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FACTORS INFLUENCING REPORTS OF RABID ANIMALS IN OKLAHOMA

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Abstract: Linear regressions were calculated to evaluate the distribution of reports of rabid animals and some of the factors that might influence reporting rates in Oklahoma. There was a significant relationship between the distribution of human populations and reports of rabid animals other than cattle and skunks. There was no evidence that the presence of the livestock industry per se had an influence on reporting rates. Distance to the laboratory was apparently a factor influncing submission of heads of cattle and skunks, but not other rabid animals. Reporting rates for rabid skunks are probably poor and those reported may represent only a small fraction of actual numbers. Reports of rabid pets, and to a lesser extent rabid cattle, are probably better biological indicators of the true distribution and intensity of the skunk rabies problem. These reports indicate that problem areas for rabies in Oklahoma, where skunks are the primary rabies vector, are characterized by high indices of habitat diversity.

INTRODUCTION

The analyses reported in this paper were designed to answer such questions as: Is there a relationship between human populations and reporting rates for rabies in Oklahoma? Does a relationship exist between the livestock industry and reporting rates for rabid skunks in Oklahoma? Does distance to a diagnostic laboratory influence the submission of animal heads? Are interrelationships apparent between the categories of rabid skunks, rabid cattle, and other rabid animals as we would expect where skunks are considered the primary vectors for rabies?

Another objective was to study the landscape epidemiology of skunk rabies. Studies of the ecology of other zoonoses have led to the recognition of certain characteristics of habitat that serve as reliable indicators of existence of these diseases. "The most important environmental factors determining these associations are climate, soil, vegetation, and other topographical features"[1], hence the term "landscape epidemiology". A characteristic landscape has been identified for some diseases. For example, areas at the junction of montane forest and grassland may be expected to harbor tick-borne encephalitis and spotted fever.

Marx[15] and McLean[16] pointed out the need for studies of the interrelationships between environment and associated populations of rabies vectors. An ability to recognize a landscape characteristic for skunk rabies would help in locating areas with a potential for epizootics and in planning control programs.

Striped skunks *(Mephitis mephitis)* are considered the primary vector of rabies in Oklahoma. They comprised 53.5 percent of the rabid animals examined from 1961 through 1970. Rabid skunks have been found in widely scattered locations in the state each year and rabies was apparently enzootic in the skunk population. Rabid livestock, principally cattle, have accounted for 27 percent of the cases; bats, 7 percent; cats, 6.2 percent; dogs, 3.6 percent; and an occasional rabid bobcat, fox, coyote, raccoon, and spotted skunk were also reported.

The best opportunity for the maintenance of enzootic skunk rabies would presumably occur within good skunk habitat where the greatest population densities of skunks are found. The likelihood of rabies being maintained within poor skunk habitat is probably less because of low population densities of skunks, limited movement of rabid skunks [18,21], and a tendency for populations to occur in small isolated clumps.[12,22,23]

A good index for the landscape epidemiology of skunk rabies would show a close relationship to an index for areas with rabies problems. The number of reported rabies cases and the number of years rabid animals are reported from a county provided indices to the skunk rabies problem areas. Studies in other states have indicated that the reported incidence of rabid wildlife may not accurately reflect the intensity of the problem[13,24]. This may be especially true for rabid skunks because humans are reluctant to handle any ill animals and the repulsive odor associated with skunks presents an added deterrent to the submission of skunk heads for examination. Although reports of rabid wildlife may not reflect the intensity of the problem, there is evidence that these reports delineate the problem areas[24]. The reporting of rabid domestic animals is more complete, especially for dogs and cats, because pets are frequently involved when humans are exposed to rabies and humans have an opportunity to notice when these pets show symptoms of rabies. Since the sylvatic rabies cycle is now considered the most likely source of infection for all cases of rabies in the United States[16], records of rabid domestic animals should provide the most accurate indices to areas in Oklahoma with skunk rabies problems.

A quantitative measure of skunk habitat was needed to compare with indices to problem areas for skunk rabies. Several authors have described good skunk habitat. They repeatedly mentioned mixtures of various habitats and rolling terrain[7,8,11,17,19,20,21]. These mixtures contribute to the amount of edge present in an area because an edge is created wherever two habitat types come together. According to the Law of Interspersion[14], the population density of vertebrate animals with low mobility, that require more than one vegetation type, is directly proportional to the amount of edge.

If the Law of Interspersion holds true for skunks, a wide variety of habitat, woods, ponds, streams, improved pasture, range, and various cultivated crops, all in scattered units, and further interspersed by rolling terrain, should indicate ideal habitat. Diversity, which is a measure of the amount of edge, should be a key measure of quality of habitat for striped skunks. Areas that are less suitable for skunks would be less diverse and would contain large, unbroken monotypes of rangeland, agricultural fields[23] or forestland[8], and extremely steep terrain.

