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Statistical Analysis of Rabies Submissions in Kentucky and Weather as a Potential Predictor of Positive Cases

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Wayne Sanderson, PhD, Committee Chair

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Statistical Analysis of Rabies Submissions in Kentucky and Weather as a Potential Predictor of Positive Cases

Capstone Project Paper

A paper submitted in partial fulfillment of the
requirements for the degree of
Master of Public Health
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Abstract

Background

The rabies virus is a zoonotic pathogen that is nearly 100 percent fatal once symptoms occur. Because it is still active in wildlife populations in Kentucky, the need for preventive measures and surveillance is critical. Temperature and precipitation have been shown to affect rabies. This study examined rabies submissions in Kentucky, weather and geographical distribution to both describe and predict cases.

Methods

Data from the University of Kentucky Veterinary Diagnostics laboratory were used to assess rabies submissions from 2005 through 2015. These submissions were anonymously submitted by the public and the Florescent Antibody Test was used to determine infection status. Submissions were totaled across years to interpret distribution over time. The rate of positive submissions over total submissions by county was used to evaluate where rabies occurred in Kentucky. Next, maps were made to assess distribution geographically. Fisher's exact test was used to determine differences between climate regions. Linear regression was used to examine the association between climate region data and positive rates of submissions.

Results

Yearly distribution of submissions was fairly stable with a spike of both submissions and positive results for the years 2008-2009. Fisher's Exact test revealed significant differences between climate region. Post-hoc analysis showed a non-significant difference between the northern region of Kentucky compared to other regions. Maps

of distribution of positive rates showed a belt of activity in southern Kentucky. A warmer observed regional temperature was a statistically significant predictor of positive rates of rabies submissions in linear regression models for all species as well as bats when considered separately. However, this increase was exceptionally small and provided little clinical significance.

Conclusion

Rabies in Kentucky is still active. While the majority of submissions come from the northern parts of the state, the southern portion of Kentucky has a higher proportion of positive submissions. Based on the results of this study, temperature should be considered when trying to predict future cases of rabies in Kentucky. More research using additional predictors could help establish a stronger relationship.

Introduction

The rabies virus is a zoonotic pathogen that is nearly 100 percent fatal once symptoms occur.[1] A member of the *Lyssavirus* genus, this RNA virus can infect all mammals and accounts for the deaths of approximately 59,000 people per year globally.[1] Rabies is still active in the United States, with 5.5 percent of animals tested for rabies being found positive in 2015. Of these cases, 92.4 percent came from wildlife populations. [1]

Because rabies is still active in wildlife populations, the need for preventive measures and surveillance is critical. Kentucky borders several states that are targeted using the Oral Rabies Vaccine zones, making the state part of the vanguard for potential exposure to rabies in the eastern United States. Current knowledge of state specific statistics is especially crucial for doctors and veterinarians who need to make informed decisions in cases where exposure might have occurred. Onset of the disease can occur in as little as a week of exposure.[2] When limited time is available to assess these cases, physicians and wildlife management face the problem of having to wade through large sets of information to find data that might be relevant to their situation.

While estimates in Kentucky are lower than the national average due to surveillance and vaccination prevention strategies, the primary data on rabies submissions from the Kentucky Department of Public Health had not been published or used as a resource to understand the disease within the state. There is a substantial gap

in the scientific literature on the distribution of rabies as well as risk factors and protective factors for Kentucky.

Previously studied risk factors for rabies include the percentage of farmland, rurality, and demographics.[3] Rabies infection also has a seasonality pattern and could benefit from a model that incorporates previously assessed predictors and weather. Heat and precipitation could influence the behavior of both animals and people in regard to exposure. Additionally, rabies transmission can be affected by how infected fluids enter the body. Prevention with suspected bites outside of Post Exposure Prophylaxis (PEP) includes cleaning the wound because washing away the virus can prevent infection.[2]

The goals of this study were to describe the rates of rabies submissions, assess rabies trends, and identify potential risk factors that can be used as predictors of the disease in Kentucky based on rabies submissions from the years 2005 through 2015.

LITERATURE REVIEW

This literature review is comprised of articles and journals that come from numerous health organizations. Database searches were conducted using resources such as PubMed and the American Veterinary Medicine Association. Keywords and phrases used in searches included rabies surveillance, rabies predictors, geographic predictors of rabies, rabies and weather, and rabies control. The purpose of this review is to gain an understanding of how the disease spreads, demonstrate the need in the

literature for descriptive studies of rabies in Kentucky, and evaluate the possible influence of weather on the rabies virus.

General Characteristics of Rabies

Rabies is caused by the RNA rhabdovirus which stems from the genus Lyssavirus. There are at least 6 different serotypes that have been identified.[2] The virus accounts for the deaths of approximately 59,000 people per year globally.[1] Transmission occurs when saliva infected with the virus comes in contact with broken skin or the mucus membrane. This usually occurs from bites, but transmission can also from scratches, secretions and occasionally inhalation of aerosolized virus.[2] After the host is contaminated, the virus slowly begins to replicate and spread through nerve tissue until it reaches the brain.[2] Once the virus infects the brain, clinical signs begin to appear, and prevention is no longer effective. Carnivorous mammals and bats are seen as the most common reservoirs of the virus; however, all mammals can potentially develop and transmit rabies.[4]

Characteristics of Rabies in the United States

In the United States, 91.6% of animals reported to be rabid were from wildlife populations for 2012 and 92.4% of reported animals were from wildlife populations in 2015.[1,5] Seasonality trends in wildlife populations have been reported and are relatively consistent throughout the years.[5] Reported cases of both rabid raccoons and skunks tend to peak in March with a moderate second peak around August. Reports of rabid bats tend to peak primarily in August.[5]

Raccoon variant rabies can be found along the east coast of North America. In order to create a barrier preventing the spread of raccoon rabies, oral rabies vaccination (ORV) zones were established in strategic locations.[6] ORV collaborations have been set up across multiple states and Canadian territories and ORV is currently used as a primary method of impeding raccoon variant rabies distribution.[7] Because of these vaccine zones and the natural barriers of the Appalachian mountains, raccoon variant rabies is currently not present in Kentucky.

