The Ecology of Rocky Mountain Spotted Fever in Eastern United States with particular reference to Virginia

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I. EPIDEMIOLOGY[1]

By

EARL L. ATWOOD,[2-5] JOHN T. LAMB,[3] and
DANIEL E. SONENSHINE[4]

INTRODUCTION

Rocky Mountain spotted fever was first identified in the eastern United States by Badger, *et al*, in 1931 (1). Topping (1941) and Harrell (1949) reported (2;3) that there was a much greater frequency of cases of the disease in women and children in the eastern as compared to the western states. In the eastern United States, the *Dermacentor variabilis* tick is the most important vector to man (4;5) and is frequently found in close association with human habitations. In the eastern states, the age group with the largest number of cases was 1-15 years, whereas the majority of the cases in the western states occurred in persons over 40 years of age. Since 1950, the number of reported cases of Rocky Mountain spotted fever in the United States has declined steadily. This decline cannot be identified with any known change in the ecology of the disease and it is probable that in reality the number of cases have actually increased. The start of the decline in reported cases corresponds with the beginning of the use of broad spectrum antibiotics. It has become common practice for physicians to treat all febrile illness promptly with these drugs without waiting for either a clinical or serological diagnosis. In many instances the antibiotic has modified the disease so that the classic signs and symptoms necessary for a clinical diagnosis cannot be made (7). At the same time, it has been shown that if the antibiotic is given early enough in the illness it will retard if not prevent the development of complement-fixing antibodies (8). This prevents definitive serological diagnosis in some cases. For these reasons the number of cases reported after 1949 no longer reflects the actual incidence of the disease.

Attempts to estimate the real number of cases of Rocky Mountain spotted fever which have occurred in recent years are hazardous. There are reasons to believe the disease has not declined but has actually in-

1. This work was supported, in part, by a grant, A103218, from the National Institute of Allergy and Infectious Diseases, National Institute of Health, Bethesda, Maryland.
2. Section of Biostatistics, Division of Preventive Medicine, Walter Reed Army Institute of Research, Walter Reed Army Medical Center, Washington, D. C. 20012.
3. Bureau of Insect and Rodent Control, Virginia State Health Department, Norfolk, Virginia. 23502
4. Department of Biology, Old Dominion College, Norfolk, Virginia. 23508
5. Present Address: Department of Biology, Old Dominion College, Norfolk, Virginia, 23508

creased. A regression line fitted to the number of reported cases for the pre-antibiotic treatment period 1935-49 was found to be highly significant, with a rate of increase of about 1.54 per cent per year in number of reported cases. In considering the factors which would tend to increase the incidence it is noted that between 1935 and 1960 there has been a steady growth of the population living in the United States except for the war years when it remained essentially static. At the same time the percentage of people living in suburban or rural areas where they are liable to be exposed to ticks has increased. In addition, farm census data indicates a 20 per cent increase between 1935 and 1960 in areas considered to be suitable tick habitat, mostly in the form of woodland and abandoned fields. Bearing this in mind we have projected the trend of incidence between 1935 and 1949 to the period 1950 to 1963 as representing the actual number of cases which occurred, Fig. 1. This projection line is an estimate only and is based on the assumption that had the broad spectrum antibiotics not been used for treatment the increasing trend in the number of reported cases would have continued.

The Epidemiology of Rocky Mountain Spotted Fever in Virginia

In recent years, Virginia has had the highest reported attack rate of any eastern state, 6.6 per 100,000 persons (7). The reported cases of Rocky Mountain spotted fever in Virginia for the period 1935 to 1950 are shown in Table I. Further, Virginia is in the South Atlantic region, wherein the highest incidence of Rocky Mountain spotted fever has been reported. Another reason for considering the Virginia cases is that extensive investigation of the environmental surroundings, particularly in regard to small rodent activity and land utilization was done by the Virginia State Health Department in connection with 87 of the 89 cases reported in 1960 and 1961 in that state. Trapping was done in the immediate surroundings (*i.e.*, within and adjacent to the area of outdoor activity of the patient) of each case to determine the presence and relative abundance of small rodents which may serve as hosts for ticks. The land utilization was classified as to types which were extensive or predominant in the immediate vicinity; namely, cultivated fields or lawns, abandoned fields, woods, and hedgerows. Lastly, the cases were classified as to type of general area; namely, urban, suburban, and rural.

