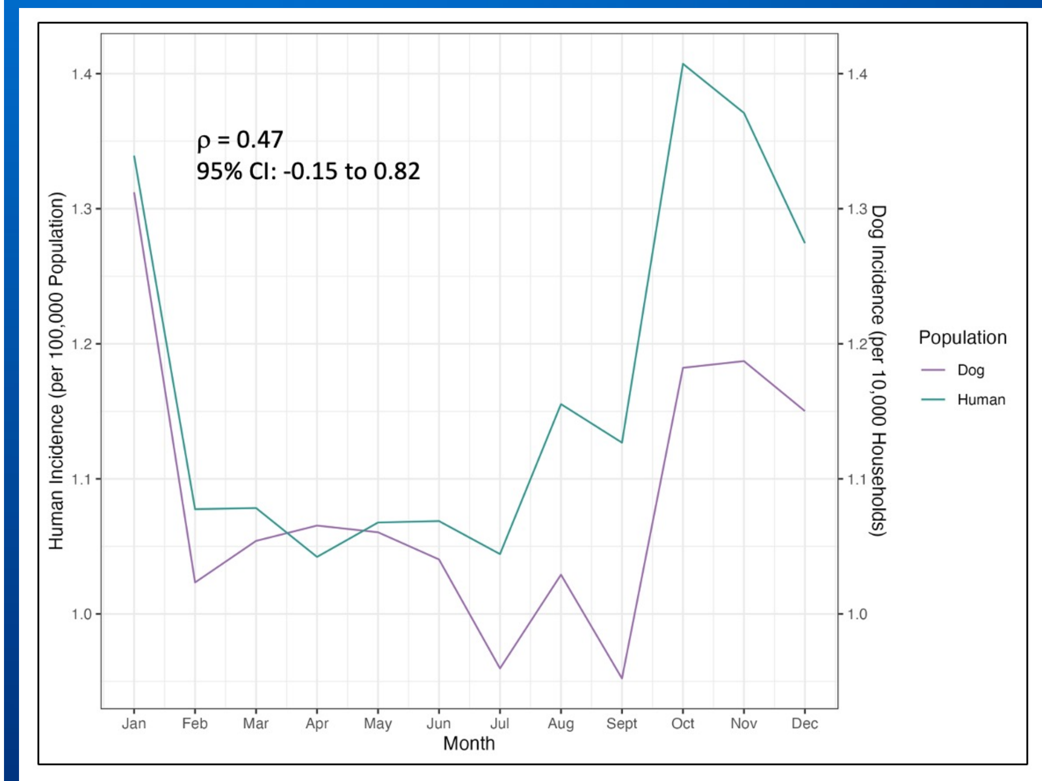
Results
Seasonal Incidence Curves Dog vs Human, AZ

