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Geographical Distribution and Density of *Ixodes dammini* (Acari: Ixodidae) and Relationship to Lyme Disease Transmission in New Jersey

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As part of continuing studies of Lyme disease, deer were surveyed during three hunting seasons in 1981 to obtain information on geographic distribution and density of *I. dammini* in New Jersey. *I. dammini* occurred throughout central and southern New Jersey. Four deer management zones (DMZs) were shown to have high tick densities. Geographical distribution and density data were independently regressed against 25 environmental and physical factors. Elevation was shown to be the most important factor in explaining the variability in both *I. dammini* distribution and density. Lyme disease cases were closely associated with the distribution of *I. dammini* and 57.3 percent of 117 Lyme disease cases occurred in the four DMZs previously identified as having the highest tick density.

INTRODUCTION

Lyme disease is an inflammatory disorder with a characteristic annular lesion, erythema chronicum migrans (ECM), which may be followed by arthritic, cardiac, and/or neurological manifestations. First described in Connecticut in 1975 [1], Lyme disease has since been reported from the Northwest, Wisconsin, Minnesota, and portions of the Northeast, including New Jersey, and has been epidemiologically associated with *Ixodes dammini* ticks [2,3,4]. Few reports existed in the literature regarding the geographical distribution of this species in New Jersey. As part of studies to evaluate the increased frequency of Lyme disease in New Jersey, we investigated the range and density of *I. dammini* throughout the state.

METHODS

The geographical distribution of *I. dammini* was determined by surveys of white-tailed deer (*Odocoileus virginianus*) killed by licensed hunters on 26 September, 7 December, and 16 December 1981. Tick densities were determined using the 7 December 1981 data only. New Jersey hunting regulations require that all legally

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killed deer be brought to check stations where precise locations of kill within deer management zones (DMZs) are recorded. New Jersey's 36 DMZs and the check stations surveyed are shown in Fig. 1. Trained personnel were assigned to 9, 17, and 10 check stations on the three survey days, respectively. Several check stations which historically processed a large number of deer from a wide geographical area were used for two or all three surveys. In addition, several taxidermists submitted ticks from deer taken on the survey days.

Investigators and taxidermists examined each deer for ten minutes, removed and retained all ticks from the head and neck (including ears) of each deer, and recorded the location of kill. Representative specimens were identified at the National Institutes of Health, Rocky Mountain Laboratories, Hamilton, Montana [Keirans JE: personal communication].

For the purposes of statistical manipulation, a DMZ was included in the range of *I. dammini* if one or more specimens were obtained from that DMZ on any of the survey days. Within the established range of *I. dammini,* statistical differences in tick density between DMZs were tested using a single factor analysis of variance (ANOVA). Subsequent statistical testing employing the Student, Newman, Kuels (SNK) Multiple Range and Least Significant Difference (LSD) procedures permitted us to classify data into high, moderate, and low *I. dammini* density DMZs.

Geographical distribution and density of *I. dammini* by DMZ were regressed

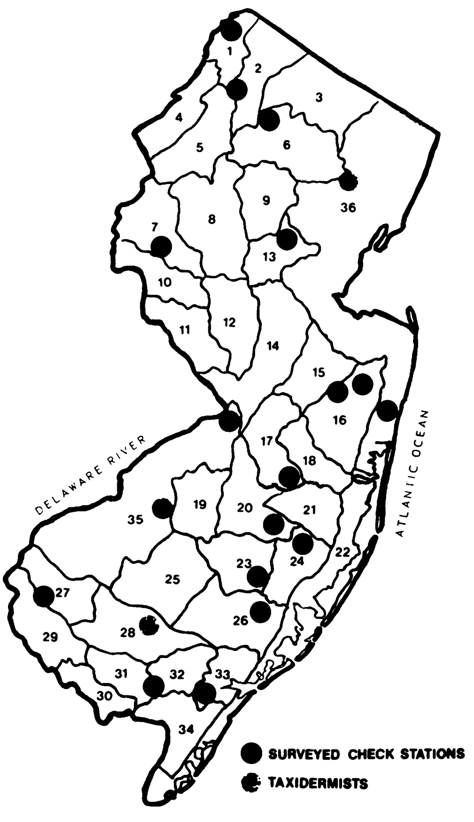

FIG. 1. Location of surveyed deer check stations.

