Master of Public Health Report

EFFECT OF STATE LEVEL RABIES CONTROL POLICY AND TERRESTRIAL MAMMAL RESERVOIR ON CANINE AND FELINE RABIES CASES IN THE UNITED STATES

by

LESLIE ENGELMAN
MPH Candidate

submitted in partial fulfillment of the requirements for the degree

MASTER OF PUBLIC HEALTH

Graduate Committee:
Sanjeev K. Narayanan
Derek Mosier
Michael Cates

Field Experience Site:
Kansas State University
August 2012 through May 2014

Field Experience Preceptor:
Cathleen A. Hanlon DVM, MPH

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2014

Abstract

Rabies is a fatal, encephalitic disease caused by numerous variants of a lyssavirus to which all mammals are susceptible. In the United States, domestic animal rabies prevention and control is subjective to individual state health departments; leading to a wide variety of control policies. This study was conducted to determine whether a correlation could be found between state rabies control policy and the incidence of rabies in canines and felines from 2009 through 2012. In addition, since several terrestrial mammal rabies reservoirs are native to different states throughout the country, an evaluation of relationship between prevalent terrestrial mammal rabies reservoir and the number of rabies positive cases was performed. States were grouped into regions based on the predominant rabies reservoir within state lines to determine if any correlation exists between the number of positive rabies cases in canines and felines and the terrestrial mammal reservoir. A state by state examination of domestic animal rabies control policy was conducted and positive rabies case data for canines and felines from 2009 through 2012 were obtained by contact with state public health representatives and from official state websites. Statistical analysis was performed using a Chi-Squared test for independence. This analysis determined that the number of canines and felines that tested positive for rabies in each state was correlated to the domestic animal rabies control policy utilized and the terrestrial mammal rabies reservoir in that state. These results suggest that renovation of state rabies prevention and control, and reporting policies as well as additional study would provide a more descriptive analysis of the effectiveness of various rabies control policies as well as provide an opportunity to analyze the breadth and depth of the rabies burden and its impact on human health in the United States.

Background

Rabies Virus

Rabies is an encephalitic disease caused by a lyssavirus. Exposure typically occurs when the patient is bitten by an infected animal and virus is shed from the saliva into the wound. Once within the body, the rabies virus moves from the site of exposure through the nervous system and makes its way to the brain. The incubation period in humans and animals exposed to the virus is difficult to predict, as the migration time from the site of exposure to the brain can take as little time as a week to several weeks or months. Once the virus reaches the brain the prognosis is death. Rabies is considered a fatal disease and only a couple of cases have been documented of survival and recovery once symptoms become apparent [1].

From a global perspective, 55,000 to 70,000 human deaths per year attributed to rabies give this disease a sense of tragic urgency that can illicit action on the part of various groups seeking to aid in relieving disease burdens around the world. In the U.S., human deaths from rabies have decreased dramatically from approximately 100 per year in the 1990s to 1 human death in 2012 [2]. Though no less tragic, these few and far between cases make rabies seem like a very distant problem and have resulted in an attitude of complacency towards rabies control in the U.S. that could be dangerous.

All mammals are susceptible to and can transmit the rabies virus. The main global reservoir is the canine, and most human rabies deaths are caused by the canine variant of the virus. The U.S. was declared free of the canine rabies variant in 2007 and efforts in other parts of the globe have pushed canine rabies out of many developed countries in Western Europe, leaving the majority of the disease burden in third world nations. [3]. These rabies success stories prove that it is possible to eliminate the canine rabies variant; however the threat of re-introduction of the canine variant is ever present and other terrestrial mammal reservoirs harbor and propagate the disease here in the U.S. [4].

The Indonesian island nation of Bali had been rabies free until 2008, when it is suspected that a fisherman's dog from another island brought the virus ashore. Since 2008 over 140 people have died while the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO), and Bali governmental agencies attempt to eliminate the disease from the island [5].

Rabies in the United States

Hawaii is the only state in the U.S. that is considered totally rabies free. That status has been maintained with diligent biosecurity and restriction of animal import. Throughout the country various wild animal populations harbor and propagate the virus, providing it with a foothold and presenting opportunities for human exposure. In western states, rabies virus variants are found in foxes. The mid-west harbors two variants, north-central and south-central skunk virus. The east coast is endemic for raccoon variant rabies. Bat rabies is endemic across the continental U.S. [2] Human exposure to these rabies variants can occur not only through contact with the wildlife reservoir, but also through pets that have been exposed and infected by wildlife [1]. By vaccinating those animals that live closely with humans, a protective buffer can be created between humans and the rabies reservoirs here in the U.S.

Rabies Prevention and Control in the U.S.

The Centers for Disease Control and Prevention (CDC) has released a model for controlling domestic animal rabies in the U.S. The most recent publication of this model is *The Compendium of Animal Rabies Prevention and Control, 2011*. This document provides guidance for aspects of animal rabies prevention, such as vaccination and pet registration, and control measures such as quarantine [1]. Despite having such a comprehensive model for domestic animal rabies prevention and control, there are currently no standardized rabies control regulations in the U.S. States are responsible for writing and enforcing their own rabies control policies which has provided many opportunities for inconsistencies among and within state regulation.

The purpose of this study was to determine if a relationship exists between state level domestic animal rabies prevention and control strategies and positive rabies cases in canines and felines. A secondary objective was to group states based on the predominant terrestrial mammal rabies reservoir and to determine if a relationship exists between the presence of the terrestrial mammal rabies reservoir and positive rabies cases in canines and felines.