Rabies in Kentucky

Despite the lack of raccoon-variant rabies, Kentucky still has active rabies cases. The state's percentage of positive cases within the wildlife population is estimated to be 2% with the primary reservoirs being bat and skunk populations.[1,8] While rabies is described at the national level on nearly a yearly basis, relatively few studies have done any analysis on rabies specific to Kentucky.[1,9] One of the most recent studies conducted in 1999 that looked at applying a geospatial filter to help improve rabies surveillance.[10] The only other main additions to the literature regarding rabies specifically in Kentucky during this nearly 20-year stretch includes an article describing the diagnosis of a human case of rabies that happened to be in Kentucky and an article describing risk assessment for a group of volunteers who had been exposed to bats.[8,11] There is a substantial gap in the literature for current evaluations of rabies in Kentucky.

Predicting Models for Rabies

Predictive approaches for raccoon rabies have included population level models such as simple epidemic models that assess rabies given a uniform mixing of populations

and multi-host deterministic models that account for cross-species interactions.[12] Additionally, spatial analyses that look at natural and man-made barriers such as roads, rivers, mountains and vaccine drops have been used to determine how landscapes shape rabies outcomes.[12] Other models have used seasonality based on life patterns of hosts.[12] Research on big brown bats found that cyclical birth and death rates had an impact on rabies trends across time.[13]

Temperature and Rabies

Additional concepts in the seasonal bat research note that bats are facultative heterotherms, meaning their body temperature decreases during hibernation. Because of this it is theorized that viral incubation rates are prolonged during the winter months.[13] Experiments on Mexican free tailed bats injected with rabies virus that controlled for temperature found that bats that were placed in cold conditions were less likely to develop rabies than those in warmer conditions.[14] However, once these bats were transferred over to warmer conditions, the onset of rabies was quicker and viral levels in saliva were more pronounced.[14] Similar experiments on pallid bats revealed the same relationship of temperature on infection outcomes. Pallid bats placed in cooler environments showed negligible traces of the disease compared to those placed in warmer settings when they were injected with rabies strains.[15] They did mention the importance of the metabolic rate of these in addition to ambient temperature worked together. As experiments were undertaken during different seasons and metabolic rates adjusted, the incubation times for rabies also changed.[15]

In mice, experiments were conducted to see the effects of high ambient temperature through the different stages of rabies infection. Temperature did not effect the later stages of infection.[16] Conversely, high heat was found to be protective during the incubation of mice, delayed onset of signs, and was linked to decreased mortality. They hypothesized that based on these results, bodily temperature variation could impact the dynamics of infections, especially animals who hibernated such as skunks and bats.[16]

Precipitation and Rabies

A study of skunks in Arizona found that precipitation could be a predictor for rabies.[17] They looked at long-term trends of skunk breeding seasons and past rainfall to see how precipitation impacted disease outcomes. Models predicted that heavy rainy seasons few years prior to outbreaks were indicators of severity.[17] Their explanation of these results is that rain may have an impact on food supply which contributes to overall skunk populations.[17] If population of skunks increase, this would also increase the potential for interaction and spread of rabies.[17]

Summary of Need

Based on this literature review, there is a considerable need for analysis of rabies distribution and prediction in Kentucky. The literature tends to look only at specific species trend, so models that address overall distributions as well as species specific distributions could help enhance an understanding of where hot spots are regardless of animal type. While temperature and weather are shown to be influential on their own, a

model that includes both variables and incorporates multiple species could be useful in predicting the rate of rabies.

Materials and Methods

Data Set

The research design is an ecological study. Microsoft® Excel and R Studio® were used to evaluate 10 years of rabies submissions from 2005 to 2015. The study population was defined as submissions across the state of Kentucky that were sent to the Health Department-Laboratory Services Division in Frankfort, Kentucky. These submissions are currently tested, maintained and archived by the University of Kentucky Veterinary Diagnostic Laboratory (UKVDL) in Lexington, Kentucky. All data collection for animal submissions was passive and anonymous. Submissions included the following information: county of origin, test result, species, exposure, and date of submission. The Florescent Antibody Test determined the test result. Results are categorized as positive, negative, or unsatisfactory for testing. Submissions were available for 106 counties. The Kentucky counties not available include the following: Ballard, Caldwell, Calloway, Carlisle, Crittenden, Fulton, Graves, Hickman, Hopkins, Livingston, Lyon, McLean, Todd, and Trigg. For the time period between 2005 and 2015, 8883 submissions were recorded. These submissions were used for calculating date figures. 116 submissions that were missing county of origin or test date were excluded from later analysis. The total number of reported submissions for Kentucky that met the criteria of complete submission details were 8767 submissions for the years between 2005 and 2015.

Population data comes from the 2010 United States Census. This includes county-level total population and population per square mile for all relevant counties in Kentucky. Multiple county-level rates were calculated using this data including total submissions per population, total submissions per population per square mile, total positives per population, total positives per population per square mile, total positives over total submissions per population, and total positives over total submissions per population per square mile. For the purpose of this study, population and population per square mile were used as the metric for population density.

Weather data comes from the Midwestern Regional Climate Center climate division data for the state of Kentucky. Data contain the temperature and precipitation for each month by the five climate regions in Kentucky. Each county was assigned to its respective climate region, so that monthly regional data could be used as an approximation for weather in each county. The time frame starts on January 2005 and ends with December 2015.

The key response variable is the rate of positive rabies submissions. This was measured by the total number of positive submissions over the total number of all submissions at the county level. Weather is the key covariate of interest in this study. Monthly weather data was not available for each county in Kentucky, therefore it is being assessed using climate regions as a proxy for the county level. Weather is measured by monthly temperature in Fahrenheit and monthly precipitation in inches.

Analysis

Initial analysis compared submissions for all species as well as submissions for bats and skunks separately by creating bar graphs by year between 2005-2015. This was done by charting the total number of rabies submissions in Kentucky for each year. In order to include all submissions, even submissions lacking a county of origin were allowed that were not aggregated in further analysis. Charts of total number of positive rabies submissions in Kentucky for each year were then created to look at trends across time for true cases of rabies as well. This part of the analysis was used to understand the distribution of both confirmed cases and total submissions through the time frame used for the study.

