Spotted Fever Rickettsiosis Dynamics in the United States

Murphy John, Undergraduate Student, Department of Mathematics and Statistics, University of New Mexico
Yan Lin, Ph.D., Department of Geography and Environmental Studies, University of New Mexico

Abstract

Spotted Fever Rickettsiosis (SFR) refers to a group of tick-borne diseases caused by Rickettsia bacteria. Over the past two decades, there has been a significant surge in SFR cases, rising from 495 reported cases in 2000 to a peak of 6,248 in 2017. A significant concentration of SFR is observed in the southeastern United States, with five states contributing to more than 50% of reported instances. The high prevalence of SFR in these states has led to a scarcity of research on cases occurring in other regions of the United States as well as the spatio-temporal pattern of the burden. To bridge this gap, this study leveraged comprehensive social vulnerability index, healthcare shortage, and environmental data from all U.S. counties between 2016 and 2019. To investigate the impact of canine hosts in the prevalence of SFR, this study incorporates veterinary accessibility and dog population data. Utilizing advanced spatial analysis techniques, this project characterized SFR geographical patterns and identified contributing factors. This research also identified and analyzed high-incidence SFR areas, offering crucial insights for public health officials. These findings have potential to inform targeted interventions in high-risk areas, aiding in the effective mitigation of SFR transmission.

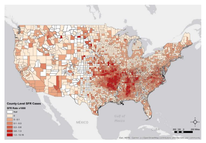
Research Scope

To examine contributing factors of Spotted Fever Rickettsiosis in the contiguous United States.

To characterize geographic patterns of Spotted Fever Rickettsiosis using spatial cluster detection analysis.

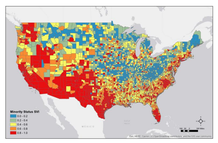
Data

SFR Rates (2016-2019)



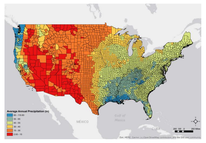
Source: Centers for Disease Control and Prevention National Center for Emerging and Zoonotic Infectious Diseases Division of Vector-Borne Diseases

Minority Status Social Vulnerability Index (SVI) (2020)



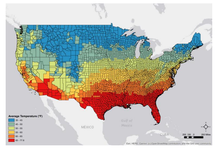
Source: Centers for Disease Control and Prevention Agency for Toxic Substances and Disease Registry

Average Annual Precipitation (2016-2019)



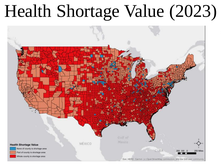
Source: National Centers for Environmental Information

Average Temperature (2016-2019)



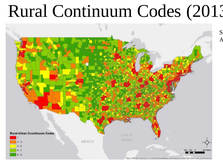
Source: National Centers for Environmental Information

Health Shortage Value (2023)



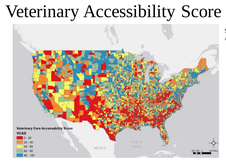
Source: Rural Health Information Hub

Rural Continuum Codes (2013)



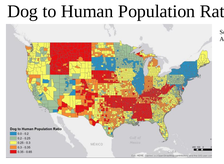
Source: U.S. Department of Agriculture

Veterinary Accessibility Score (2022)



Source: The Veterinary Care Accessibility Project

Dog to Human Population Ratio (2022)



Source: The Veterinary Care Accessibility Project

Methodology

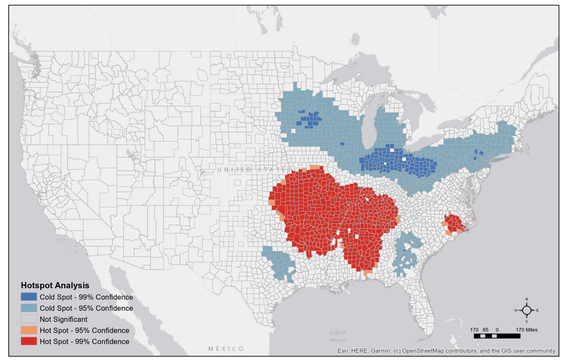
A linear regression model was built to examine the county-level association between SFR rate (dependent variable) and all other variables (independent variables): Socioeconomic Status Social Vulnerability Index (SVI), Household Characteristics SVI, Minority Status SVI, Housing Type and Transportation SVI, Average Temperature, Average Annual Precipitation, Healthcare Shortage Value, Rural-Urban Continuum Codes, Veterinary Care Accessibility Score, and Dog to Human Population Ratio. To detect whether multicollinearity exists in the regression model, variance inflation factor (VIF) was calculated. Variables with a VIF higher than 5.0 were removed from the regression model. The remaining variables were: Minority Status SVI, Average Temperature, Average Precipitation, Rural-Urban Continuum Codes, Veterinary Care Accessibility Score, and Dog to Human Population Ratio. Global spatial autocorrelation test and local Hot Spot Analysis (Getis-Ord Gi*) was conducted for SFR rates. Due to the significant spatial autocorrelation in SFR rates, spatial regression was conducted.