Approach and Methods

The *Compendium of Animal Rabies Prevention and Control, 2011* was reviewed to determine the national recommendations for canine and feline best management practices in rabies control policy. Positive rabies case data for canines and felines for the years 2009 through 2012 were obtained from the Journal of the American Veterinary Medical Association's annual publications *Rabies Surveillance in the United States During 2009; 2010; 2011;* and *2012.* The same publication produces a map that provides a description of the distribution of rabies virus variants in states across the U.S. The map from the report published in 2012 was used to group states into rabies reservoir regions based on the prevalent terrestrial mammal reservoir. States were separated into groups based on the predominant wildlife rabies virus variant present in the state as determined by PCR virus sequencing. Rabies positive cases in canines and felines within a state assigned to a wildlife reservoir region were not sequenced to determine the exact virus variant responsible for disease in each case.

Additional information on individual state policy and for canine and feline rabies positive case data were provided by public health representatives from each state who responded to e-mail requests for information. The e-mail was sent to the list of state public health veterinarians obtained from the National Association of State Public Health Veterinarians (NASPHV) website which provided contact information for acting and designated veterinary public health representatives. Specifically requested in the e-mail were information regarding individual state regulations addressing rabies control, as well as the number of canines and felines that were tested for rabies each year from 2009 through 2013 and the number of canines and felines that had positive rabies test results for those years. 25 responses that provided information requested by the e-mail were received and provided information on rabies control policy and/or guidance as to the online location of the requested information. 13 responses provided information on the number of canines and the number of felines that tested positive in their state for the years 2009 through 2012, only 6 could provide positive case number for 2013. Only 4 states provided the total number of canines and felines tested for 2009 through 2012 as the majority of states do not keep rabies incidence data on record.

State policy information not provided by individual state public health representatives was obtained from state internet websites by searching for rabies control policy information on a state by state basis. Hawaii and Alaska were omitted from this study due to their exclusion from the lower 48 United States. Data was organized for analysis using Microsoft Excel 2013, and analyzed using the Chi-Square test for independence.

Results

Domestic Animal Rabies Prevention and Control Policy

For the purpose of this paper, the word "statute" can be used interchangeably with "law" and is used to describe regulations enacted by the governing body of the state that relate to prevention and control of rabies in canines and felines residing within that state. State statutes are the highest level of regulation in that state and are superseded only when federal statute contradicts the state [6]. Administrative code refers to regulations that are created and enforced by an administrative body, such as a state public health department or state department of agriculture. An administrative body will be responsible for creating and enforcing regulations created within their authority [7].

Examined states were placed into groups based on the rabies control regulations in place; both state statute and administrative code, only state statute, only administrative code, and neither state statute nor administrative code. These statutes and codes vary from state to state in their language, the restrictions placed on pet owners, the requirements for owning and maintaining animals, and enforcement policy. Table 1 shows that 25 states have state statute and administrative code that targets the control of rabies in canines and felines, eight states have state statutes for rabies control, six states have administrative code, and the remaining nine states have no state level rabies control regulation. Table 2 demonstrates that each year felines made up greater than 75% of the total of canines and felines that tested positive for rabies.

Table 1: Number of states examined that utilize both state statute and administrative code, only state statute, only administrative code, and neither state statute or administrative code.

Control Policy	Number of States
State Statute and Administrative Code	25
State Statute	8
Administrative Code	6
Neither	9

Table 2: The proportion of positive rabies cases that can be attributed to canines vs. felines in the U.S. for the years 2009 through 2012.

Year	Total Positive	% Canine	% Feline
2009	371	20.49	79.51
2010	353	16.71	83.29
2011	364	17.58	82.42
2012	315	20.32	79.68

Thirteen states house the power to enforce rabies control policy at the state level, providing these states with opportunities to require a vaccination certificate for import of animals across state lines and the ability to track registered pet movements within the state. Eight states have county level enforcement authority, which allows for inconsistency within the state regarding vaccination and registration requirements. The remaining 29 states leave rabies regulation and enforcement up to individual municipalities. From one city to the next rabies vaccination requirements, animal registration policy, quarantine procedures, and enforcement protocols may vary as little as in their language or as much as in their existence at all.

The number of canines that tested positive for rabies and the number of felines that tested positive for rabies from each group of states were totaled in Table 3 below. This was used to generate Table 4 which displays the summed totals for the years 2009 through 2012 combined. Table 5 displays

the total number of rabies positive cases in canines and felines combined in each group of states from 2009 through 2012.

Table 3: The total number of canines that tested positive for rabies and the total number of felines that tested positive for rabies in each group of states for the years 2009 through 2012.

Total Positive	2009		2010		2011		2012	
Control Policy	Canine Positives	Feline Positives	Canine Positives	Feline Positives	Canine Positives	Feline Positives	Canine Positives	Feline Positives
State Statute and Administrative Code	50	237	36	229	33	244	46	198
State Statute	9	35	10	39	14	39	9	34
Administrative Code	1	9	4	5	10	3	7	1
Neither	16	14	9	21	7	14	2	18

Table 4: The total number of canines that tested positive for rabies and the total number of felines that tested positive for rabies from 2009 through 2012 in each group of states.

Total Positive	2009-2012	
Control Policy	Canine Positives	Feline Positives
State Statute and Administrative Code	165	908
State Statute	42	147
Administrative Code	22	18
Neither	34	67

Table 5: The total number of canines and felines that tested positive for rabies in each group of states for the years 2009 through 2012.

Policy	2009	2010	2011	2012	2009-2012
	Total Positives	Total Positives	Total Positives	Total Positives	Total Positives
State Statute and Administrative Code	287	265	277	244	1073
State Statute	44	49	53	43	189
Administrative Code	10	9	13	8	40
Neither	30	30	21	20	101
All States	371	353	364	315	1403

Table 6 displays the observed number of occurrences for each variable: control policy and total number of canines and felines that tested positive for rabies from 2009 through 2012. The numbers in parentheses are the calculated expected number of occurrences for each variable. Table 7 displays the

calculated comparisons of the variables with the calculated chi-squared values for this statistical analysis.