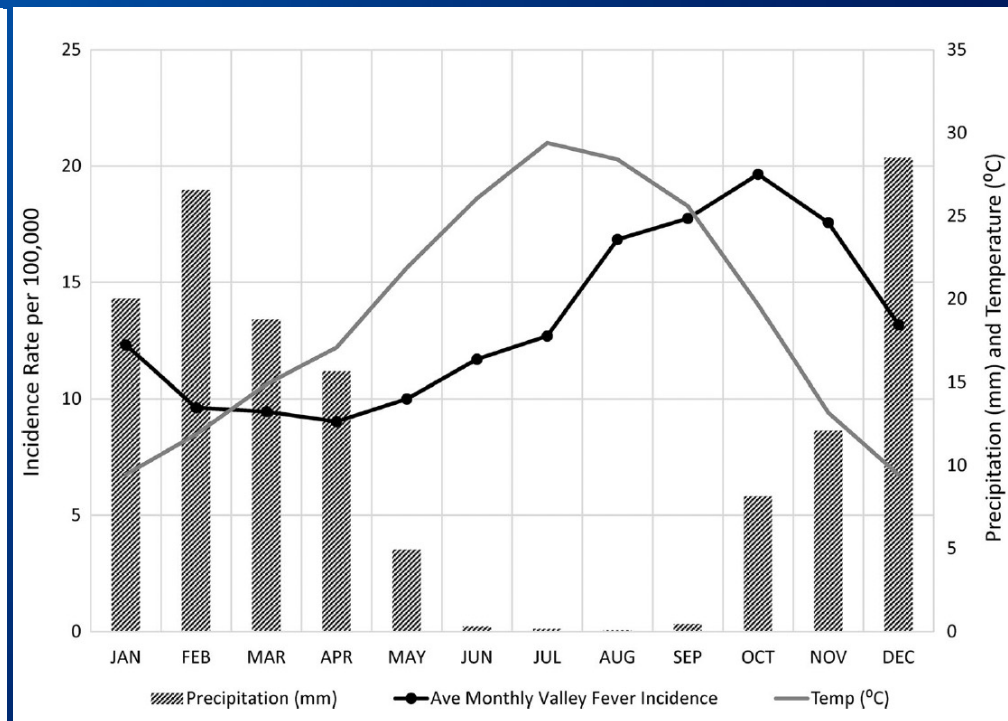




Comrie et al. Environ Health Perspect 2005;113:688-692 (ref 5)

Results
Seasonal Incidence Curves Dog vs Human, AZ





Weaver and Kolivras. Ecohealth 2018;15:840-852 (ref 6)

Conclusions

- Capture and analysis of almost all serologic test results
- High overall prevalence of seroreactivity
- Test numbers and % counties testing increased between 2012 and 2023
- Signalment risk factors
  - Medium and large dogs
  - Small breed protective, except terriers
  - Specific breed predispositions
  - Age 1 to 8 years
  - Intact female status protective
  - Highlight value of dogs as model

Conclusions

- Dog incidence and spatial data correlated with human data
  - Including hot spots in CA, TX, AZ, NM, NV
- Incidence in AZ at least 80 to 100-fold greater than other states
- Possible fungal presence in new regions in OR, WA, ID, MT, CO, TX
- Increased incidence in existing regions
  - Climate niche model may be an underestimate
- Monthly incidence curves followed precipitation patterns

Limitations

- Dogs are not humans
- Dog travel
- All cases not captured
  - Especially 2012 and 2023
- Spatial and temporal variations in dog ownership
  - Imperfect denominator
- Incubation period in dogs vs. humans?
  - 'lag' effect
- Variability in location granularity
- Inter-laboratory variation in test results
- Effect of increased testing
- Predictive value of positive test results

Next Steps

- Further spatiotemporal analysis (R and ArcGIS Pro), lag model
  - Temperature, precipitation, drought cycling, soil pH, soil moisture, dust exposure
  - Land cover/land use
  - Zip code level studies
- Incorporation of AVMA pet ownership data
- Spatial interpolation studies
  - Predictive model incorporating climate and dog data
- Active surveillance efforts in new emerging regions
  - Non-traveled dogs

MPH Applied Practice Experience
Foundational Competency Attainment

MPH Foundational Competency		Description
2	Select quantitative and qualitative data collection methods appropriate for a given public health context	Gathered signalment information and serologic test data for 10-year period with sufficient spatial and seasonal granularity to identify how dog data might inform public health decision making
3	Analyze quantitative and qualitative data using biostatistics, informatics, computer-based programming and software	Used Excel, Graphpad Prism, and ArcGIS Pro to perform statistics and map distribution of *Coccidioides* seroreactivity in dogs. Analyzed spatial and temporal distribution of *Coccidioides* exposure in dogs and made comparisons to findings in humans
4	Interpret results of data analysis for public health research, policy, or practice	Interpreted results considering previous studies on risk factors and predicted spread of coccidioidomycosis. Made conclusions regarding how results could influence future modelling strategies, public health policy (reporting procedures), and public health practice (increased awareness/education, environmental controls and PPE, vaccination)
19	Communicate audience-appropriate public health content, in writing and through oral presentation	Wrote abstract, draft manuscript, ILE report; delivered oral presentations to communicate study findings and implications to public health professionals, academics, and industry members
21	Perform effectively on interprofessional teams	Engaged a multidisciplinary collaborative team (epidemiologists, veterinarians, physicians, public health professionals, statisticians, geographers, laboratory diagnosticians) to gather and analyze data using state-of-the-art technology