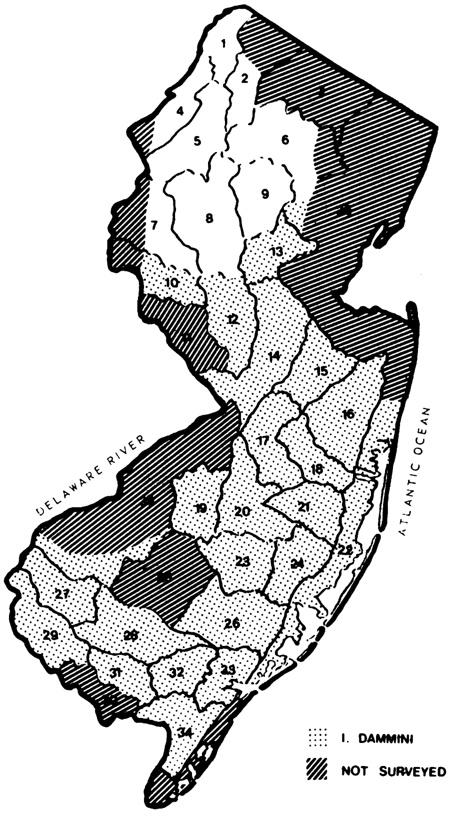

FIG. 2. Geographical range of *Ixodes dammini.*

against a variety of independent physical and environmental parameters. These variables were grouped into five categories: *(1)* climatology, *(2)* land use patterns, *(3)* demography, *(4)* physiography, and *(5)* zoogeography. The factors in each of these categories have been previously described [5].

Lyme disease has been reportable in New Jersey since 1980; all known cases occurring since 1978 have been carefully monitored. Whenever possible, locations of likely exposure to ticks have been elicited from patient interviews. The locations of these case exposures were plotted by DMZ.

RESULTS

Geographical Distribution of I. dammini

I. dammini were removed from 46.0 percent of 567 surveyed deer. The geographical distribution of *I. dammini* is shown in Fig. 2. The hash-marked sections of DMZs 3, 11, 25, 30, 35, and 36 represented either highly urbanized areas or portions of zones where no deer were killed on the survey days. *I. dammini* were found in the southern two-thirds of the state, encompassing DMZs 10, 12, 13, and all surveyed areas farther south.

Identification of the various factors affecting the observed geographical distribution was attempted by regressing 25 variables against the presence of *I. dammini* by DMZ. The observed variability in distribution was best explained by a single factor, elevation (coefficient of determination: $R^2 = 0.8831$, F = 211.64, d.f. = 1,28, $p < 0.0001$). The inclusion of additional variables did not appreciably enhance the model.

Certain physiographic regions of New Jersey are marked by distinct changes in elevation (Fig. 3) [6]. Figure 4 shows the geographical distribution of *I. dammini* superimposed over the five physiographic regions of New Jersey. The range of *I. dammini* closely follows the border between the Highlands and Piedmont regions where a dramatic change in elevation occurs.

Density of I. dammini

On 7 December 1981, 375 deer were surveyed for ticks. The mean density of *I. dammini* for all deer (infested + non-infested) was plotted by DMZ. Least signifi-

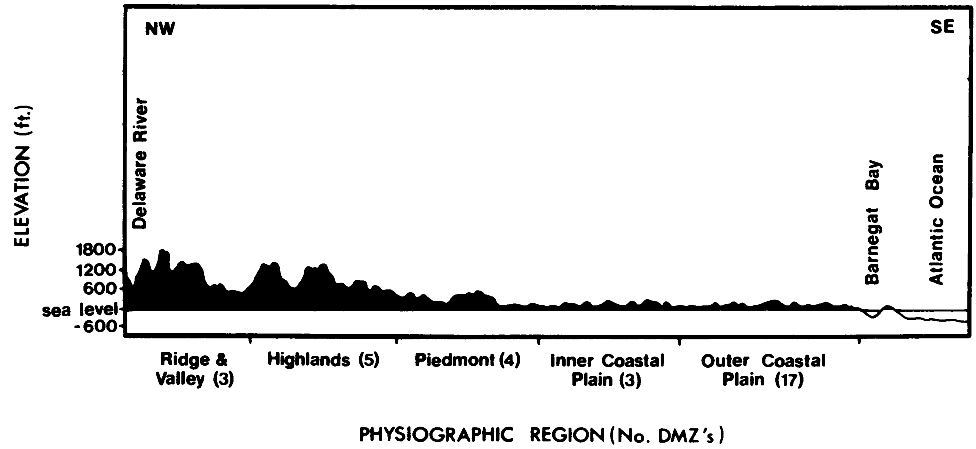

FIG. 3. Topographic cross section of New Jersey (NW to SE).