Table 6: The chi-squared calculation table showing the observed number of occurrences and the calculated (expected) number of occurrences for each variable and the row and column totals used for statistical analysis.

Observed and (Expected) Outcome Frequency		2009-2012	
Control Policy	**Number of States**	**Total Positives**	**Row Totals**
State Statute and Administrative Code	25 (36.32)	1073 (1061.68)	1098
State Statute	8 (6.52)	189 (190.48)	197
Administrative Code	6 (1.52)	40 (44.48)	46
Neither	9 (3.64)	101 (106.36)	110
Column Totals	48	1403	1451

Table 7: Calculated chi-square analysis table and calculated critical value.

Calculated Chi-Square Values		2009-2012	
Control Policy	**Number of States**	**Total Positives**	
State Statute and Administrative Code	3.53	0.12	
State Statute	0.34	0.01	
Administrative Code	13.18	0.45	
Neither	7.90	0.27	
			Chi-square critical value= 25.80

For this analysis, because the calculated chi-square critical value is greater than the critical value for 3 degrees of freedom at all values of α, it can be determined that for this set of data the number of canines and felines that tested positive for rabies from 2009 through 2012 is related to the state's rabies control strategy. This indicates that there is a statistically significant relationship between the number of canines and felines that test positive for rabies in a state and the state level regulations in place, but

does not indicate the strength or direction of the relationship between number of positive cases and state level regulation.

See Appendix A for tables displaying the total number of canine and the total number of feline rabies positive cases for individual states in the evaluated groups for each year from 2009 through 2012.

Terrestrial Mammal Reservoir Rabies Virus Variant

The greatest risk to domestic animal species is exposure to terrestrial mammal rabies reservoirs [8]. Because the terrestrial mammal rabies reservoirs vary from state to state and the population density of these species is also not uniform, domestic animals in some states have a much higher risk of being exposed to rabies. However, transport of domestic animals across state lines for sale, show, and recreation has increased through the past decade. Movement of wildlife reservoir species across state lines is unpredictable and largely untraceable. With no consistent national rabies control policy, the risk of introducing a rabies variant into regions that have previously not been exposed or reintroducing a rabies variant into areas that had seen its elimination is viable.

Every state in the U.S. except for Hawaii is endemic for one or more insectivorous bat rabies virus variants. Examined states were placed into groups based on the terrestrial mammal rabies reservoir endemic within the state.

The greatest number of states examined has the raccoon variant of the rabies virus endemic within their borders; these states are between the Atlantic coast and the Appalachian mountain range, which acts as a natural barrier between them and other states that do not harbor raccoon variant virus. This geographical element, combined with active rabies control practices such as using rabies vaccine baits have prevented raccoon rabies from spreading across the country [1]. States from Louisiana west to Arizona and from Texas north to Nebraska are home to the south central skunk rabies variant. Of these ten, Texas, New Mexico, and Arizona are also endemic for a fox variant. States from Wisconsin west to Montana are endemic for north central skunk rabies variant, which can also be found in patches of eastern Michigan, Kentucky, and Tennessee. California also has a unique skunk rabies virus variant as well as a fox rabies variant. The remaining states; Idaho, Illinois, Indiana, Mississippi, Nevada, Ohio, Oregon, Utah, and Washington, do not have a predominant terrestrial mammal reservoir but do have insectivorous bat species that are reservoirs for bat rabies variants in those states. These nine states comprise the final group that was considered to have no predominant terrestrial mammal rabies reservoir.

Table 8 displays the number of states in each group as determined by the predominant terrestrial mammal rabies reservoir; 18 states in the raccoon region, 10 states in the south central skunk region, 10 states in the north central skunk region, and 10 states in the no terrestrial reservoir region.

Table 8: The number of states placed in each rabies reservoir region.

Reservoir Region	Number of States

Raccoon	18
North Central Skunk	10
South Central Skunk	10
No Terrestrial Reservoir	10

In Table 9, the number of canines that tested positive for rabies was summed for each rabies reservoir region, and the same was done for the number of felines that tested positive for rabies and those totals are displayed by year. Table 10 displays the total number of canines that tested positive for rabies from 2009 through 2012 and the total number of felines that tested positive for rabies from the same years. Table 11 below displays the total of canines and felines that tested positive for rabies in each rabies reservoir region for the years 2009 through 2012.

Table 9: The number of canines and felines that tested positive for rabies for the years 2009 through 2012 in states that have a prevalent terrestrial mammal rabies reservoir and in those with no terrestrial mammal reservoir.

Total Positive	**2009**		**2010**		**2011**		**2012**	
Reservoir Region	**Canine Positives**	**Feline Positives**	**Canine Positives**	**Feline Positives**	**Canine Positives**	**Feline Positives**	**Canine Positives**	**Feline Positives**
Raccoon	29	242	22	238	29	248	28	209
North Central Skunk	25	17	11	20	14	13	6	15
South Central Skunk	22	37	24	38	20	40	29	26
No Terrestrial Reservoir	0	0	0	0	1	0	0	0

Table 10: The total number of rabies positive canines from 2009 through 2012 and the total number of rabies positive felines from 2009 through 2012 in each rabies reservoir region.

Total Positive	2009-2012	
Reservoir Region	Canine Positives	Feline Positives
Raccoon	108	937
North Central Skunk	57	65
South Central Skunk	96	141
No Terrestrial Reservoir	1	0

Table 11: The total of rabies positive canine and feline cases for the years 2009 through 2012 in each reservoir region.