The next evaluation was a comparison of the variance between the four weather regions in Kentucky to see if there is a difference in submission rates. Weather Region 1 is located in Western Kentucky, Region 2 in the Mid-south, Region 3 in Northern Kentucky, and Region 4 in Eastern Kentucky. A map showing the location of these regions was created. These rates were calculated as the number of positives submissions per region divided by the total number of submissions per region. Histograms were created based to assess overall normality and normality between weather regions. Tables of submissions by region were created for all species as well as bats and skunks. Data were not normally distributed, so the rates were originally log transformed. However, even with the transformation, the assumption of normality was not met. Therefore, a chi-squared test was applied to the non-transformed rates. Total submissions met the basic criteria for the chi-square test, however, skunk and bat

submissions did not meet the minimal number criteria for positives. To assess regions, Fisher's Exact Test was performed on all submissions as well as bats and skunks and post hoc analysis was done using pairwise comparisons of Fisher's Exact Test with Bonferroni corrections afterwards. Fisher's Exact was chosen for its ability to handle smaller sample sizes of positive cases and the Bonferroni correction was chosen in order to reduce type 1 error.[18,19]

Geographic area is crucial to my analysis as both the outcome of interest and predictive factors are based off of location. Therefore, my next analysis was to create maps that explored the relationship between my data and locations. Maps were created using QGIS® software. Maps were made for the raw counts of total submissions, total positives, rates of positives over total submissions, the rates of positives over total submissions over population per square mile, and locations of Kentucky climate regions. No cluster analysis was performed due to the potential for a geographic bias. Instead, bias in maps was adjusted based on population density by county. This map was added because the number of positive submissions can depend on the abundance of total samples and the abundance of total samples can depend on the population density. Since data was collected passively from the public, submissions were more likely to come from cities or locations that have convenient access to cities.

Based on the histograms and because the primary outcome of interest was a rate rather than count data; a general linear regression model was used for the next phase of the analysis. This allowed for a description of the probabilities of the outcome of interest. Because weather data were based on monthly intervals and population data

were based on 10-year census data, all data were merged at the individual rabies submission level by county to create the final data set for the regression. The final merged dataset included submission date, county, climate region, species, test result, monthly temperature by region, monthly precipitation by region, population by county, population per square mile by county, the rate of positive submission over total submissions by county and the rate of positive submissions over total submissions by population per square mile.

Results

Out of all 8767 total submissions, 186 submissions were positive over the ten year period (2.11%). Of skunk submissions, there were a total of 238 submissions with 78 positive (32.77%). Of bat submissions, there was a total of 1835 submissions with 71 positive (3.87%). For the four climate regions, Region 1 had 336 total submissions with 5 positives (1.37%), Region 2 had 2307 total submissions with 38 positives (1.16%), Region 3 had 5016 total submissions with 126 positives (2.51%) and Region 4 had 1078 total submissions with 17 positives (1.58%).

Figure 1 shows the time trend of rabies submissions in Kentucky for 2005 through 2015. Submissions are relatively stable across years with a slight jump in 2008 and 2009. Figure 2 shows the trend of positive rabies submissions for the same period. There is a spike in positives for 2008 and 2009 followed by a return to relatively stable but declining numbers subsequently. Figure 3 shows the time trend of total bat submissions. The submissions oscillate between roughly 100 and 200 submissions with a

few larger years. Figure 4 shows the time trend of positive bat submissions. These submissions also fluctuate by year but with are much more exaggerated and do not completely match the patterns of total bat submissions. Figure 5 shows the time trend of skunk submissions. These submissions are stable with a spike in 2008 and 2009 being the exceptions. Figure 6 shows the time trend of positive skunk submissions. Positive skunk submissions are fairly stable except the spike in 2008 and 2009.

The chi-square test for total submission rates between climate regions was statistically significant with a value of 8.73 and a p-value of 0.03. Post-Hoc analysis of total submissions was conducted by looking at the residuals of the chi-squared. Region 3 appeared to be different from the other 3 regions. Fisher's Exact Test was significant for total submissions with a p-value of 0.038 and skunk submissions with a p-value of 0.0095. Bat submissions for Fisher were not significant with a p-value of 0.107. Pairwise comparison of total submissions showed that region 3 was different, but not statistically significant. Pairwise comparison of skunk submissions revealed at statistically significant difference between region 2 and 3 with a p-value of 0.013.

Map 1 also demonstrates the geographic distribution of submissions center around Fayette County. Map 2 shows the positives that are also mainly found arranged near Fayette County but also a small belt was present in Southern Kentucky. When rates of positives were included in Map 3, the belt became even more pronounced with Butler County having the highest rate of positives. Map 4 shows the rates of positives when population per square mile is accounted for. It yields similar results to map three. Map 5 shows the rates of positives for bats and Map 6 shows the rates of positives for

skunks. Map 7 shows the 2010 census population in Kentucky and Map 8 shows the 4 climate regions for reference. Jefferson County had the highest population.

Linear Regression models of all species found temperature to be a significant predictor. Bat submissions also had temperature as a significant predictor. Neither precipitation nor the interaction of precipitation and temperature were found to be significant in any of the models. The model of all species had an adjusted R^2 of 0.07. The model of skunks had an adjusted R^2 of 0.26 and the model of bats an adjusted R^2 of 0.1.

Discussion

First, yearly submissions fluctuate over time but remain relatively stable aside from a large spike between 2008 and 2009. 2008 was around the time when issues of testing validity had occurred in Kentucky. Because of this, it is hypothesized that more sampling had been performed to during this time and this would account for the spike in submissions. Overtime, positive submissions appear to be stable or declining, which matches trends in the United States. While bat positives vary by year in Kentucky, this also matches the cyclical patterns described in the literature. Second, the majority of submissions come from Fayette County in Region 3 and this most likely accounts for the variation between submissions by weather region, although geography and weather could also be contributing factors to regional differences. Continuing with the maps, there appears to be a belt of positives per submissions in Southern Kentucky, which follows an almost straight line through the southern counties. There are some roads in Southern Kentucky that mirror this pattern, and this could be influencing either the

distribution of positive rabies cases or have a confounding effect on people who make submissions in that area. This is because where roads, there is more likely to be human activity that could lead to more submissions. Another potential way roads could influence cases would depend on whether or not street lights are present. If roads in this area have street lights, then this might attract bugs at night which would attract bats. Roads that have a large amount of roadkill could also add to submissions out of convenience for people who submit. Insects from street lights or road kill could easily attract bats or carnivorous terrestrial mammals that would normally be less likely to come into contact with other animals or people. While roads could potentially explain some this phenomenon in this belt area, more research is needed to produce a valid conclusion. Regardless of whether roads contribute to this phenomenon, southern Kentucky has the highest rates of positive submissions. When considering PEP for those who have been exposed to wildlife, the counties indicated on the map of rates provides information on the areas that are most likely to have rabies infection. The all species map can be used for general exposure and the species-specific maps offer guidance to those exposed to bats or skunks in specific areas. These rate maps improve upon the current knowledge of rabies in Kentucky because the maps account for some of the bias in sampling, allowing the areas with the actual problems to be observed. The rate maps could also be used for evaluating ORV success and targeting counties that could benefit the most from intervention.