Regression Analysis

Table 1: Regression Analysis Results

	Estimate	SE	P value
Intercept	-0.6436	0.115	0.000
Minority Status SVI	-0.3349	0.054	0.000
Average Temperature	0.0084	0.002	0.000
Average Precipitation	0.0048	0.001	0.000
Rural-Urban Continuum Codes	0.0184	0.006	0.001
Veterinary Care Accessibility Score	-0.0015	0.000	0.002
Dog to Human Population Ratio	1.0960	0.168	0.000
R-squared	0.104		
AIC	5002		

Hot Spot Analysis



Moran's I: 0.3158	P value: 0.000

Table 2: Hot Spot Descriptive Statistics

	Mean	Minimum	Median	Maximum	Standard Deviation
SFR Rate (x1000)	0.817	0.0	0.393	13.188	1.261
Minority Status SVI	0.413	0.014	0.399	0.966	0.252
Average Temperature	60.008	52.7	59.6	67.3	3.155
Average Precipitation	53.686	36.15	55.14	67.52	7.276
Health Shortage Value	1.823	0	2	2	0.435
Rural-Urban Continuum Codes	5.181	1	6	9	2.555
Veterinary Care Accessibility Score	38.426	0.798	33.490	99.809	25.511
Dog to Human Population Ratio	0.348	0.170	0.355	0.475	0.0625

Table 3: Cold Spot Descriptive Statistics

	Mean	Minimum	Median	Maximum	Standard Deviation
SFR Rate (x1000)	0.017	0.0	0.0	0.496	0.043
Minority Status SVI	0.442	0.0003	0.408	0.997	0.277
Average Temperature	52.247	41.4	51.2	69.9	6.715
Average Precipitation	44.289	27.19	44.41	65.6	5.685
Health Shortage Value	1.342	0	1	2	0.6243
Rural-Urban Continuum Codes	4.158	1	4	9	2.4056
Veterinary Care Accessibility Score	53.488	0.665	55.512	100	28.191
Dog to Human Population Ratio	0.252	0.126	0.254	0.411	0.060

Spatial Lag Regression

Table 4: Spatial Lag Regression Results

	Estimate	SE	P value
Weight	0.631	0.018	0.000
Intercept	-0.225	0.094	0.016
Minority Status SVI	-0.189	0.044	0.000
Average Temperature	0.004	0.002	0.012
Average Precipitation	0.002	0.001	0.045
Rural-Urban Continuum Codes	0.010	0.005	0.026
Veterinary Care Accessibility Score	-0.001	0.000	0.016
Dog to Human Population Ratio	0.350	0.137	0.012
R-squared	0.407		
AIC	4086.79		

Discussion

Nation-wide Analysis
On the nation-wide scale, Temperature, Precipitation, Rural-Urban Continuum Codes, and Dog to Human Population Ratio have significant positive correlations with SFR Rate. That is, as these variables increase, the SFR Rate increases. Note that an increase in Rural-Urban Code is interpreted as a more rural area. Conversely, the variables Minority Status SVI and Veterinary Care Accessibility Score have significant negative correlations with SFR Rate on the nation-wide scale. This means as these variables decrease, the SFR Rate increases. Notably, a decrease in Minority Status SVI implies fewer individuals identifying with minority groups. A decrease in Veterinary Accessibility Score implies less access to veterinary care.

Hot Spot Analysis
Hot Spots are where features with high values of SFR Rates cluster spatially. The Hot Spots in this analysis are located in the southeastern United States. These areas have increased Temperature, Precipitation, Health Shortage Value, Rural-Urban Continuum Codes, and Dog to Human Population Ratios. Note that increased Health Shortage Value is interpreted as lack of access to healthcare. The Cold Spot areas are where low values of SFR Rate cluster spatially. These areas are identified predominately in the northeastern United States but small Cold Spots are found in the southeast. They are characterized by increased Minority Status SVI and Veterinary Accessibility Score.

Conclusions
Decreased Minority Status (smaller minority population) is consistently associated with increased SFR Rates. This is hypothesized to be a result of the location of ticks being in more rural areas. This hypothesis is further supported by the positive association between Rural-Urban Codes (more rural areas) and SFR Rate. The role of canine hosts is apparent by the association of Veterinary Accessibility Score and Dog Population Ratio variables. As Veterinary Accessibility decreases, SFR rate increases. As Dog population Ratio increased (more dog population) SFR Rate increases. The Spatial Lag Model produces similar associations as the Regression Model but the inclusion of a spatial lag term improves the R-squared and AIC values. This emphasizes the importance of a spatial indicator in a model of SFR Rates.

Future Work

Further investigation is warranted to understand the nationwide correlations between environmental factors, socio-economic indicators, and SFR Rates. Additionally, expanding the hot spot analysis could provide insights into localized patterns and aid in the development of targeted interventions to mitigate SFR Rates in high-risk areas. A closer look at the role of canine hosts in the spatial distribution of SFR Rates is also suggested. Understanding how these factors influence SFR Rates can inform targeted interventions aimed at controlling the spread of tick-borne diseases.

Acknowledgements

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