Reservoir Region	2009	2010	2011	2012	2009-2012
	Total Positives	Total Positives	Total Positives	Total Positives	Total Positives
Raccoon	271	260	277	237	1045
North Central Skunk	42	31	27	21	121
South Central Skunk	59	62	60	55	236
No Terrestrial Reservoir	0	0	1	0	1
Total	372	353	365	313	1403

Using the total number of rabies positive canines and felines from 2009 through 2012 a chi-square test for independence was performed. Table 12 displays the observed number of occurrences for each variable: reservoir region and total number of canines and felines that tested positive for rabies from 2009 through 2012. The numbers in parentheses are the calculated expected number of occurrences for each variable. Table 13 displays the calculated comparisons of the variables with the calculated chi-squared values for this statistical analysis.

Table 12: The chi-squared calculation table showing the observed number of occurrences and the calculated (expected) number of occurrences for each variable and the row and column totals used for statistical analysis.

Observed and (Expected) Outcome Frequency		2009-2012	
Reservoir Region	**Number of States**	**Total Positives**	**Row Totals**
Raccoon	18 (35.13)	1044 (1026.87)	1062
North Central Skunk	10 (4.33)	121 (126.67)	131
Couth Central Skunk	10 (8.17)	237 (238.83)	247
No Terrestrial Reservoir	10 (0.36)	1 (10.64)	11
Column Totals	48	1403	1451

Table 13: Calculated chi-square analysis table and calculated critical value.

Calculated Chi-Square Values		2009-2012	
Reservoir Region	**Number of States**	**Total Positives**	
Raccoon	8.35	0.29	
North Central Skunk	7.41	0.25	
Couth Central Skunk	0.41	0.01	
No Terrestrial Reservoir	255.17	8.73	
			Chi-square critical value= 280.63

Based on the calculated chi-square critical value being greater than the critical value for 3 degrees of freedom at all values of α, it can be determined that for this set of data the number of canines and felines that tested positive for rabies from 2009 through 2012 is related to the terrestrial mammal rabies reservoir present in that state. This indicates that there is a statistically significant relationship between the number of canines and felines that test positive for rabies in a state and the

predominant terrestrial mammal rabies reservoir in that state, but does not indicate the strength or direction of the relationship between number of positive cases and terrestrial mammal rabies reservoir.

Additional Considerations:

To evaluate state rabies control policy on an individual basis each state would need to take a comprehensive look at the rabies control strategy they currently have in place and past rabies control strategies to compare rabies incidence data from the time before their current policy was implemented to the present [9]. This comparison would produce a measure of the effectiveness of the rabies control laws themselves based on public health outcomes produced by the implementation of those laws within each state, and would provide the data necessary to determine if current state regulations have had an impact on public health. If these analyses were performed it would provide the foundation for a state to state comparison of rabies control laws and their effectiveness in the U.S.

Data obtained did not include information on the total number of canines and felines that were tested each year from every state so a comparison of the number of animals tested could not be conducted. It was noted that only a few states that responded to the request for information kept records of the total number of animals tested for rabies in a given year. Information on the percent of animals tested that proved to be positive for rabies would have provided the opportunity to evaluate if some of the variation in positive rabies cases across the country is due to the volume of tests performed and population density of the evaluated species.

Lack of standardized state protocols leads to variability in the number of animals tested for rabies in each state every year. The high percentage of positive rabies cases that are reported from states with both state statute and administrative code addressing domestic animal rabies control and prevention could be due to increased surveillance in those states. Additional information concerning states' specific rabies testing policies (which animals to test and under what circumstances they should be tested) would provide possible insight as to what percent of animals that could be considered rabies suspects are actually submitted for testing. States that conduct more rabies diagnostic tests may be reporting a greater number of rabies positive cases due to increased testing rather than a truly higher incidence of rabies within the state.

The number of feline rabies positive cases each year since 2009 has been greater than 75% of the total positive canine and feline cases; felines tested each year were three times as likely to be positive for rabies than canines tested. Some states' policies are specific only to canines and completely exclude felines from rabies control regulations. Other states require proof of vaccination to register pets and only require registration of canines. Feral canine control, in most areas of the U.S., is much more stringent then feral feline control leading to populations of feral or semi-feral felines that are unvaccinated and have no population control measures in place. A study of regions that have various feral feline population control strategies could reveal a trend of decreased numbers of rabies positive felines from regions with trap-vaccinate-release or other feral feline population control programs.

Population density of terrestrial wildlife reservoir species has an effect on the risk of possible rabies exposure to both pets and humans. Human population density directly correlates to pet

population density, higher human population results in higher pet population; however higher human population in some regions decreases the wildlife reservoir population density, inversely affecting risk of pet exposure to rabies. An analysis of population density in relation to rabies control policy implementation and the percent of canines and felines tested for rabies that prove positive would provide further insight into this variable.

In order to evaluate the impact of the lack of standardized rabies control policy on human health outcomes, a study to analyze various states rabies control strategies in relation to the number of humans treated with rabies post exposure prophylaxis (PEP) would be extremely beneficial. However, information on the number of patients treated with PEP is not reported to any federal organization and state level record keeping is determined by each individual state health department. To gather this data would be an intense undertaking at the state level, and to complete a state by state evaluation of the "success" of a rabies control policy based on human patients treated for rabies exposure would be difficult. Such a study would provide a valuable tool to evaluate which existing state level rabies control strategy is most effectively providing the greatest protection to human health.