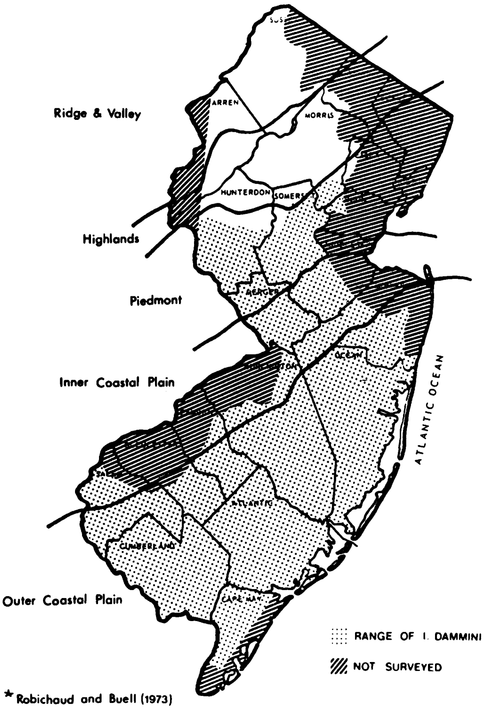

FIG. 4. Physiographic regions of New Jersey and relation to *I. dammini* range.

cant differences were calculated and constructed around each mean for *I. dammini*. Within the range of this species, the use of SNK and LSD procedures permitted the statistical categorization of each DMZ into low (0–4.9 ticks/deer), moderate (5.0–9.9 ticks/deer) and high (>10 ticks/deer) tick density. The respective density classifications by DMZ are presented in Fig. 5. Although only portions of some DMZs were surveyed due to hunting success, accessibility, and urbanization, the entire zone was included in the evaluation of *I. dammini* density on deer if one or more specimens were obtained from any portion of the DMZ.

In this survey, no deer were examined from DMZs 3, 11, 25, 30, and portions of 22, 35, and 36. DMZs 16, 19, 28, and 33 showed high *I. dammini* densities; DMZs 15, 20, 22, 26, 27, and the southern portion of 36 were classified as having moderate tick densities; and DMZs 10, 12–14, 17, 18, 21, 23, 24, 29–32, 34, and 35 were considered low density areas. DMZs 1, 2, and 4–9 were not within the range of *I. dammini*.

As with *I. dammini* distribution, the density data were regressed against 25 physical and environmental factors. The best one-variable model explaining *I. dammini* density by DMZ included elevation and accounted for 38.68 percent (R^2 = 0.3868) of the observed variability. The addition of two deer density variables (number of deer per DMZ and numbers of deer in undeveloped areas per DMZ) increased the R^2 to 0.4906. The inclusion of other variables did not appreciably increase the R^2.

Geographical Distribution of Lyme Disease Cases (LD Cases)

Between 1978 and 1982, 117 cases of Lyme disease were reported from New Jersey. As part of surveillance, patients provided locations of known or likely exposure to ticks. The locations, presented in Fig. 6, then, do not necessarily represent place of residence.

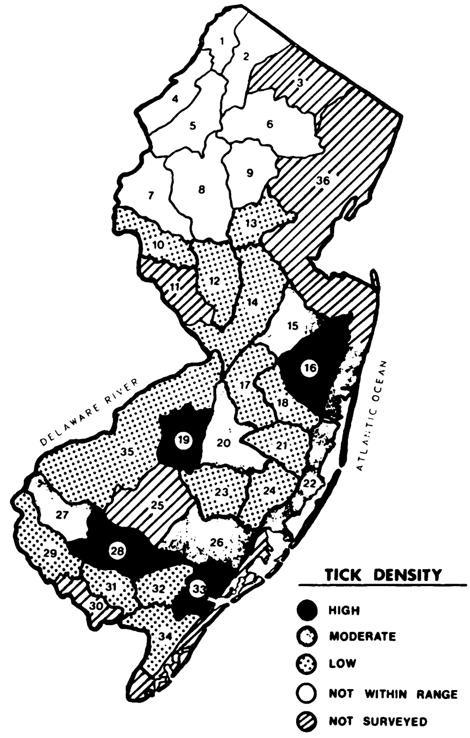

FIG. 5. *Ixodes dammini* density on deer by deer management zones of New Jersey.