MPH Applied Practice Experience
Emphasis Area Competency Attainment

MPH Emphasis Area Competency		**Description**
1	Pathogens/pathogenic mechanisms	In-depth understanding of causative agents of coccidioidomycosis and pathogenesis of infection
2	Host response to pathogens/immunology	Understanding of host factors that influence susceptibility to coccidioidomycosis, especially hormonal, genetic, and immunologic (e.g., HIV, transplantation, age); influences of host immunity on serologic test results; current status of vaccine development
3	Environmental/ecological influences	Understanding of “grow and blow” hypothesis, effects of climate variables and dust exposure on incidence, rodent activity, animal movement
4	Disease surveillance	Understanding of disease risk factors (occupational/racial, sex, age, immune status), current surveillance methods at state and national levels and limitations of surveillance, made recommendations for reporting of dog serologic data
5	Disease vectors	Understanding of the role of rodents as disseminators of *Coccidioides* spp., association between environmental pollutants such as fine particulate matter and disease outbreaks, and influence of immunosuppressive and antineoplastic drugs on immune response to *Coccidioides* spp.

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Antech Laboratories
Kelly Crucillo and Allen Bryan at UC Davis Cocci Serology Laboratory
Protatek Laboratory
MiraVista Diagnostic Laboratory

CDPH: Gail Sondermeyer-Cooksey

UC Berkeley: Simon Campo, Amanda Weaver, Jennifer Head, Justin Remais

Kansas State University: Ellyn Mulcahy, Hélène Avocat, Zach Mills, Christopher Carter, Amelia Brady, Rebecca Burks

UC Davis: GR Thompson, Beatriz Martinez-Lopez, Kristen Aiemjoy


Questions

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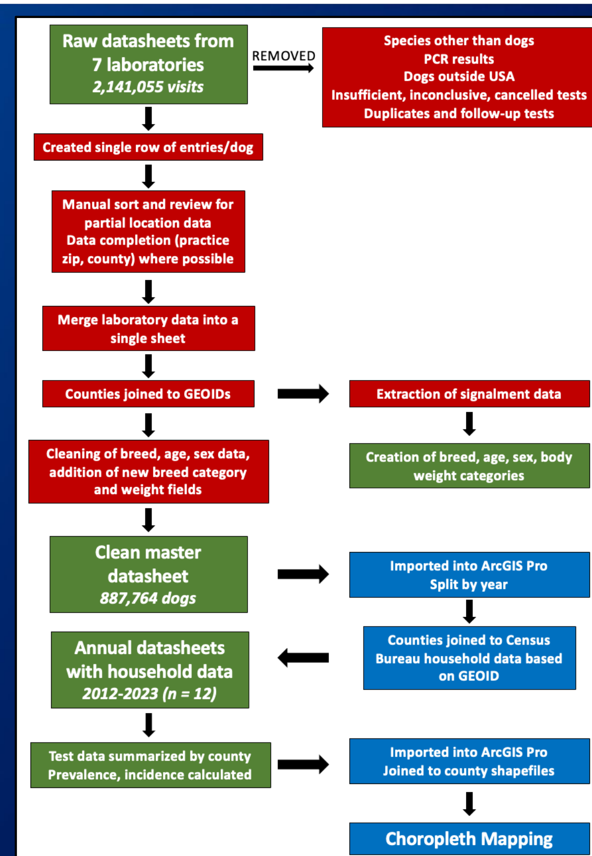
MPH Applied Practice Experience
Products