Finally, the regression revealed a positive relationship with temperature that agreed with the findings from the literature review with skunks being the exception. The

relationship between skunk submission rates and precipitation was not observed compared to previous findings. However, this could be due to the naturally different environmental conditions between the example from the literature and conditions in Kentucky. In the study in Arizona, it makes sense that rain would improve population and infection because of the arid climate of the state. Dry conditions would prevent plant growth; decreasing access to food and thus decreasing skunk population. In Kentucky, rain is more frequent and access to food is not as driven by precipitation to the same extreme. Given what is known about temperature and rabies, winter months would possibly suspend rabies activity in Kentucky which would resume once spring and summer return. While not statistically significant, precipitation had a negative relationship with the rate of positives which also matched my initial hypothesis. It should also be noted that when an interaction between temperature and precipitation were placed in the model during the exploratory analysis, the interaction was also insignificant. Even with the statistical significance of temperature on the general and bat submissions, the model showed only a fraction of an increase in the rate of positives.

Strengths and Limitations

Several limitations must be addressed. Because submissions were sent to the Veterinary Diagnostic Lab in Fayette County and data were collected passively, there is selection bias of having higher submissions in locations closer to Fayette County due to the convenience of distance from the lab. An additional state laboratory is located in western Kentucky that also performs rabies testing. However, due to issues in testing accuracy, these results were not considered to be as reliable as the UKVDL and thus

were not included in the state-wide analysis. Because of location bias and the competing lab, this study does lose some of its generalizability and would not be as powerful in assessing rates especially in western Kentucky. With climate region acting as a proxy for weather by county, there are limitations to the accuracy of measurements for each county. Especially for counties that are on the boarders of each region, the approximation of weather measurements might not hold true as much as the sentinel counties where the data were actually recorded. Because there are a lot of zeros in the data, this truncates the results and therefore the linear regression can only account for so much variation. Regarding confounding, there are several variables mentioned in the literature that could be influencing rabies rates. The seasonal behaviors of animals, access to food, availability of habitat, could be influencing the regression in ways that were not accounted for in this study. Other potential confounders could involve the behavior of people who provide submissions and their understanding of the disease potentially through education or experience. Strengths included the validity of test results. Because the UKVDL will only test submissions that yield a valid result, positive results could be confidently treated as such because any sample that was deemed unfit for testing was marked as "unsatisfactory for testing" for the result.

Conclusion

Based on the results of this study, temperature does not appear to be clinically useful in determining the proportion of positive submissions in Kentucky. The most relevant areas of activity for rabies in Kentucky appear to be in the south. In future research that stems from findings such as these, it may be useful to build a model that

not only includes weather and population data, but also includes additional predictors such as cropland, altitude, roads and forested area.

Appendix

Figure 1.

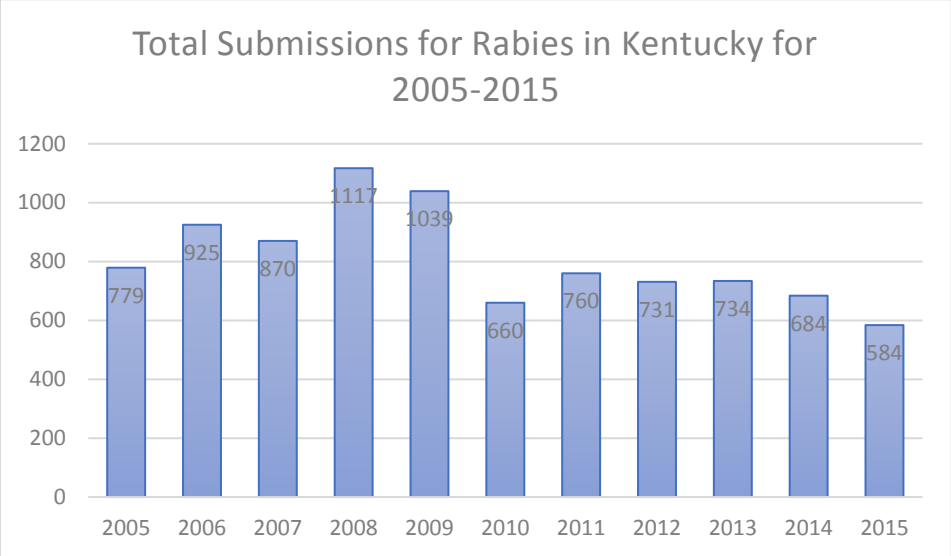


Figure 2.

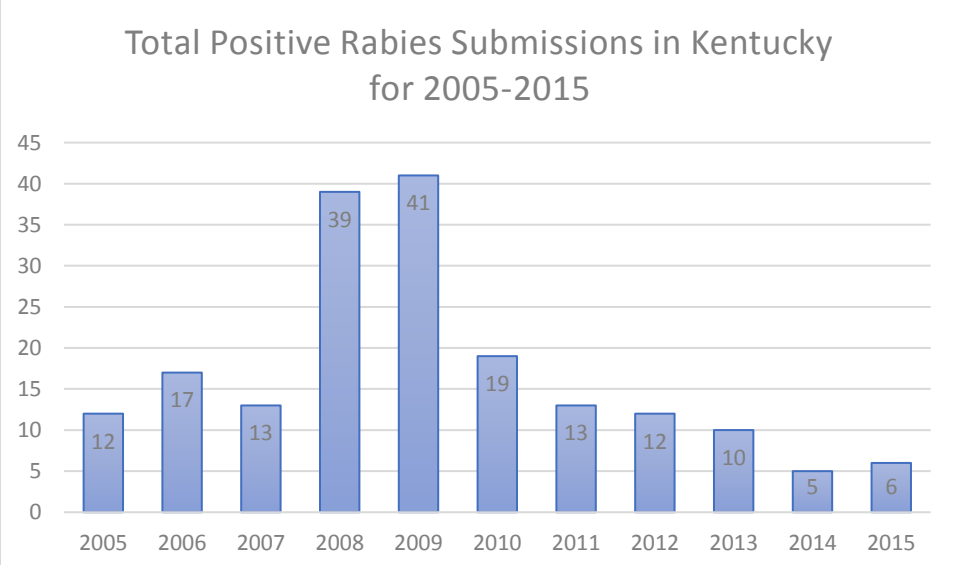


Figure 3.