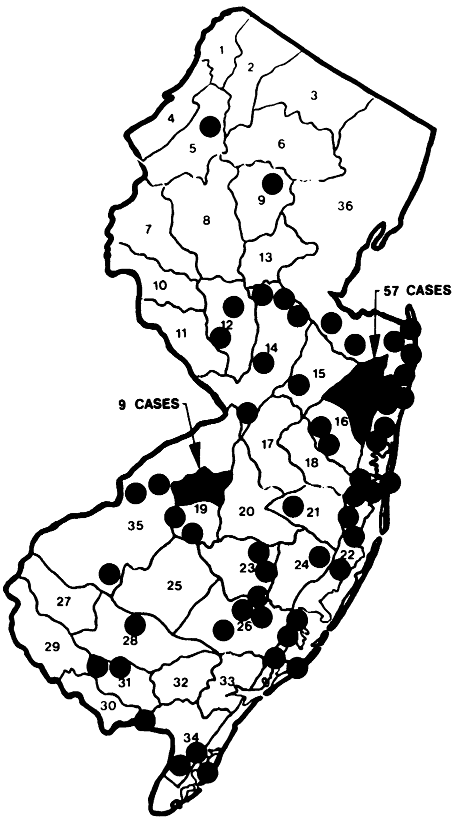

FIG. 6. Distribution of sites where Lyme disease cases were exposed to ticks (1978–1982).

DISCUSSION

From our survey of deer for ticks, we were able to identify the geographical distribution of *I. dammini* in New Jersey. Elevation accounted for a high proportion of the observed variability of *I. dammini* occurrence within the state. While this was shown to be the most important variable, it is unlikely that elevation per se could effect such a major influence on tick range. Rather, we believe that elevation represents the complex interaction between climate, physical factors, and biota of a particular physiographic region.

Various hypotheses have been offered to explain varability in *I. dammini* distribution. Previous research has addressed the influence of climate [7], deer population dynamics [8,9,10], behavioral differences in hosts [11], and a distance-elevation index [12]. From our statewide study, we evaluated how these and other factors influenced *I. dammini* range over a much wider geographical area than previously attempted. In our survey, any tendency for local conditions to have a disproportionate effect on tick populations would be minimized.

The effect of climate on the range of *I. dammini* was evaluated in our analysis. Minimal statewide differences in annual rainfall, mean seasonal temperature, and so on may have accounted for our inability to demonstrate climatologic influences on *I. dammini* range. Climatologic variables, particularly when considered individually, had little apparent effect on distribution of this species.

The theory that deer population dynamics is a major factor affecting the geographical distribution of *I. dammini* was also not supported by our data. For the theory to be valid, deer density within the range of *I. dammini* in New Jersey would have to be greater than in those areas where the tick is absent. A comparison of deer density of DMZs [Burke D: personal communication] within the range of *I. dammini* ($\bar{x}$ = 6.98 deer/km^2, n = 22) and outside the range of this species ($\bar{x}$ = 10.6 deer/km^2, n = 8) revealed that deer density is significantly greater (t = 1.82, 28 d.f., $p < 0.05$) in the northern portion of the state where *I. dammini* have not been collected to date. Deer abundance, therefore, appears to have limited influence on the geographical distribution of this species in New Jersey.

Within the range of *I. dammini*, we demonstrated statistical differences in tick density by DMZ. Statistically higher *I. dammini* densities were found in four DMZs including DMZ 16, the location of the first recognized Lyme disease focus in New Jersey [13,14]. As with *I. dammini* distribution, regression analysis showed elevation to be the single most important variable. Deer density, while having little effect on *I. dammini* distribution, was shown to influence tick density by DMZ, presumably by increasing host availability.

Density data were pooled by physiographic region and subjected to ANOVA. Tick density within the Outer Coastal Plain was higher but statistically equivalent to that of the Inner Coastal Plain and statistically different from the remaining physiographic regions. It is interesting to note that of the 117 Lyme disease cases identified between 1978–1982 [13], 96 (82.0 percent) were acquired within the Outer Coastal Plain. One hundred and eleven of 117 cases (94.9 percent) occurred in the combined areas of the Inner and Outer Coastal Plains. Furthermore, the majority of all four high density DMZs fall within the Outer Coastal Plain.

The geographical distribution of Lyme disease cases in New Jersey appeared to correlate well with the range of *I. dammini.* Within the range of the tick, foci of Lyme disease cases were closely associated with DMZs of greatest tick density. The four highest tick density DMZs accounted for 57.3 percent of the Lyme disease cases in New Jersey.

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