An example of the immediate surroundings of human cases of Rocky Mountain spotted fever where tick and small rodent populations were maintained close to the homes is shown in Fig. 2.

Occurrence by Physiographic Province. Perhaps the first indication that the distribution of cases may be related to physiographic provinces is found in Price's (9) study of 971 cases in Maryland. He found that only 9 cases had been reported from the three counties in the western mountains during the 20-year period of his study. A distribution of 940 cases in Virginia was compiled by H. S. Fuller from case records of Dr. R. R. Parker, Rocky Mountain Laboratory,[5] Hamilton, Montana, (Fig. 3). When the rates for the 20-year period are reduced to average per annum rate per 100,000, it is found that the highest reported rate during the period 1931 to 1950 occurred in the Piedmont physiographic province. This area had an average per annum rate of 4.1 cases per 100,000, whereas in the Coastal Plain province the rate was 2.1 and in the Mountainous province the rate was 1.1 per 100,000. In six of the Mountainous province counties no cases were reported during this period. Mountain and Coastal Plain counties with the highest case rates for their province were those adjacent to the Piedmont (Fig. 3).

A more recent study of the distribution of cases of Rocky Mountain spotted fever in Virginia by the Virginia State Health Department has also shown a significantly higher incidence in the Piedmont. The distribution of 171 cases reported in Virginia during the four year period 1960 through 1963 reveals that 100 cases were reported from the Piedmont region. A statistical test comparing the ratio of the difference

5. U. S. Public Health Service.

between population density and incidence of the disease in the Piedmont versus the remainder of the state, for this period, indicated the probability of such a difference being due to chance is less than 1 in 10,000.[6] The region with the second largest number of cases was the coastal plain, with 41 cases. It is also interesting to note that of the 30 cases reported from the mountain region, 24 were adjacent to the Piedmont, in the Shenandoah Valley and Blue Ridge area.

Distribution by Type Locality and Land Use. Locality distribution of cases was studied in 171 reported cases in Virginia for the period 1960 through 1963. The distribution by type locality of these cases was as follows: Rural, 83; Suburban, 66; Urban, 21; unknown, 1. The large number of cases in the suburban type, 38.6 per cent of the number investigated, is particularly interesting because this type of settlement is increasing both in area and population.

The possibility of a relationship between patterns of land use and other factors in the environmental surroundings with the incidence of Rocky Mountain spotted fever was investigated in 87 of the 89 cases reported in Virginia during 1960 and 1961. Data on land use and locality type for these cases are tabulated by physiographic province in Table II. It will be noted that in 52 of the 87 cases investigated, or 59.8 per cent, abandoned fields were among the dominant features in the immediate surroundings. Woods were abundant in the immediate vicinity of 46 cases, or 52.9 per cent of the total. Cultivated fields or lawns were abundant in only 33 per cent of the cases; hedgerows were noted in only 23 per cent of the cases.

Data were also examined from these 87 cases for small rodents trapped in the land use types in Table II. The two species of small mammals taken during this trapping activity, i.e., white footed mouse (*P. leucopus*) and meadow vole (*M. pennsylvanicus*) have previously been reported as hosts of the sub-adult stages of the dog tick, *Dermacentor variabilis*, by Smith, *et al.* (5). In examining Table III, it will be noted that white footed mice were trapped at 74 of the 87 cases (85.1%) and meadow voles at 22 case locations (23.3%). This reveals that the white footed mouse occurs more frequently in the woods, fields and hedges or fence rows at Rocky Mountain spotted fever case localities than does the meadow vole and suggests it may be the more important of these two sub-adult hosts of the *D. variabilis* tick vector. It should also be noted that the ratio of occurrence of white footed mouse case localities within the Piedmont versus Mountain province was 4.2 to 1 and Piedmont versus Coastal Plain province was 2.7 to 1. The occurrence of meadow vole localities within the Piedmont versus Mountain province was 3.75 to 1 and Piedmont versus Coastal Plain province was 5.0 to 1.

It is especially interesting and perhaps significant that small mammals could be demonstrated in the immediate vicinity of almost all of the cases, and that suitable habitat for ticks and their wild mammalian hosts was evident at most of the case localities. These relationships were evvident in all three of the physiographic regions, but the incidence of occurrence was highest in the Piedmont.