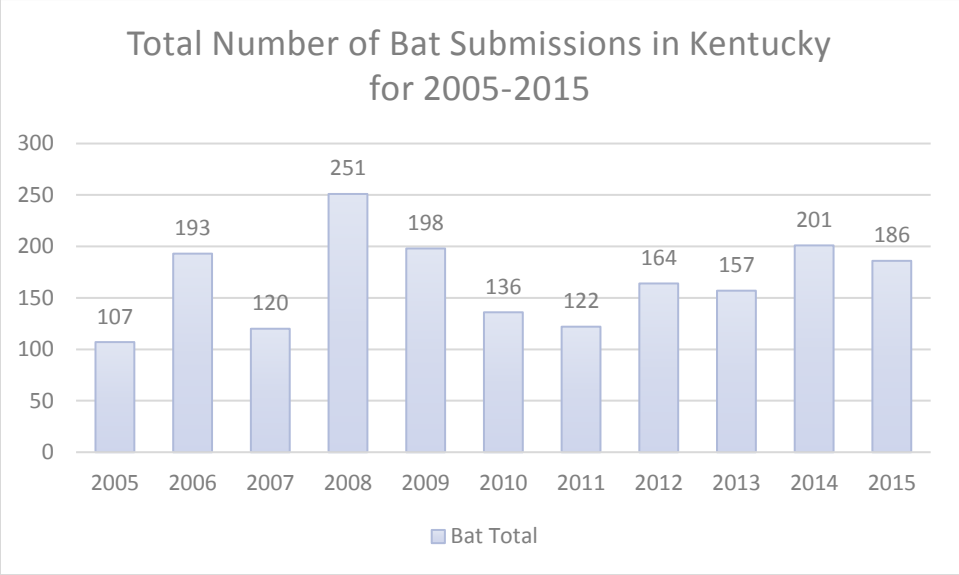


Figure 4.

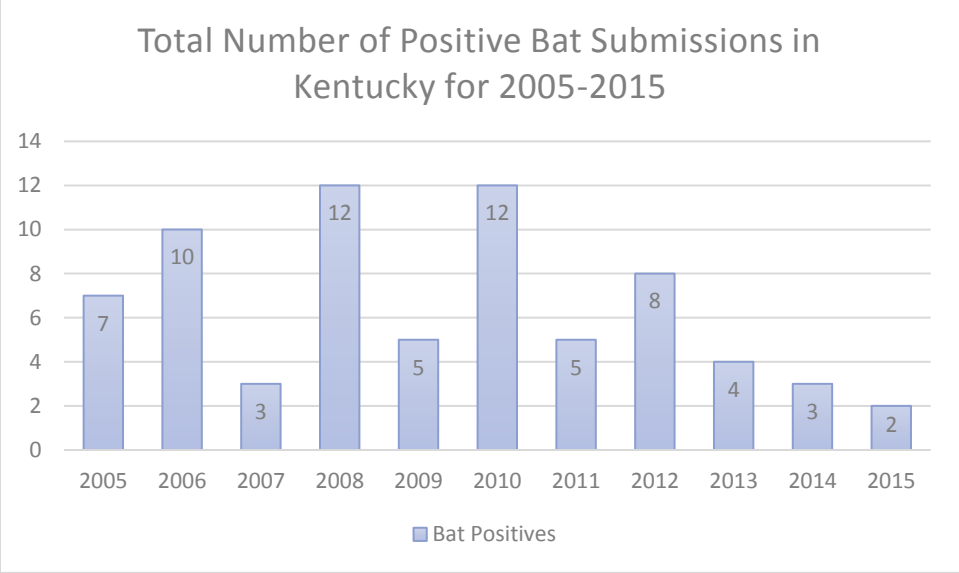


Figure 5.

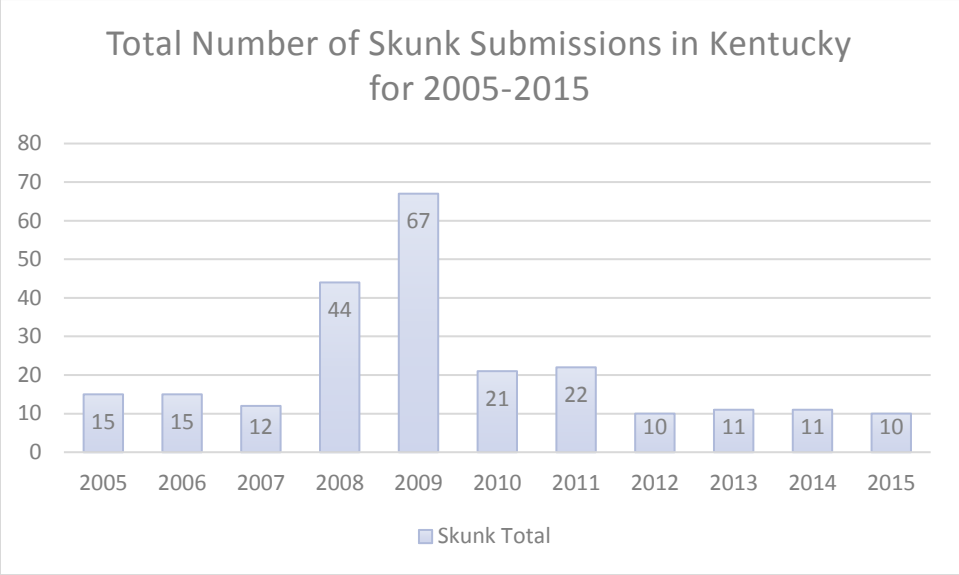
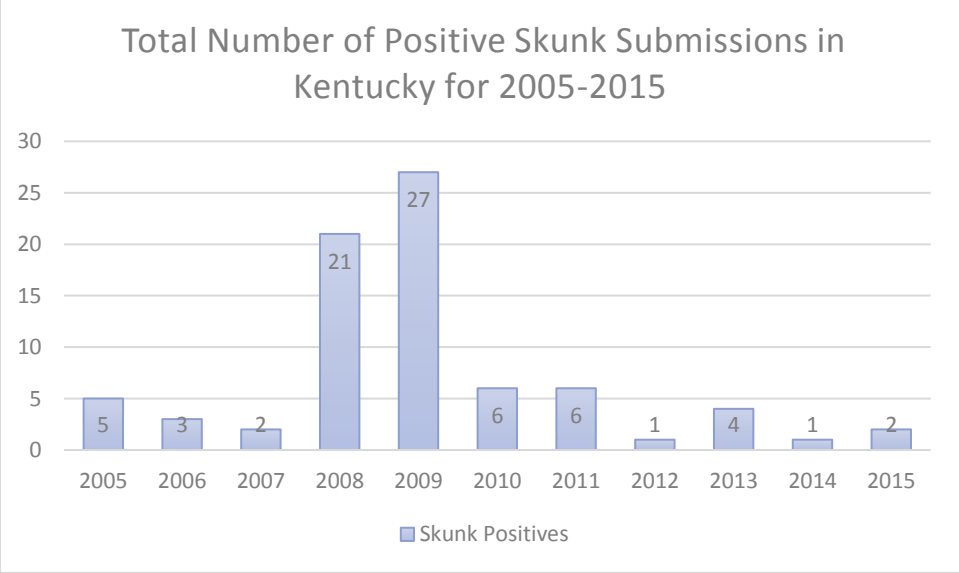
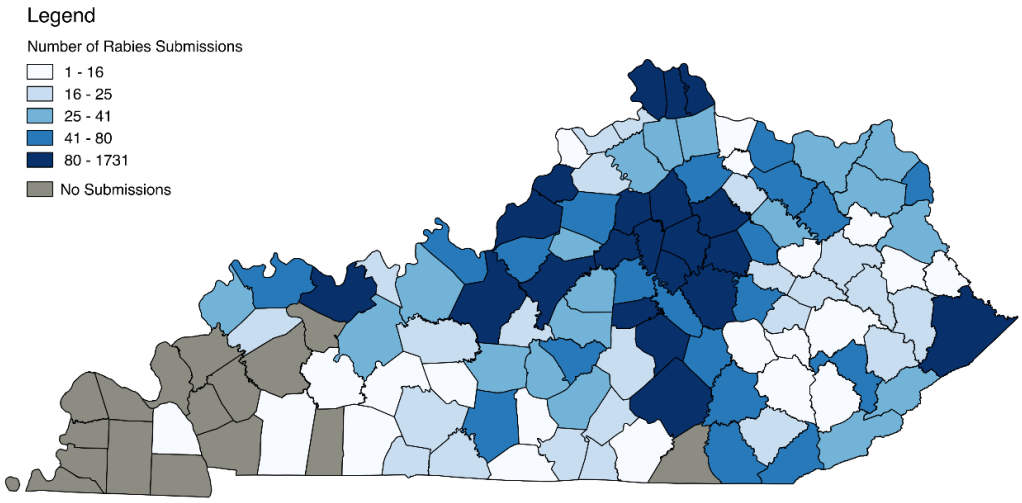