- Master and cleaned datasheets
- Over 40 ArcGIS Pro-generated maps
- Test positivity and incidence curves
- Conference abstract
- Applied Practice Experience and Integrated Learning Experience reports
- Paper for submission to Lancet Planetary Health (in preparation)
- Oral presentations
  - Remais-Barker collaborative research group (July 11 2023, one hour)
  - Anivive Life Sciences and University of Arizona Center for Valley Fever (August 21 2023, 30 minutes)
  - American Veterinary Medical Association leadership and data scientists (August 28 2023, 30 minutes)
  - Centers for Disease Control and Prevention endemic mycoses group quarterly meeting for state partners (October 24 2023, 48 nationwide public health participants)
  - Final defense presentation

Methods
Statistical Analysis

- Inter-annual and monthly/seasonal incidence
  - Compared with human data for AZ and CA
    - CA Department of Public Health (monthly county-level) and CA Department of Finance
    - AZ Department of Health Services (annual county-level; dog data aggregated)
    - Pearson's correlation coefficient (R)
- Spatial analysis (ArcGIS Pro, USA Albers Equal Area Conic)
  - Data joined with county shapefiles (US Census Bureau)
  - Choropleth mapping (tests, test positivity, incidence)
  - Spatial autocorrelation (Moran's I)
  - Hot spot analysis (Getis Ord-Gi*, fixed distance band method)



Results
Behavior Group Breed Analysis

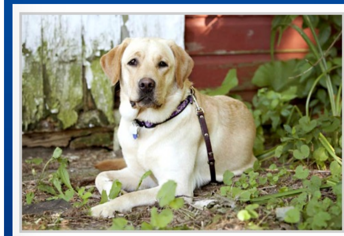
Breed	Number positive	Number negative	Test Positivity	OR (95% CI)	P value
Pointers	9432	8318	53.1%	1.91 (1.80 – 2.02)	< 0.0001
Bull Type Terriers	3458	3272	51.4%	1.78 (1.66 – 1.90)	< 0.0001
Parson Type Terriers	44	43	50.6%	1.72 (1.12 – 2.64)	0.01
Golden Retrievers	12103	12115	50.0%	1.68 (1.59 – 1.77)	< 0.0001
Primitive Sighthounds	2446	2698	47.6%	1.52 (1.42 – 1.64)	< 0.0001
Shetland sheepdog	432	1999	17.8%	0.36 (0.32 – 0.41)	< 0.0001
Japanese Chin	84	340	19.8%	0.41 (0.33 – 0.53)	< 0.0001
German Spitz Related Breeds	1861	6772	21.6%	0.46 (0.43 – 0.50)	< 0.0001
Miniature Pinscher	1060	3354	24.0%	0.53 (0.49 – 0.58)	< 0.0001
Teacup	15453	46692	24.9%	0.56 (0.53 – 0.59)	< 0.0001

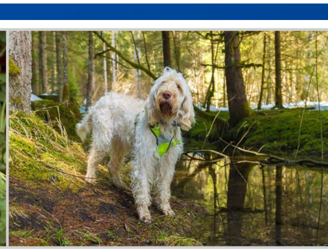
Reference group Jack Russell Terriers (2820/7562, prevalence 37.3%)

Results
AKC Breed Group Analysis

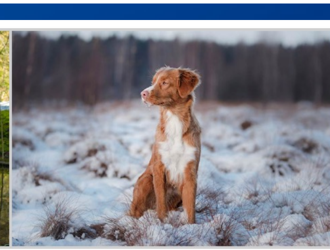
Breed Group	Number positive	Number negative	Test Positivity	OR (95% CI)	P value
Foundation Stock Service	1261	1536	45.1%	1.31 (1.22 – 1.41)	< 0.0001
Hound	16046	29931	34.9%	0.86 (0.84 – 0.88)	< 0.0001
Miscellaneous	1852	228	34.7%	0.85 (0.68 – 1.06)	0.14
Mix Breed	40384	53543	43.0%	1.20 (1.18 – 1.23)	< 0.0001
Non-Sporting	20204	40665	33.2%	0.79 (0.78 – 0.81)	< 0.0001
Sporting	53850	66193	44.9%	1.30 (1.28 – 1.32)	< 0.0001
Terrier	27265	38964	41.2%	1.12 (1.09 – 1.14)	< 0.0001
Toy	30461	93440	24.6%	0.52 (0.51 – 0.53)	< 0.0001
Working	36220	48352	42.8%	1.20 (1.17 – 1.22)	< 0.0001