The overall trend of variability across record keeping, testing policy, and disease reporting can be described as a lack of surveillance. Surveillance is a critical component of disease elimination as well as a key factor in continued disease control. Donald A. Henderson, head of the WHO Global Smallpox Eradication Campaign was quoted as saying, "Unless an effective reporting and surveillance programme is developed, there is no prospect whatsoever for a successful eradication programme" [10]. Responsive vaccination programs that are put in place due to a disease outbreak are more costly and the probability of eliminating the disease is much lower than proactive vaccination and surveillance programs [11]. An increase in rabies control policy consistency throughout the U.S. coupled with implementation of a domestic canine and feline registration program requiring proof of vaccination status would provide the appropriate model for ensuring proper vaccination coverage of these species.

Conclusions

The *Compendium of Animal Rabies Prevention and Control, 2011* states, "The recommendations regarding domestic animal vaccination, management of animals exposed to rabies, and management of animals that bite humans are the core elements of animal rabies control and human rabies prevention". The results of this study demonstrate the number of rabies positive canines and felines in a state for the examined years is statistically related to the rabies control policy in place. Lack of standardized rabies control policy across the nation undermines surveillance for this disease and puts domestic animals and their human care givers at risk of exposure to the virus. The number of rabies positive canines and felines is also statistically related to the rabies virus variant present in a given region, and the reintroduction of rabies variants to areas that have previously seen their elimination is documented in other countries. Standardized rabies control measures adopted nationwide, implemented at the state level, and enforced in all communities would provide increased protection from such an occurrence.

Future studies that would provide additional insight to domestic animal rabies prevention and control in the United States include:

- Analysis of rabies incidence in each state based on the total number of canines and felines tested in each state each year.
- A comparison of current rabies control strategy and rabies incidence vs. past rabies control strategy and rabies incidence to provide a measure of the effectiveness of the rabies control strategy based on any measurable change in incidence of the disease in each state.
- A state to state comparison of the effectiveness of various rabies control strategy based on currently practiced rabies control policy and current rabies incidence.
- Analysis of individual state rabies testing policy to determine if higher rabies incidence in any given state is attributable to state testing policy.
- A comparison of terrestrial mammal reservoir population density in relation to human population density to determine the impact of environmental and population demographics on rabies incidence in a given state or region.

An additional study that would provide an analysis of the human health impact of rabies in the U.S. could include:

- A combination of the above proposed studies.
- An examination of individual states' human rabies treatment guidelines.
- Data collection on the number of patients seeking or referred for rabies post exposure prophylactic treatment each year and the reason for seeking or referral of treatment.

Standardized domestic animal rabies control policy on a state level that includes a diligent surveillance program would provide beneficial insight to the distribution and character of rabies in the U.S. as well as providing a higher level of protection against disease outbreak.

Appendix A

Table A1 displays the number of canines that tested positive for rabies each of the examined years in the group of states that utilize both state statute and administrative code, Table B2 displays the number of felines that tested positive for rabies in those states for those years.

Table A1: The number of canines that tested positive for rabies for the years 2009 through 2012 in states that have both state statute and administrative code addressing domestic animal rabies prevention and control.

State Statute and Administrative Code		2009	2010	2011	2012
Postal Code	State	Canine Positives	Canine Positives	Canine Positives	Canine Positives
AL	Alabama	2	1	0	4
AZ	Arizona	0	0	0	0
AR	Arkansas	2	1	0	3
CA	California	0	2	0	1
CT	Connecticut	1	0	1	0
FL	Florida	1	0	1	2
IA	Iowa	2	1	0	0
IL	Illinois	0	0	0	0
IN	Indiana	0	0	0	0
KY	Kentucky	5	0	3	2
MA	Massachusetts	0	0	0	0
MD	Maryland	0	0	3	0
ME	Maine	0	0	0	1
MS	Mississippi	0	0	0	0
NC	North Carolina	7	2	4	9
NE	Nebraska	1	1	0	1
NJ	New Jersey	0	0	0	0
NM	New Mexico	0	0	1	2
NY	New York	0	1	1	0
PA	Pennsylvania	6	4	3	0
RI	Rhode Island	0	0	0	0
TN	Tennessee	5	3	4	2
TX	Texas	14	15	9	16
VA	Virginia	4	5	3	3
VT	Vermont	0	0	0	0

Table A2: The number of felines that tested positive for rabies for the years 2009 through 2012 in states that have both state statute and administrative code addressing domestic animal rabies prevention and control.

State Statute and Administrative Code		2009	2010	2011	2012
Postal Code	**State**	**Feline Positives**	**Feline Positives**	**Feline Positives**	**Feline Positives**
AL	**Alabama**	3	1	0	4
AZ	**Arizona**	1	0	0	0
AR	**Arkansas**	0	0	1	1
CA	**California**	0	0	0	1
CT	**Connecticut**	2	1	7	3
FL	**Florida**	11	15	11	8
IA	**Iowa**	3	1	3	1
IL	**Illinois**	0	0	0	0
IN	**Indiana**	0	0	0	0
KY	**Kentucky**	1	0	0	0
MA	**Massachusetts**	9	9	2	2
MD	**Maryland**	19	17	17	13
ME	**Maine**	1	1	2	4
MS	**Mississippi**	0	0	0	0
NC	**North Carolina**	19	17	26	25
NE	**Nebraska**	9	6	2	5
NJ	**New Jersey**	20	12	22	20
NM	**New Mexico**	0	1	0	0
NY	**New York**	27	42	38	22
PA	**Pennsylvania**	57	56	50	41
RI	**Rhode Island**	0	2	3	2
TN	**Tennessee**	0	1	0	1
TX	**Texas**	15	20	30	14
VA	**Virginia**	40	27	30	28
VT	**Vermont**	0	0	0	3

Table A3 depicts the number of canines that tested positive in states with only state statute for the years 2009 through 2012; Table A4 shows the number of felines that tested positive for rabies in those states for the same years.