Figure 6.



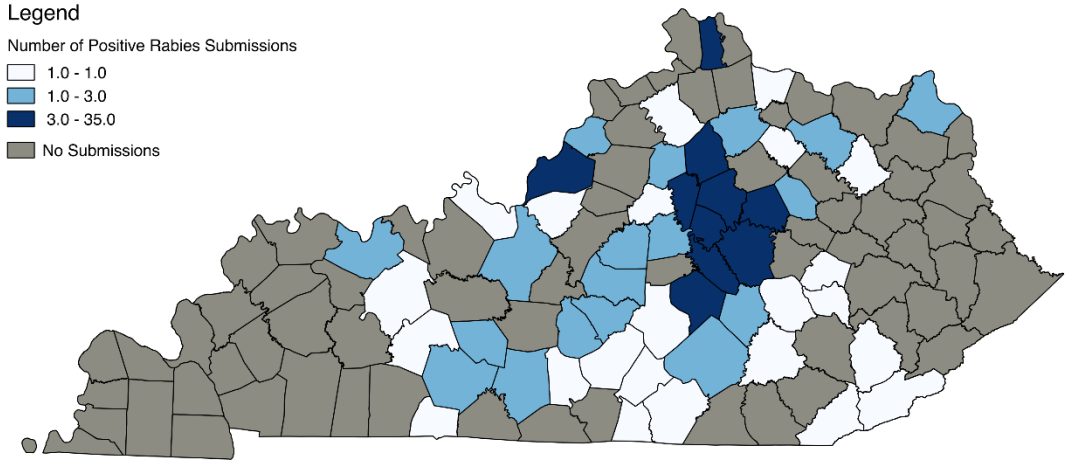
Map 1.

Map of Rabies Submissions for All Species in Kentucky from 2005-2015



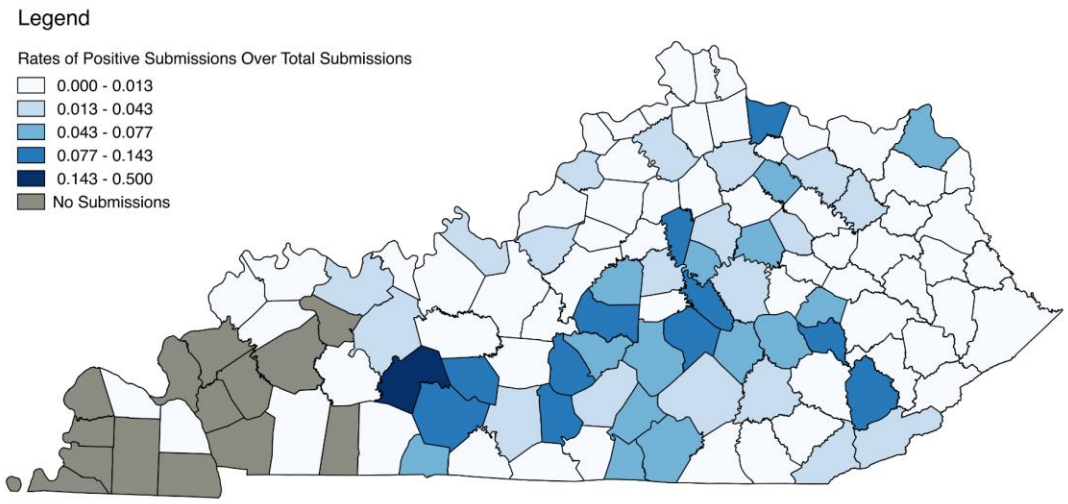
Map 2.