Reference group Herding group (32080/83291, prevalence 38.5%)



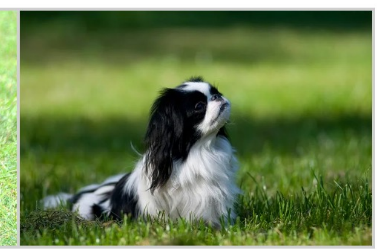


Spinone Italiano



Nova Scotia Duck Tolling Retriever

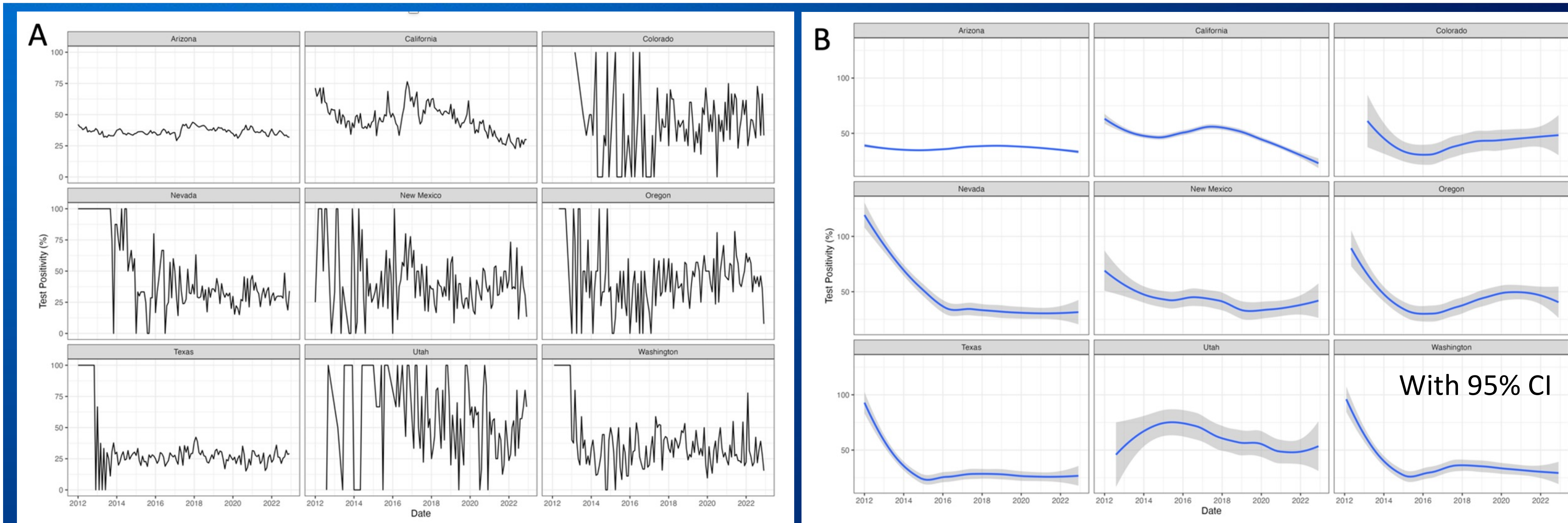
Affenpinscher



Japanese Chin

Results

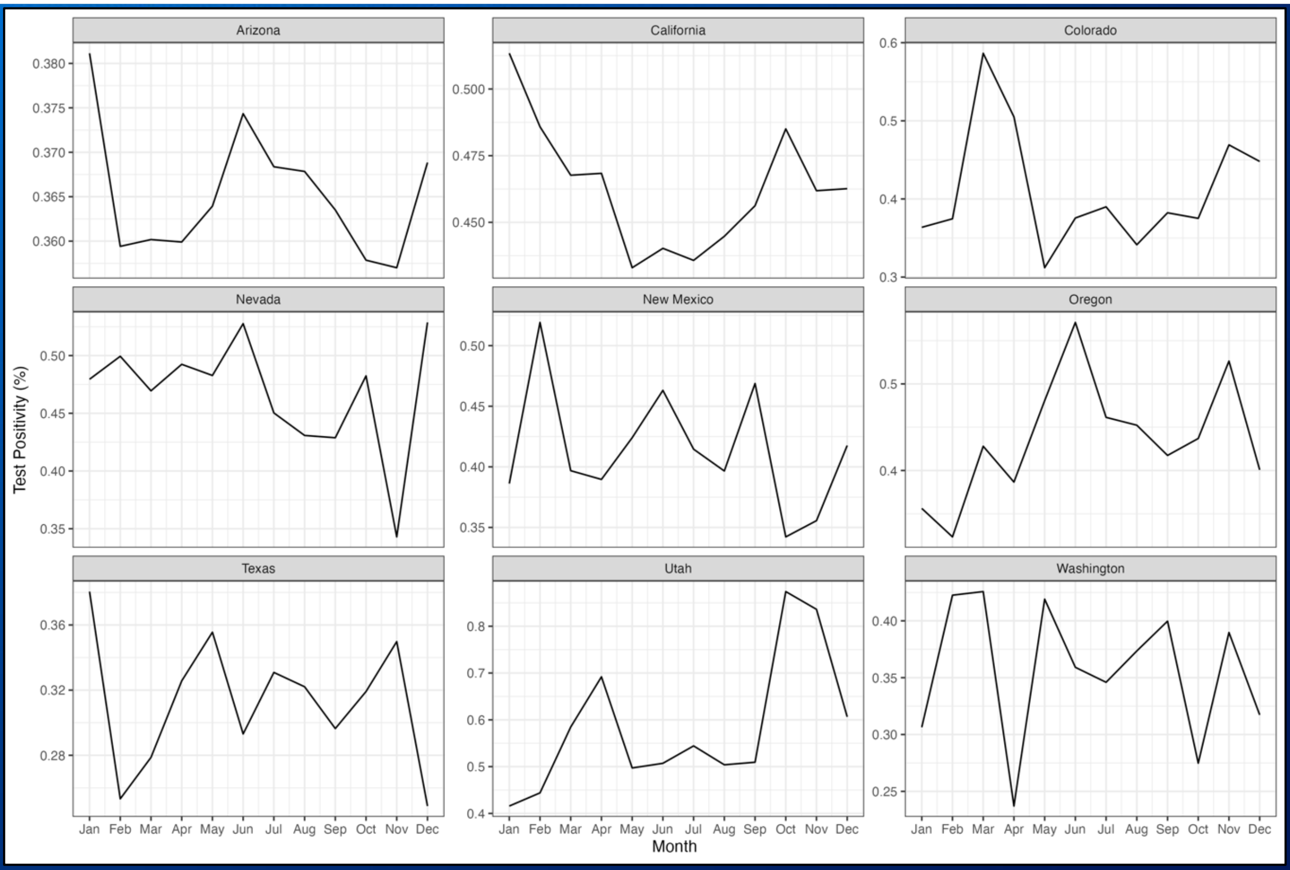
Raw and Smoothed Test Positivity Curves, 2012-2023