Table A3: The number of canines that tested positive for rabies for the years 2009 through 2012 in states that have only state statute addressing domestic animal rabies prevention and control.

State Statute		2009	2010	2011	2012
Postal Code	State	Canine Positives	Canine Positives	Canine Positives	Canine Positives
DE	Delaware	0	0	0	0
GA	Georgia	3	4	12	7
MI	Michigan	0	1	1	0
NH	New Hampshire	0	0	0	0
OR	Oregon	0	0	0	0
SC	South Carolina	5	4	1	0
WI	Wisconsin	1	0	0	0
WV	West Virginia	0	1	0	2

Table A4: The number of felines that tested positive for rabies for the years 2009 through 2012 in states that have only state statute addressing domestic animal rabies prevention and control.

State Statute		2009	2010	2011	2012
Postal Code	State	Feline Positives	Feline Positives	Feline Positives	Feline Positives
DE	Delaware	4	5	3	3
GA	Georgia	16	21	22	24
MI	Michigan	1	1	0	0
NH	New Hampshire	2	2	1	1
OR	Oregon	0	0	0	0
SC	South Carolina	8	3	5	4
WI	Wisconsin	0	0	0	0
WV	West Virginia	4	7	8	2

Table A5 displays the number of canines that tested positive for rabies in states with only administrative code. Table A6 shows the number of felines that tested positive for rabies in the same states for the selected years.

Table A5: The number of canines that tested positive for rabies for the years 2009 through 2012 in states that have only administrative code addressing domestic animal rabies prevention and control.

Administrative Code		2009	2010	2011	2012
Postal Code	State	Canine Positives	Canine Positives	Canine Positives	Canine Positives
LA	Louisiana	0	1	0	0
MO	Missouri	0	0	0	0
NV	Nevada	0	0	0	0
OK	Oklahoma	1	3	10	7
UT	Utah	0	0	0	0
WA	Washington	0	0	0	0

Table A6: The number of felines that tested positive for rabies for the years 2009 through 2012 in states that have only administrative code addressing domestic animal rabies prevention and control.

Administrative Code		2009	2010	2011	2012
Postal Code	State	Feline Positives	Feline Positives	Feline Positives	Feline Positives
LA	Louisiana	1	0	0	0
MO	Missouri	1	1	0	0
NV	Nevada	0	0	0	0
OK	Oklahoma	7	4	3	1
UT	Utah	0	0	0	0
WA	Washington	0	0	0	0

Table A7 contains the number of canines that tested positive for rabies in states that have neither state statute nor administrative code for the years 2009 through 2012, while Table B8 shows the number of felines that tested positive for rabies in those states for the same years.

Table A7: The number of canines that tested positive for rabies for the years 2009 through 2012 in states that have neither state statute nor administrative code addressing domestic animal rabies prevention and control.

Neither State Statute nor Administrative Code		2009	2010	2011	2012
Postal Code	State	Canine Positives	Canine Positives	Canine Positives	Canine Positives
CO	Colorado	0	0	0	0
ID	Idaho	0	0	0	0
KS	Kansas	4	3	0	0
MN	Minnesota	4	3	1	1
MT	Montana	0	0	0	1
ND	North Dakota	1	2	2	0
OH	Ohio	0	0	1	0
SD	South Dakota	7	1	3	0
WY	Wyoming	0	0	0	0

Table A8: The number of felines that tested positive for rabies for the years 2009 through 2012 in states that have neither state statute nor administrative code addressing domestic animal rabies prevention and control.

Neither State Statute nor Administrative Code		2009	2010	2011	2012
Postal Code	State	Feline Positives	Feline Positives	Feline Positives	Feline Positives
CO	Colorado	0	1	0	1
ID	Idaho	0	0	0	0
KS	Kansas	3	5	4	4
MN	Minnesota	5	8	4	4
MT	Montana	1	0	0	0
ND	North Dakota	1	4	1	6
OH	Ohio	0	0	0	0
SD	South Dakota	4	3	4	2
WY	Wyoming	0	0	1	1

Appendix B

Table B1 below displays the number of canines that tested positive for rabies for the years 2009 through 2012 from states in the raccoon rabies reservoir region. Table B2 shows the number of felines that tested positive for rabies in those same states for the same years.

Table B1: The number of canines that tested positive for the years 2009 through 2012 from states that are in the raccoon reservoir region.

RACCOON RESERVOIR REGION		2009	2010	2011	2012
Postal Code	State	Canine Positives	Canine Positives	Canine Positives	Canine Positives
AL	Alabama	2	1	0	4
CT	Connecticut	1	0	1	0
DE	Delaware	0	0	0	0
FL	Florida	1	0	1	2
GA	Georgia	3	4	12	7
ME	Maine	0	0	0	1
MD	Maryland	0	0	3	0
MA	Massachusetts	0	0	0	0
NH	New Hampshire	0	0	0	0
NJ	New Jersey	0	0	0	0
NY	New York	0	1	1	0
NC	North Carolina	7	2	4	9
PA	Pennsylvania	6	4	3	0
RI	Rhode Island	0	0	0	0
SC	South Carolina	5	4	1	0
VT	Vermont	0	0	0	0
VA	Virginia	4	5	3	3
WV	West Virginia	0	1	0	2

Table B2: The number of felines that tested positive for the years 2009 through 2012 from states that are in the raccoon reservoir region.