Map of Positive Submissions of Rabies for All Species in Kentucky from 2005-2015



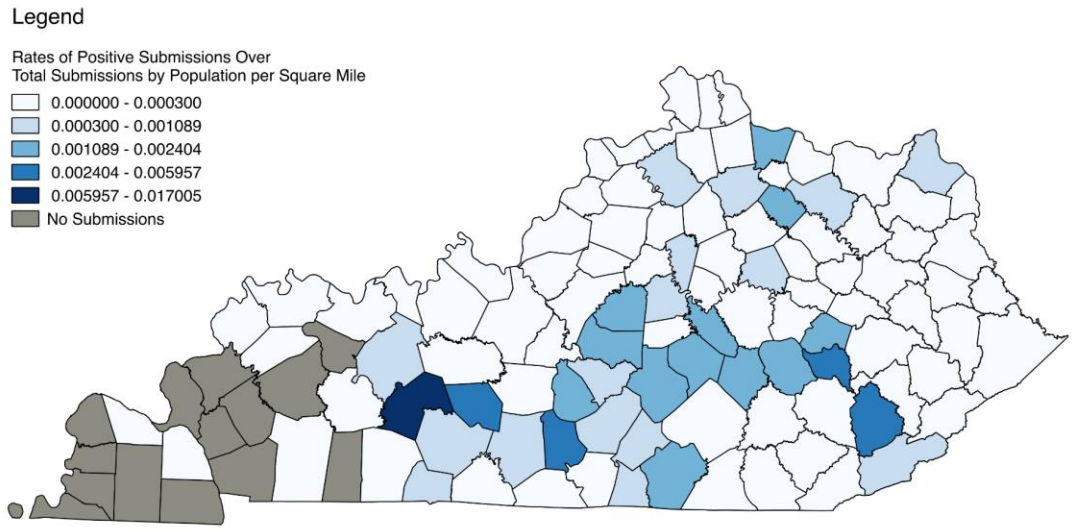
Map 3.

Map of the Rates of Positive Submissions of Each County Over Total Submissions of Each County



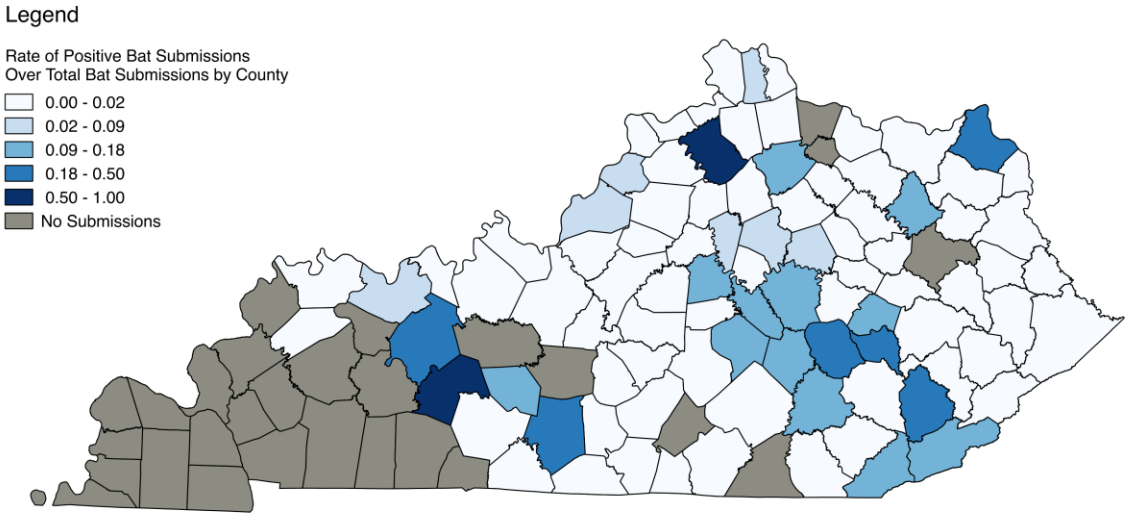
Map 4.

Map of the Rates of Positive Submissions of Each County Over the Total Submissions of Each County by Population per Square Mile



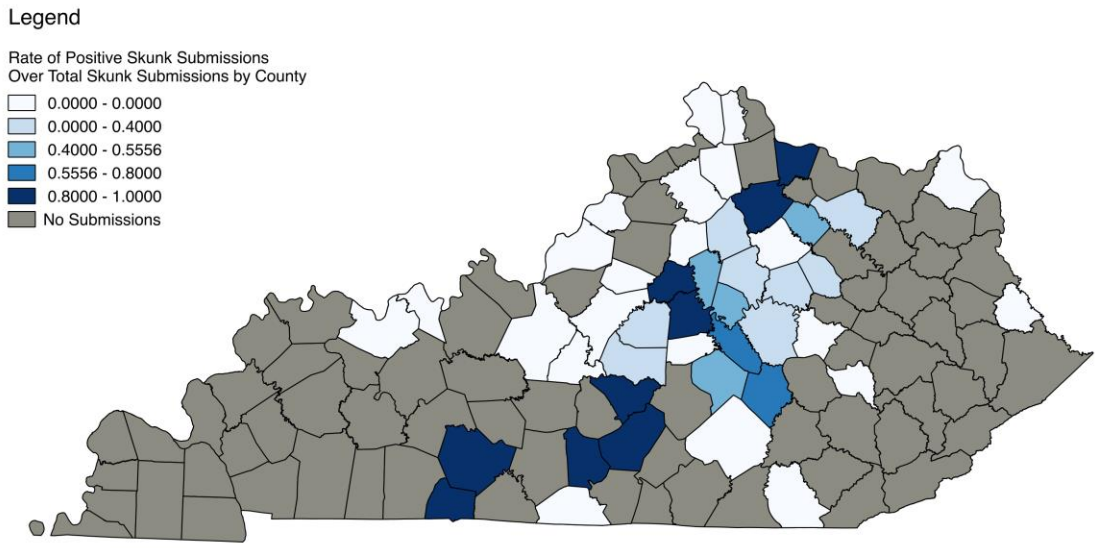
Map 5.