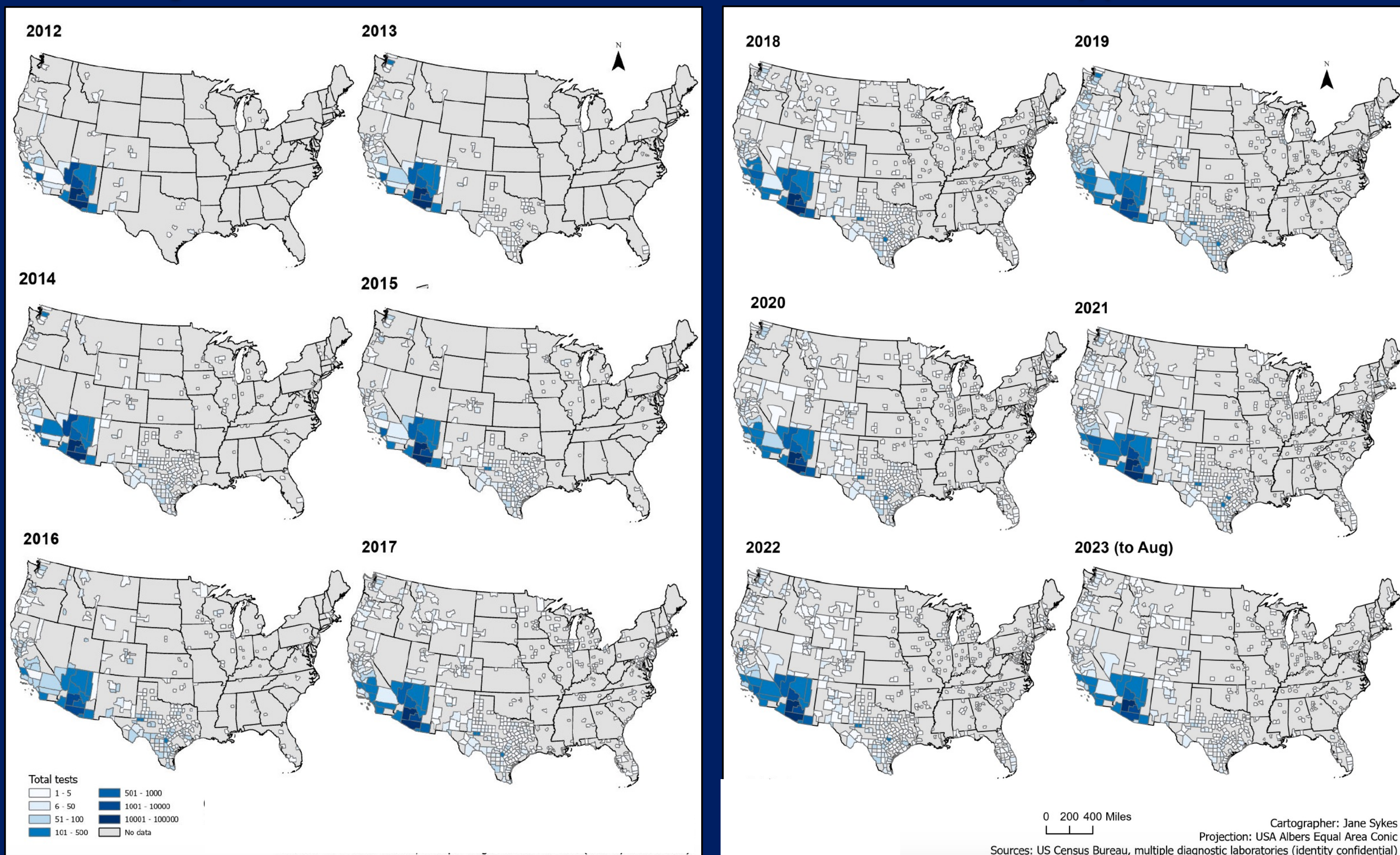
Test positivity stable in AZ (mean 35%), declining in CA since 2018 (75% to 25%), mean 50%