Trends in Land Use in Virginia. Increases in the amount of suitable tick habitat area may be expected to contribute to an increasing incidence of Rocky Mountain spotted fever. Forest, particularly young second growth and scattered hardwood stands appear to provide suitable tick habitat, probably because of the abundance of good ground cover, such as honeysuckle and bramble along its margins, which provide shelter for small mammals and favorable microclimatic conditions for tick survival. In Virginia, according to Larson and Bryan (10), forest area increased by 8.6% from 1940 to 1957, and the largest increases occurred in the southern Mountains (15%) and southern Pied-

6. Chi-Square = 20.25 with 1 d. f.

mont (10%). The increases in the Northern Piedmont and Coastal Plain were only 4% and 6%, respectively. The southern Piedmont is now the most heavily forested region. Logging has also increased greatly in Virginia, most notably in the Piedmont (21%) and the Coastal Plain (24%). However, cutting decreased in the Mountainous western region.

The increase in forest land in Virginia is almost entirely in formerly agricultural land that has been abandoned and allowed to revert to forest (10). During the 17-year period between forest surveys by the U. S. Forest Service, the area of cropland decreased from 6.0 million acres to 3.2 million acres. Another trend which is characteristic of Virginia is the replacement of pine types by hardwoods. The area covered by pines decreased in all of the physiographic provinces during the 17-year period between surveys; the hardwoods increased by 1.4 million acres. The greatest increases in hardwood forest occurred in the Mountain region; the second greatest increase was in the Piedmont; the lowest rate of increase was in the Coastal Plain. The trend towards increase in the area of hardwood forest at the expense of the evergreen is interesting because the young broadleaf deciduous forest would tend to provide more favorable microclimatic conditions for tick survival, in terms of relative humidity and air moisture content generally, than would be expected in purely evergreen forests. The increase in deciduous forest also offers more optimum habitat for tick hosts.

These data suggest that the continued prevalence of Rocky Mountain spotted fever in Virginia may be related to recent trends in land use leading to increases in the area of abandoned fields and deciduous forest. These changes, together with an increasing human population and redistribution of this population in favor of the suburban areas of settlement all tend to bring more people into close contact with habitats suitable for tick vectors. These trends are most pronounced in the Piedmont region wherein the high rate of reversion of former agricultural land to deciduous forest is coupled with frequent timber cutting. The latter tends to conserve the character of young second growth forest as logging roads are cut, large trees removed, the canopy opened, and the rapid growth of luxuriant ground cover facilitated. Much of the abandoned land is in the vicinity of suburbs, where portions of it are converted into housing developments, while other portions are left undeveloped in the immediate vicinity. Smadel (7), discussing the projected urbanization of the Maryland rural areas between Washington, D. C. and Baltimore, noted that, "'while full urbanization is inimical to the vectors and hosts of *R. rickettsii* (as for that matter, is intensive agricultural development), the creation of a 'suburbia' in the Washington-Baltimore area will place increasing numbers of persons at risk." The same trends are apparent in the northern Virginia counties and suburban areas of the major Virginia cities.

Summary

Evidence is presented which suggests that the true incidence of Rocky Mountain spotted fever is currently much greater than the number of reported cases after 1949.

An epidemiological study of Rocky Mountain spotted fever in Virginia is also described. It was observed that the region with the highest rate of disease was the Piedmont. It is also shown that the suburban areas are high risk localities, with only slightly fewer cases than the rural areas. Abandoned land, either abandoned fields or woodlands, as well as small rodent activity, was associated with almost all of the cases studied by means of on-site investigations. The manner in which certain trends in land use combine to increase the tick habitat area are discussed, particularly in regard to recent figures on the abandonment of cropland, increase in hardwood forests, and increase in logging activity.

The evidence presented suggests that the present population growth rate, pattern of settlement, and trends in land use are contributing to an increasing risk of Rocky Mountain spotted fever.

The authors are aware of the limitations of a retrospective analysis of the type presented, with respect to understanding the dynamics of the disease. An ecological study is necessary to determine the interrelationship of the components of the ecosystem in which spotted fever circulates. Such a study is in progress and the results will be reported in a later paper.