MATERIALS AND METHODS

To determine an index to diversity, I calculated the percentage of the area of each county which was occupied by the following categories: urban, small water, improved pasture, range, forest, wheat, peanuts, corn, cotton, barley, soybeans, sorghum, wild hay, and alfalfa hay[2]. I also calculated the percentage of rolling terrain[5], a measure of diversity not found in a category like forest, that contains several sub-divisions of vegetation and associated edge.

Percentages were treated as whole numbers and all percentages for a county were multiplied by each other. Counties with a greater variety of habitat had higher numerical products as indices to habitat diversity. More precise means of measuring diversity are available[10] but they were not practical for an entire state. The advantage of the technique used in my analyses was that it utilized data already collected by governmental agencies.

The indices to habitat diversity were compared with records of rabid animals examined at the Oklahoma State Health Department Laboratory from 1960 through 1970. Data were tabulated by county and species for each year. Records prior to 1960 were available only on a statewide basis and were not useful for my analyses. Data on bats was excluded because the epidemiology of rabies in bats was different from that for other animals.

Questionnaires were sent to 300 veterinarians in Oklahoma asking about submission, to the state laboratory, of heads from cattle suspected of being rabid.

Linear regressions (R^2) were calculated between the following factors for each county: rabid skunks (n=672), rabid cattle (n=301), other rabid animals (dogs, cats, livestock other than cattle, and wildlife other than skunks, n=195), other rabid animals plus cattle, county acreage[3], cattle population, human population, distance in miles to the diagnostic laboratory, and the index to habitat diversity. The medium human populations between the 1960 and 1970[4] census were used in the calculations. The data for cattle populations[2] were for 1967, the closest period to the mid-1965 date for the rabies reports that I had access to.

I also tabulated the number of years that rabid animals were reported from each county, 1960 through 1970, and compared that with habitat diversity and the distribution of human populations.

The calculation of linear regressions provides a numerical value (R^2) which indicates the proportion of the variance of one variable which can be attributed to its linear regression on another variable. A high R^2 means that one variable can be predicted from a knowledge of the other variable. High R^2 values do not prove causation because two independent variables might be influenced by virtue of a common link with some third variable or might be related only by chance. A low R^2 value indicates either the variables are unrelated or they are related in a nonlinear fashion.

RESULTS AND DISCUSSION

There were statistically significant relationships between rabid skunks and rabid cattle ($R^2=0.155$, $P<0.01$) and between rabid skunks and other rabid animals plus cattle ($R^2 = 0.283$, $P < 0.01$; Table 1). These values imply that the distribution of rabid animals in the three groups are somehow interrelated. The relationship between rabid skunks and other rabid animals plus cattle was further improved by removing cattle from the latter category ($R^2 = 0.362$, $P < 0.01$). This improvement may be explained by the known incompleteness in the submission of heads from rabid cattle.

One hundred and thirty-five veterinarians responded to my questionnaire and reported examining 333 rabid cattle in the past decade. They submitted heads to the state laboratory for confirmation of only one half of these animals. In the counties where fewer than six rabid cattle were examined 1960-1970, 75 percent of the heads were submitted to the laboratory for examination. In counties where 6 to 40 rabid cattle had been examined 1960-1970, only 35 percent of the heads were submitted for examination. A chi-square test indicated the difference in reporting rates in different parts of Oklahoma was statistically significant ($P < 0.005$). Records of rabid livestock delineate areas where rabies occurs but do not accurately indicate the intensity of the problem.

Rabid cattle were closely related to other rabid animals ($R^2 = 0.322$, $P < 0.01$). Rabid cattle were significantly related to the total cattle population ($R^2 = 0.145$, $P < 0.01$) indicating that the distribution of rabid cattle was partly a function of the distribution of the total cattle population.

Marx[15] indicated that workers in the livestock industry may be especially alert for rabid wildlife, resulting in greater submission of animal heads from counties where the livestock industry was prevalent. The low relationship between total cattle population and rabid skunks ($R^2 = 0.082$, $P > 0.05$) indicates the livestock industry per se has no significant influence on reporting rates.

There was no significant evidence that human populations had a strong influence on reporting rates for skunks ($R^2 = 0.077$, $P > 0.05$) or cattle ($R^2 = 0.000$, $P > 0.05$). A significant relationship existed between human populations and

TABLE 1. Linear regressions between pairs of variables in 77 Oklahoma counties, 1960-1970.