RACCOON RESERVOIR REGION		2009	2010	2011	2012
Postal Code	State	Feline Positives	Feline Positives	Feline Positives	Feline Positives
AL	Alabama	3	1	0	4
CT	Connecticut	2	1	7	3
DE	Delaware	4	5	3	3
FL	Florida	11	15	11	8
GA	Georgia	16	21	22	24
ME	Maine	1	1	2	4
MD	Maryland	19	17	17	13
MA	Massachusetts	9	9	2	2
NH	New Hampshire	2	2	1	1
NJ	New Jersey	20	12	22	20
NY	New York	27	42	38	22
NC	North Carolina	19	17	26	25
PA	Pennsylvania	57	56	50	41
RI	Rhode Island	0	2	3	2
SC	South Carolina	8	3	5	4
VT	Vermont	0	0	0	3
VA	Virginia	40	27	30	28
WV	West Virginia	4	7	8	2

Table B3 depicts the number of canines that tested positive for rabies from states in the south central skunk rabies reservoir region for the years 2009 through 2012; Table B4 shows the number of felines that tested positive for rabies during the same time period in those same states.

Table B3: The number of canines that tested positive for rabies for the years 2009 through 2012 from states that are in the south central skunk reservoir region.

SOUTH CENTRAL SKUNK RESERVOIR REGION		2009	2010	2011	2012
Postal Code	State	Canine Positives	Canine Positives	Canine Positives	Canine Positives
AZ	Arizona	0	0	0	0
AR	Arkansas	2	1	0	3
CO	Colorado	0	0	0	0
KS	Kansas	4	3	0	0
LA	Louisiana	0	1	0	0
MO	Missouri	0	0	0	0
NE	Nebraska	1	1	0	1
NM	New Mexico	0	0	1	2
OK	Oklahoma	1	3	10	7
TX	Texas	14	15	9	16

Table B4: The number of felines that tested positive for rabies for the years 2009 through 2012 from states that are in the south central skunk reservoir region.

SOUTH CENTRAL SKUNK RESERVOIR REGION		2009	2010	2011	2012
Postal Code	State	Feline Positives	Feline Positives	Feline Positives	Feline Positives
AZ	Arizona	1	0	0	0
AR	Arkansas	0	0	1	1
CO	Colorado	0	1	0	1
KS	Kansas	3	5	4	4
LA	Louisiana	1	0	0	0
MO	Missouri	1	1	0	0
NE	Nebraska	9	6	2	5
NM	New Mexico	0	1	0	0
OK	Oklahoma	7	4	3	1
TX	Texas	15	20	30	14

The number of canines that tested positive for rabies from states in the north central skunk reservoir region for the years 2009 through 2012 are displayed in table B5 below. Table B6 shows the number of felines that tested positive for rabies in the same states for those same years.

Table B5: The number of canines that tested positive for rabies for the years 2009 through 2012 from states that are in the north central skunk reservoir region.

NORTH CENTRAL SKUNK RESERVOIR REGION		2009	2010	2011	2012
Postal Code	State	Canine Positives	Canine Positives	Canine Positives	Canine Positives
IA	Iowa	2	1	0	0
KY	Kentucky	5	0	3	2
MI	Michigan	0	1	1	0
MN	Minnesota	4	3	1	1
MT	Montana	0	0	0	1
ND	North Dakota	1	2	2	0
SD	South Dakota	7	1	3	0
TN	Tennessee	5	3	4	2
WI	Wisconsin	1	0	0	0
WY	Wyoming	0	0	0	0

Table B6: The number of felines that tested positive for rabies for the years 2009 through 2012 from states that are in the north central skunk reservoir region.

NORTH CENTRAL SKUNK RESERVOIR REGION		2009	2010	2011	2012
Postal Code	State	Feline Positives	Feline Positives	Feline Positives	Feline Positives
IA	Iowa	3	1	3	1
KY	Kentucky	1	0	0	0
MI	Michigan	1	1	0	0
MN	Minnesota	5	8	4	4
MT	Montana	1	0	0	0
ND	North Dakota	1	4	1	6
SD	South Dakota	4	3	4	2
TN	Tennessee	0	1	0	1
WI	Wisconsin	0	0	0	0
WY	Wyoming	0	0	1	1

Table B7 below is the list of states within the region that has no predominant terrestrial mammal rabies reservoir and the number of positive canine rabies cases during the years 2009 through 2012. Table B8 shows the number of positive feline rabies cases in the same group of states through the same years.

Table B7: The number of positive canine rabies positive cases for the years 2009 through 2012 in states that have no predominant terrestrial mammal rabies reservoir.

NO TERRESTRIAL RESERVOIR REGION		2009	2010	2011	2012
Postal Code	State	Canine Positives	Canine Positives	Canine Positives	Canine Positives
CA	California	0	2	0	1
ID	Idaho	0	0	0	0
IL	Illinois	0	0	0	0
IN	Indiana	0	0	0	0
MS	Mississippi	0	0	0	0
OR	Oregon	0	0	0	0
NV	Nevada	0	0	0	0
UT	Utah	0	0	0	0
WA	Washington	0	0	0	0
OH	Ohio	0	0	1	0

Table B8: The number of positive feline rabies positive cases for the years 2009 through 2012 in states that have no predominant terrestrial mammal rabies virus reservoir.

NO TERRESTRIAL RESERVOIR REGION		2009	2010	2011	2012
Postal Code	State	Feline Positives	Feline Positives	Feline Positives	Feline Positives
CA	California	0	0	0	1
ID	Idaho	0	0	0	0
IL	Illinois	0	0	0	0
IN	Indiana	0	0	0	0
MS	Mississippi	0	0	0	0
OR	Oregon	0	0	0	0
NV	Nevada	0	0	0	0
UT	Utah	0	0	0	0
WA	Washington	0	0	0	0
OH	Ohio	0	0	0	0

Bibliography

[1] C. M. Brown, L. Conti, P. Ettestad, M. J. Leslie, F. E. Sorhage and B. Sun, "Compendium of Animal Rabies Prevention and Control, 2011," National Association of State Public Health Veterinarians, Inc, Jamaica Plain, 2011.