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TABLE I

Rocky Mountain Spotted Fever in Virginia
Reported Cases, 1935 to 1950[1]

Year	*Cases*
1935	44
1936	50
1937	54
1938	72
1939	50
1940	46
1941	33
1942	47
1943	56
1944	81
1945	99
1946	92
1947	67
1948	64
1949	101
1950	77

1. Data kindly supplied by Dr. L. K. Altman, Editor, Morbidity and Mortality Weekly Report.

TABLE II

Distribution of Rocky Mountain Spotted Fever Cases in Virginia During 1960 and 1961

Number of Cases

Average Case Rates Per 100,000 Per Annum by Physiographic Provinces	Type Locality			Land Used*			
	Rural	Suburban	Urban	Lawn or Cult. Field	Aband. Field	Woods	Hedge or Fence Row
Coastal Plain 0.832	9	6	3	9	11	11	3
Piedmont 1.477	24	22	9	16	37	30	11
Mountain Region 0.748	9	5	0	4	4	5	6
Totals	42	33	12	29	52	46	20
Percentage Distribution	48.2	38.0	13.8	33.0	59.8	52.9	23.0

*These data are not mutually exclusive

TABLE III

Distribution of Small Mammal Sub-adult Tick Hosts
By Physiographic Provinces in Virginia

Avg. Case Rates Per 100,000 Per Annum by Physiographic Provinces	Sub-adult hosts of D variabilis ticks			
	Meadow Vole (M. pennsylvanicus)		White Footed Mouse (P. leucopus)	
	No. of Case* Localities	No. Animals Trapped	No. of Case* Localities	No. Animals Trapped
Coastal Plain 0.83	3	5	17	135
Piedmont 1.48	15	83	46	357
Mountain 0.75	4	5	11	96
Totals	22	93	74	588
Proportion of Occurrence in 87 cases	23.3	13.7	85.1	86.3

*These data are not mutually exclusive

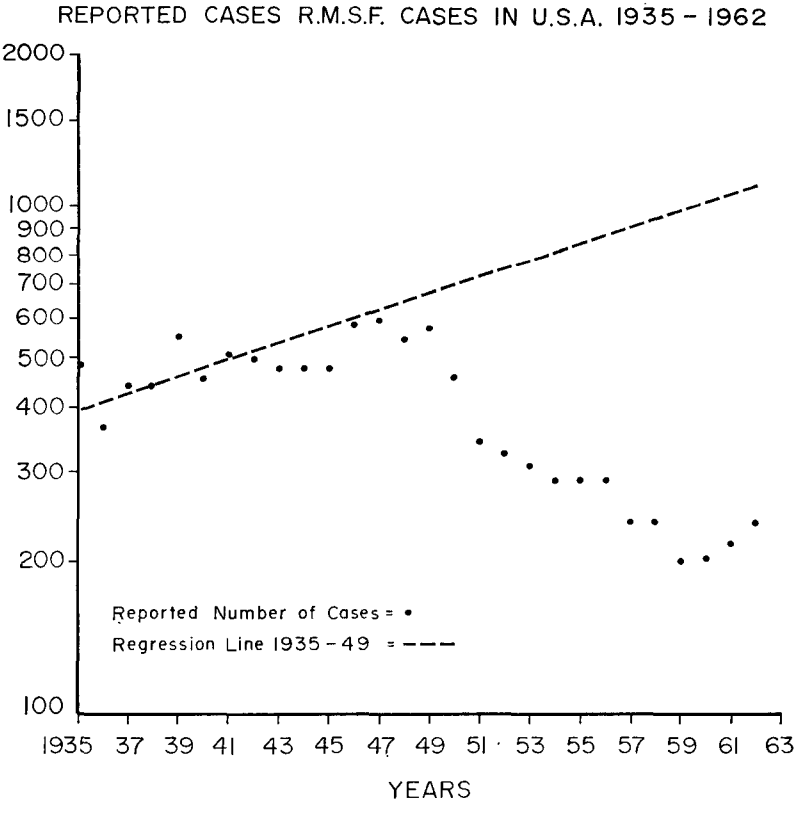

Fig. 1. Reported number of cases of Rocky Mountain spotted fever in the United States.