Map of the Rates of Positive Bat Submissions Over Total Bat Submissions of Each County



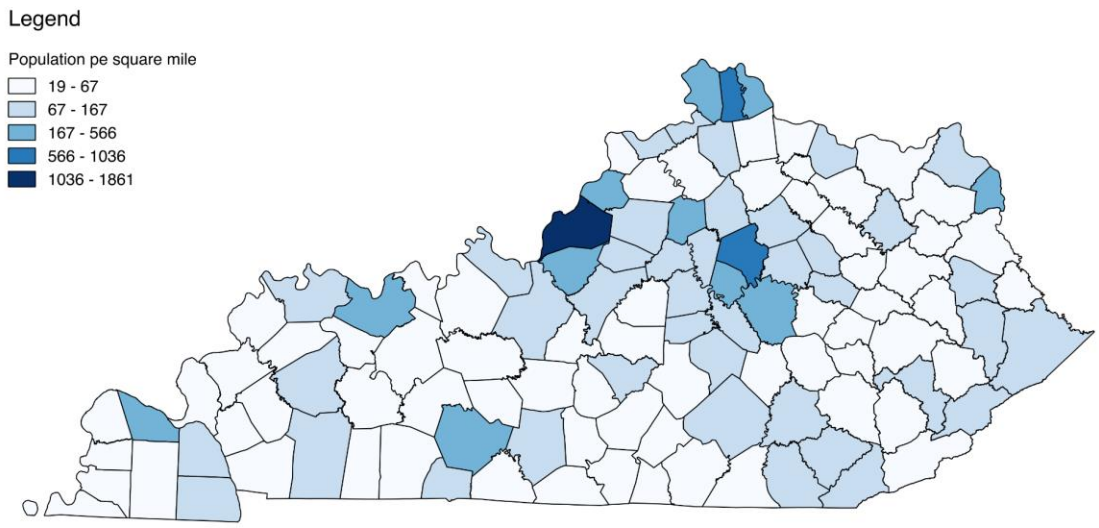
Map 6.

Map of the Rates of Positive Skunk Submissions Over Total Skunk Submissions of Each County



Map 7.

Map of Population Per Square Mile by County for Kentucky Based on 2010 Census Data



Map 8.

The Four Climate Regions in Kentucky from the Midwestern Regional Climate Center

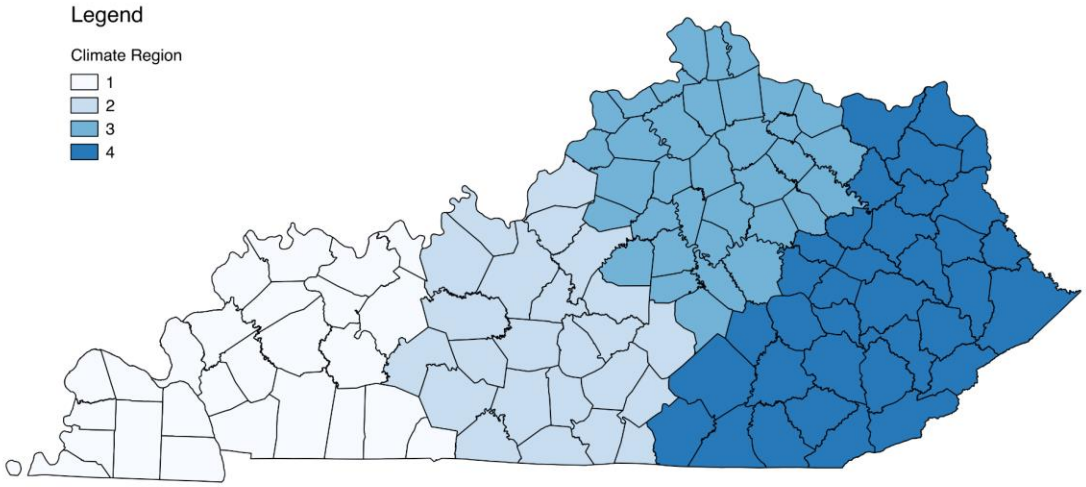


Table 1.
Submissions by Weather Region for All Species

Table of Submissions by Weather Region for All Species			
Region	Total Number of Submissions	Total Number of Positive Submissions	Percentage of Positives and 95% CI
1	366	5	1.37% (0.50, 3.00)
2	2307	38	1.65% (1.17, 2.23)
3	5016	126	2.51% (2.12, 2.97)
4	1078	17	1.58% (0.92, 2.46)
Grand Total	8767	186	2.12% (1.83, 2.44)

Table 2.
Submissions by Weather Region for Skunks

Table of Submissions by Weather Region for Skunks			
Region	Total Number of Submissions	Total Number of Positive Submissions	Percentage of Positives and 95% CI
1	3	1	33.33% (1.67, 86.8)
2	43	6	13.95% (5.86, 26.78)
3	182	69	37.91% (31.08, 45.13)
4	10	2	20.00% (3.5, 51.95)
Grand Total	238	78	32.77% (27.03, 38.93)

Table 3.
Submissions by Weather Region for Bats

Table of Submissions by Weather Region for Bats			
Region	Total Number of Submissions	Total Number of Positive Submissions	Percentage of Positives and 95% CI
1	58	4	6.90% (2.23, 15.8)
2	438	17	3.88% (2.35, 6.02)
3	1123	37	3.29% (2.36, 4.47)
4	188	12	10.17% (5.63, 16.65)
Grand Total	1807	70	3.87% (3.055, 4.84)

Table 4.
Regression Model of Total Submissions

Linear Model of All Species			
R^2	Adjusted R^2	Standard Error	No. of Observations
0.07144	0.071	0.024	8767
Estimate	β	SE	P-Value
Intercept	2.54e-02	1.17e-03	< 2e-16
Temperature	4.94e-05	1.72e-05	0.00425
Precipitation	-1.79e-04	1.34e-04	0.18156
Population Per Square Mile	-1.02e-05	3.94e-07	< 2e-16

Table 5.
Regression Model of Skunk Submissions

Linear Model of Skunks			
R^2	Adjusted R^2	Standard Error	No. of Observations
0.2713	0.262	0.028	235
Estimate	β	SE	P-Value
Intercept	5.55e-02	7.77e-03	1.08e-11
Temperature	1.63e-05	1.15e-04	0.888
Precipitation	-6.69e-04	9.51e-04	0.482
Population Per Square Mile	-2.76e-05	2.97e-06	< 2e-16

Table 6.
Regression Model of Bat Submissions

Linear Model of Bats			
R^2	Adjusted R^2	Standard Error	No. of Observations
0.1076	0.106	0.024	1804
Estimate	β	SE	P-Value
Intercept	2.51e-02	3.27e-03	2.64e-14
Temperature	1.04e-04	4.35e-05	0.016
Precipitation	-2.37e-04	2.89e-04	0.413
Population Per Square Mile	-1.25e-05	8.73e-07	< 2e-16

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Biographical Sketch

Hannah Free completed her Bachelor of Science in Statistics and minor in Biology from the University of Tennessee in 2015. Upon completing her bachelor's, she worked in the Business Analytics and Statistics department at the University of Tennessee for a semester before entering the Master of Public Health program at the University of Kentucky. Currently, Hannah is a responder for the Kentucky Public Health Assistance and Support Team. She is also working with the Central Appalachian Regional Education and Research Center and the University of Kentucky Veterinary Diagnostic Lab as a statistical and spatial disease analyst.