[2] J. L. Dyer, R. Wallace, L. Orciari, D. Hightower, P. Yager and J. D. Blanton, "Rabies Surveillance in the United States During 2012," *Journal of the Veterinary Medical Association,* pp. 805-815, 15 September 2013.

[3] Centers for Disease Control and Prevention, "CDC In the News," 7 September 2007. [Online]. Available: http://www.cdc.gove/news/2007/09/canine_rabies.html. [Accessed 3 October 2013].

[4] S. E. Manning, C. E. Rupprecht, D. Fishbein, C. A. Hanlon, B. Lumlertdacha, M. Guerra, M. I. Meltzer, P. Dhankhar, S. A. Vaidya, S. R. Jenkins, B. Sun and H. F. Hull, *Human Rabies Prevention---United States Recommendations of the Advisory Committee on Immunization Practices,* Atlanta: National Center for Zoonotic, Vector-Borne and Enteric Diseases, 2008.

[5] Food and Agriculture Organization of the United Nations, "The Battle Against Rabies - A Success Story," 28 September 2014. [Online]. Available: http://www.fao.org/news/story/en/item/158800/icode/. [Accessed 15 April 2014].

[6] Animal Protection of New Mexico, "How to Understand the Differences Between Statutes, Regulations, Ordinances and Common Law," 2010. [Online]. Available: http://www.apnm.org/publications/animal_law/how_to/understand.php. [Accessed 11 March 2014].

[7] Library of Congress, "Administrative Law Guide," 28 February 2014. [Online]. Available: http://www.loc.gov/law/help/administrative.php. [Accessed 11 March 2014].

[8] R. S. Miller, M. L. Farnsworth and J. L. Malmberg, "Diseases at the Livestock-Wildlife Interface: Status, Challenges, and Opportunities in the United States," *Preventive Veterinary Medicine,* pp. 119-132, 2013.

[9] E. Anderson, C. Tremper, S. Thomas and A. C. Wagenaar, *Measuring Statutory Law and Regulations for Empirical Research,* Philadelphia, Pennsylvania: Robert Wood Johnson Foundation, 2012.

[10] D. A. Henderson, Interviewee, *Summary Status of the Global Programme. Inter-Regional Seminar on Surveillance and Assessment in Smallpox Eradication New Delhi.* [Interview]. 1970.

[11] S. E. Townsend, T. Lembo, S. Cleaveland, F. X. Meslin, M. E. Miranda, A. Agung Gde Putra, D. T. Haydon and K. Hampson, "Surveillance Guidlines for Disease Elimination: A Case Study of Canine Rabies," 8 October 2012. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0147957112001221#. [Accessed 24 April 2014].

[12] Kansas Department of Health and Environment, "Animal and Human Health Issues," 2013. [Online]. Available: http://www.kdheks.gove/epi/human_animal_health.htm. [Accessed 3 October 2013].

[13] K. Christine, "Rabies Laws in the United States as of 7/2012," July 2012. [Online]. Available:

www.dogs4dogs.com/rabies-laws. [Accessed 8 October 2013].

[14] D. J. Briggs and F. X. Meslin, "Eliminating Canine Rabies, the Principal Source of Human Infection: What Will it Take," *Antiviral Research,* pp. 291-296, 2013.

[15] M. K. Morters, O. Restif, K. Hampson, S. Cleaveland, J. L. Wood and A. J. Conlan, "Evidence-Based Control of Canine Rabies: A Critical Review of Population Density Reduction," *Journal of Animal Ecology,* pp. 6-14, 2013.

[16] S. Shwiff, K. Hampson and A. Anderson, "Potential Economic Benefits of Eliminating Canine Rabies," *Antiviral Research,* pp. 352-356, 2013.

[17] B. Dodet, J. Korejwo and D. J. Briggs, *Eliminating the Scourge of Dog-Transmitted Rabies,* Caluire et Cuire: Vaccine, 2013.

[18] C. Dye, "National and International Policies to Mitigate Disease Threats," *Philosophical Transactions of the Royal Society,* pp. 2893-2900, 2012.

[19] E. W. Lankau, D. M. Tack and M. Nina, "Preventing Rabies in an Age of Global Travel," *Crossing Borders: One World, Global Health,* p. 54, 2012.

[20] A. Velasco-Villa, S. A. Reeder, L. A. Orciari, P. A. Yager, R. Franka, J. D. Blanton, L. Zuckero, P. Hunt, E. H. Oertli, L. E. Robinson and C. E. Rupprecht, "Enzootic Rabies Elimination from Dogs and Reemergence in Wild Terrestrial Carnivores, United States," *Emerging Infectious Diseases,* pp. 1849-1854, December 2008.

[21] P. G. Coleman, E. M. Fevre and S. Cleaveland, "Estimating the Public Health Impact of Rabies," *Emerging Infectious Diseases,* pp. 140-142, January 2004.

[22] K. Hampson, J. Dushoff , S. Cleaveland, D. T. Haydon, M. Kaare, P. Craig and A. Dobson, "Transmission Dynamics and Prospects for the Elimination of Canine Rabies," 10 March 2009. [Online]. Available: http://www.plosbiology.org/article/info%3Adoi%2F10.1371%2Fjournal.pbio.1000053#pbio-1000053-g004. [Accessed 15 April 2014].

[23] A. Agung Gde Putera, K. Hampson, J. Girardi , E. Hiby, D. Knobel, I. W. Mardiana, S. Townsend and H. Scott-Orr, "Response to a Rabies Epidemic, Bali, Indonesia 2008-2011," *Emerging Infectious Diseases,* pp. 648-651, April 2013.