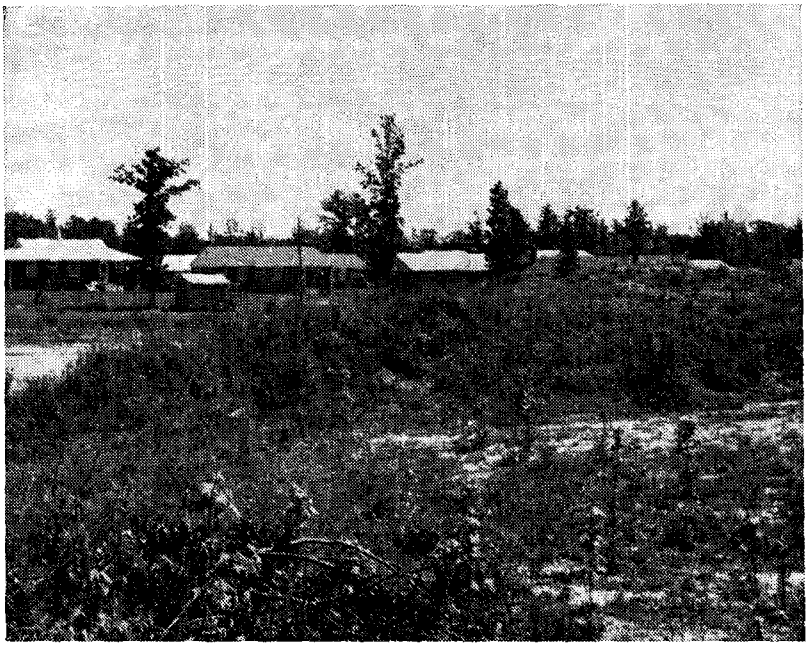

Fig. 2. Home and Surroundings of S.A.S., female, 4 years old, who contracted Rocky Mountain spotted fever on April 15, 1961. The location is in the city of Richmond. The child was reported to have visited the abandoned land shown in the foreground, and is known to have acquired a tick. *D. variabilis* and small rodent hosts were found to be present on the property.

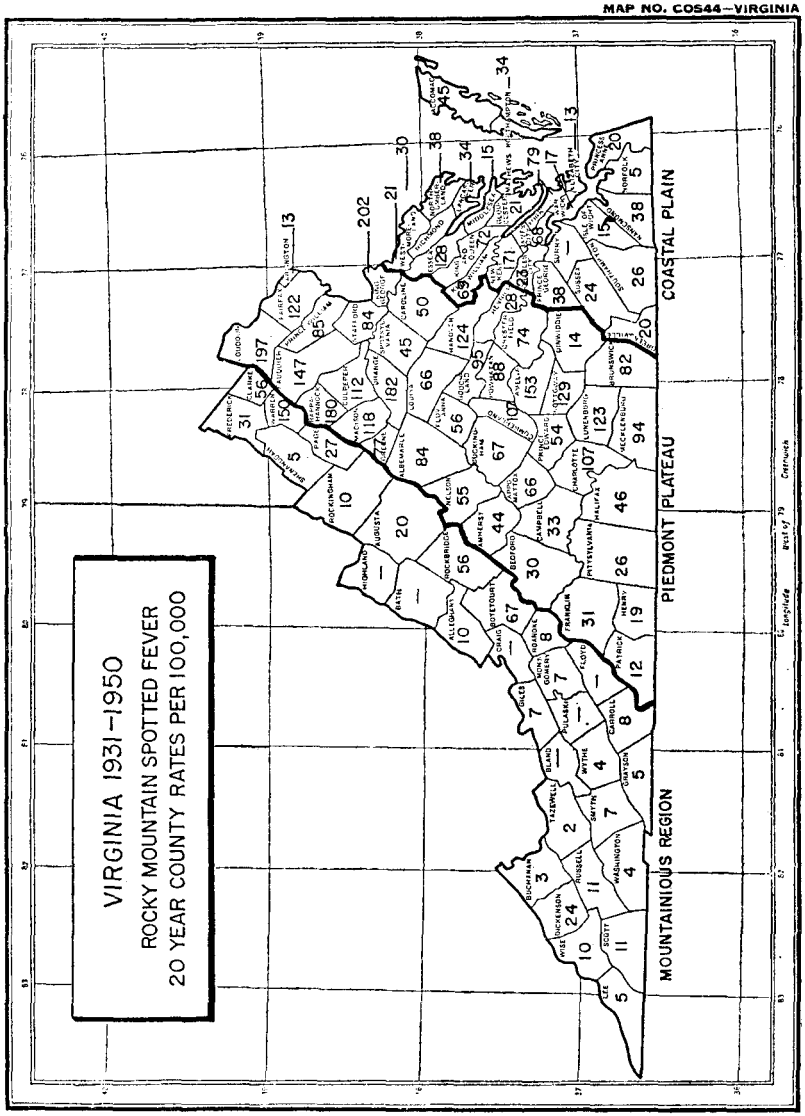

Fig. 3. Distribution of Rocky Mountain spotted fever in Virginia. Rates per county calculated per 100,000 population estimates of 1940 census for the 20-year period 1931-1950.