	Y Variables and R^2 Values							
	Rabid Skunks	Rabid Cattle	Other Rabid Animals	Other Rabid Animals Plus Cattle	Cattle Population	Human Population	Habitat Diversity	County Acreage
Rabid Skunks[1]								
Rabid Cattle	0.155*							
Other Rabid Animals	0.362*	0.322*						
Other Rabid Animals Plus Cattle	0.283*	N.C.[2]	N.C.					
Cattle Population	0.082	0.145*	0.000	N.C.				
Human Population	0.077	0.000	0.363*	0.048	0.012			
Habitat Diversity	0.046	0.609*	0.664*	0.524*	0.093*	0.000		
County Acreage	0.031	0.017	N.C.	N.C.	0.462*	N.C.	0.004	
Distance to Laboratory	0.108*	0.088*	0.003	N.C.	0.008	0.069	0.025	N.C.

*Significant at .01 level

[1]Examined at the state rabies laboratories

[2]N.C. = Not calculated

the reports of other rabid animals (pets and livestock other than cattle; $R^2 = 0.363$, $P < 0.01$).

Rabid skunks were not related to habitat diversity ($R^2 = 0.046$, $P > 0.05$). The distribution of rabid cattle was strongly related to habitat diversity ($R^2 = 0.609$, $P < 0.01$), much more than habitat diversity was related to the entire cattle population ($R^2 = 0.093$, $P < 0.01$). Habitat diversity was not descriptive of the distribution of the human population ($R^2 = 0.000$, $P > 0.05$). Other rabid animals show the strongest relationship to habitat diversity ($R^2 = 0.664$, $P < 0.01$). This is also the group for which reporting rates are believed to be most accurate. Habitat diversity is descriptive of the landscape epidemiology for rabies in Oklahoma where the disease in domestic animals represents spillover from outbreaks among skunks.

County acreage was not related to any factor except the cattle population.

Distance to the laboratory appeared to influence the submission of rabid skunks ($R^2 = 0.108$, $P < 0.01$) and cattle ($R^2 = 0.088$, $P < 0.01$), but not other rabid animals ($R^2 = 0.003$, $P > 0.05$). Neither habitat diversity nor human populations were related to distance to the laboratory ($R^2 = 0.025$, $P > 0.05$; $R^2 = 0.008$, $P > 0.05$).

The same patterns were seen when I tested another index to rabies problem areas, the number of years (1960-1970) rabid animals were reported from a county. Rabid skunks were related to other rabid animals ($R^2 = 0.248$, $P < 0.01$). Rabid cattle were related to other rabid animals ($R^2 = 0.366$, $P < 0.01$). Habitat diversity was associated with rabid cattle ($R^2 = 0.267$, $P < 0.01$) and other rabid animals ($R^2 = 0.110$, $P < 0.01$). Human populations were associated with other rabid animals ($R^2 = 0.221$, $P < 0.01$). Most of these R^2 values were less than those found for similar comparisons in Table 1, probably because they represented smaller sample sizes.

Multiple regressions can be used to determine which factors provide the best prediction of the value of another factor. I have listed the statistically more significant R^2 values calculated when two variables were used to predict a third variable (Table 2). Including additional variables might further improve the predictions but I do not wish to develop that analysis in this paper. The highest values (Table 2) are those for predicting

TABLE 2. Importance of multiple regressions of Y on selected statistically significant pairs of variables (X_1, X_2) in 77 Oklahoma counties, 1960-1970.

X_1	X_2	Y	R^2
Distance to Lab	Habitat Diversity	Rabid Cattle	0.641*
Rabid Cattle	Habitat Diversity	Rabid Skunks	0.249*
Other Rabid Animals	Rabid Skunks	Habitat Diversity	0.678*
Rabid Cattle	Other Rabid Animals	Habitat Diversity	0.614*
Habitat Diversity	Years Other Rabid Animals	Years Rabid Cattle	0.476*
Habitat Diversity	Years Other Rabid Animals	Years Rabid Skunks	0.249*
Habitat Diversity	Years Rabid Skunks	Years Rabid Cattle	0.272*
Habitat Diversity	Human Population	Years Other Rabid Animals	0.317*

*Significant at .005 level

habitat diversity from a knowledge of records of rabid animals ($R^2 = 0.678$, $P < 0.005$; $R^2 = 0.614$, $P < 0.005$) and for predicting the distribution of rabid cattle from a knowledge of habitat diversity and distance to the laboratory ($R^2 = 0.641$, $P < 0.005$). These R^2 values also suggest that habitat diversity is associated with the reports of rabid animals. Habitat diversity may be descriptive of a landscape epidemiology for rabies, it may be related only coincidentally or it may be related to factors which govern the reporting of rabies in wild animals. I plan to conduct field studies to measure habitat diversity in a more precise manner[10] and determine how it relates to skunk populations and problem areas for rabies in Oklahoma.

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