Results

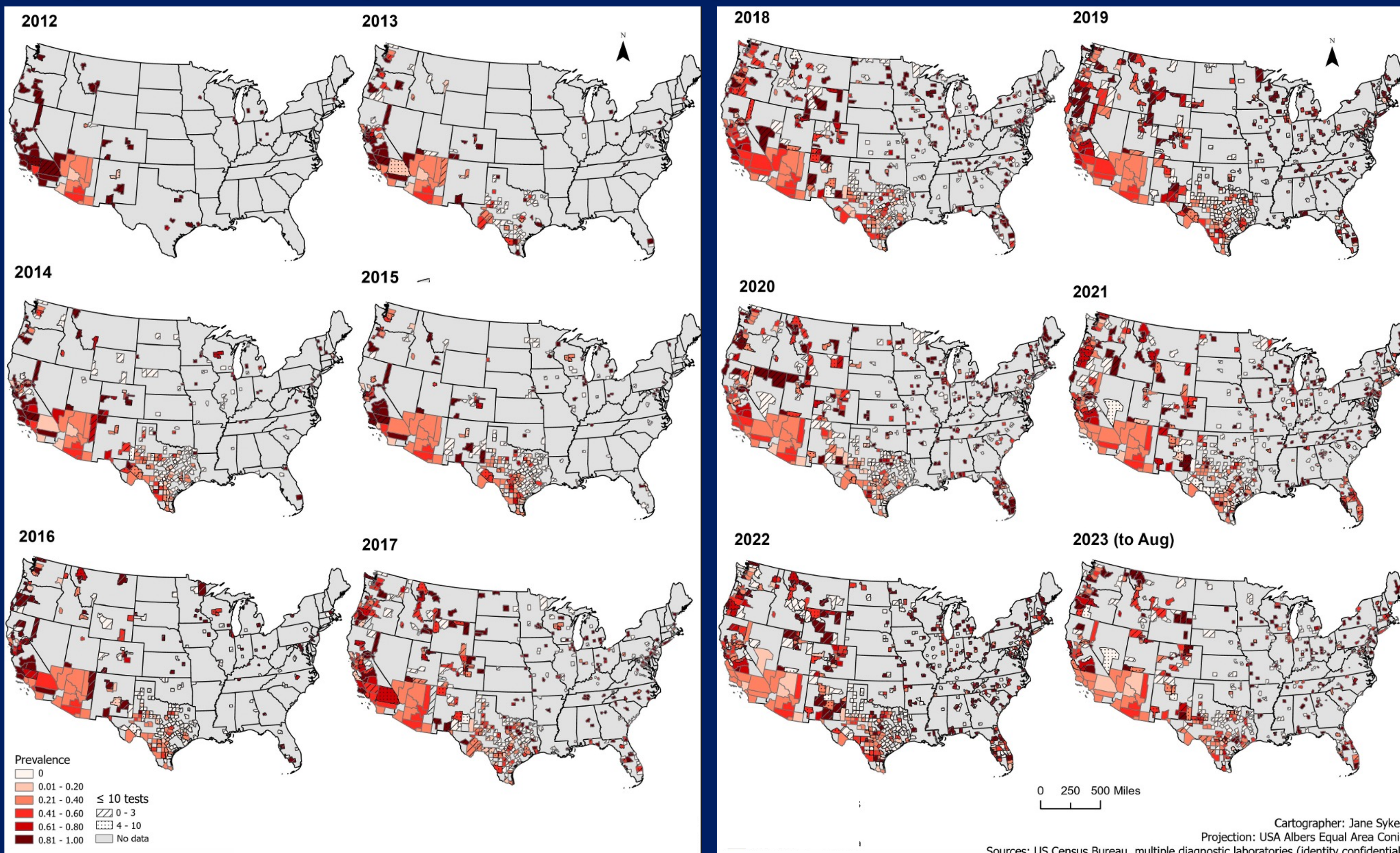
Seasonal Test Positivity Curves, 2012-2023



County Total Tests for Antibodies to *Coccidioides* spp., 2012-2023



County Test Positivity of Seroreactivity to *Coccidioides* spp., 2012-2023



County Incidence of Seroreactivity to *Coccidioides* spp., 2012-2023