

Seasonal Variation in Nymphal Blacklegged Tick Abundance in Southern New England Forests

SARAH E. RODGERS,¹ NATHAN J. MILLER, AND THOMAS N. MATHER²

Center for Vector-Borne Disease, University of Rhode Island, Kingston, RI 02881

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ABSTRACT In the northeastern United States, risk of human exposure to tick transmitted disease is primarily a function of the abundance of the blacklegged tick, *Ixodes scapularis* Say. We assessed seasonal variability in the abundance of nymphal stage *I. scapularis* over 13 yr, collected from several forested areas throughout Rhode Island. Specifically, we examined intraseasonal differences by using two temporally distinct tick collections made during the peak nymphal tick season. Intraseasonal factors significantly impacted tick abundance, with the June tick rate (mean = 40.42, SD = 14.79) significantly more abundant than the July tick rate (mean = 27.64, SD = 15.47). The greater variability in July (coefficient of variation: June, 36.61%; July, 55.95%) lead us to conclude June tick rates are relatively stable from year to year, whereas July tick rates contribute more to intraseasonal and yearly variation.

KEY WORDS tick abundance, Lyme disease, *Ixodes scapularis*, intraseasonal, variation

The blacklegged tick, *Ixodes scapularis* Say, is a vector for several diseases in eastern North America, including Lyme disease, the most frequently reported vector-borne disease in the United States. Reports suggest that tick abundance is proportional to Lyme disease cases (Fritz et al. 1996, Mather et al. 1996, Stafford et al. 1998). As an important disease vector, knowledge regarding variation in nymphal tick abundance is vital for focusing disease prevention measures and for aiding disease-modeling efforts. The nymphal stage of the tick is most efficient at disease transmission due partly to its small size, which increases the probability that a nymphal tick encounter will transmit the Lyme borreliosis spirochete, *Borrelia burgdorferi*, before detection and removal (Barbour and Fish 1993, Yeh et al. 1995).

The summer peak of nymphal tick abundance in the northeastern United States exacerbates disease transmission rates because of increased human exposure during outdoor activities at this time of year. Ideally, tick-bite risk should be communicated to the general public frequently and at high spatial resolution. Providing near real-time risk information for locations relevant to the general public is likely to be essential for encouraging disease prevention. However, tick abundance collections are labor-intensive and therefore expensive; it is intractable to measure tick abundance nearly continuously at all relevant locations.

Also, the delay involved in translating data into a readily interpretable format quickly renders the information obsolete for the purpose of risk communication. Instead, a predictive tick risk model that uses readily available landscape and weather data, if available, could provide for such a near real-time tick risk forecast. Enabling technologies such as remote sensing also could be useful in extending predictions over larger regional areas once the appropriate suite of predictive variables are identified and the model is validated (Hay et al. 2000, Rodgers and Mather 2006). Increased knowledge of within-season dynamics in nymphal *I. scapularis* abundance will allow a better understanding of tick ecology and potential bite risk for humans.

We have maintained a continuous database of tick abundance since 1993. This standardized collection of nymphal ticks over a 12-yr period provides an important data set that may be analyzed to answer a number of questions about the variability of ticks in Rhode Island in time and space. The distribution of nymphal *I. scapularis* within seasons by using data from several years has not previously been documented. This report describes the seasonal variation in nymphal tick abundance by using data from the Rhode Island State-wide Deer Tick Survey collected between 1993 and 2004. Two rounds of samples were collected during the season of nymphal activity at permanently sited locations. We assessed whether round 2 nymphal tick rates were significantly different from similarly collected round 1 nymphal tick rates, and we examined the variability of ticks for each collection round over the 12-yr period.

¹ Current address: Centre for Health Information Research and Evaluation (CHIRAL), School of Medicine, Swansea University, Singleton Park, Swansea, SA2 8PP United Kingdom.

² Corresponding address, e-mail: tmather@uri.edu.

Materials and Methods

An extensive nymphal tick surveillance program has been in continuous operation since 1993, with sampling taking place at >60 locations throughout Rhode Island (Rodgers and Mather 2006). Nymphal tick collections were made using a standard protocol at these sites (Nicholson and Mather 1996). Forested areas suitable as tick habitat were drag-sampled and simple totals of tick counts at each site were averaged and converted into a standardized rate of nymphs per hour. Our previous work showed that intersite tick abundance is spatially autocorrelated, and a variogram was used to inform a kriging process to create an interpolated tick abundance surface (Rodgers and Mather 2006).

Two rounds of tick abundance samples were collected each year (1993–2004). Samples were taken each year within the same time period, which includes the peak of nymphal tick activity (Daniels et al. 2000). Nymphal tick abundance rates were calculated based on two-round averages from a timed survey at sites located throughout Rhode Island. Round 1 was sampled from late May to the end of June, and round 2 was sampled from the beginning to the end of July; two rounds of data effectively capture nymphal tick abundance on either side of the peak. Each of the 60+ sites was visited only once per round due to time limitations; in each year, sites were given a random order and sampled in the same order for both rounds. This research also used the rate of nymphal ticks per round for each site. Annual tick abundance rate data from Rhode Island sites were coded into groups according to collection round (round 1, May–June or round 2, July). A paired *t*-test was conducted to explore the effect of round (intra-seasonal effects) on nymphal tick rate by using data from each year (round 1, $n = 12$; round 2, $n = 12$). This test takes into account the within-year correlations for observations made on the same sites. An *F*-test was used to formally compare variances of round 1 with those of round 2.

Results

Nymphal tick abundance per round for each year is shown in Fig. 1. From 1993 to 1999, we observed a seemingly biannual distribution of tick abundance, with odd numbered years having decreased abundance. However, this pattern dissipated in more recent years, and attempts to match tick abundance with several climatic drivers, for example, rainfall totals, have not yielded significant results. Each year except 2004 had a lower nymph per hour collection rate in round 2. The data were examined using Q-Q plots, and they do not significantly deviate from a normal distribution. The same results were obtained using nonparametric tests. There were significant differences in tick abundance for the different collection rounds. On average, there were 12 more nymphs per hour collected in round 1 than in round 2 (40 and 28 ticks per hour, respectively; $P = 0.0001$). Round 1 was also less variable than round 2; the standard deviation for round 1 is 14.79 and for round 2 is 15.47; the coefficient of variation for each of rounds 1

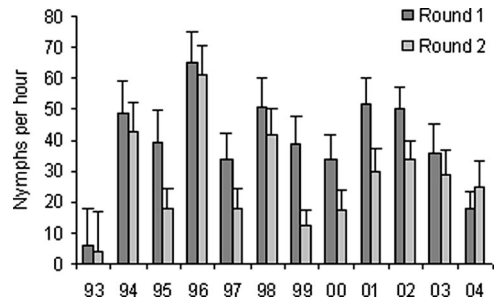


Fig. 1. Average nymphs per hour for round 1 (late May–June) and round 2 (July) collections for each year. Collection rate average from >60 forested sites in Rhode Island (1993–2004). Error bars of standard deviation.

and 2 is 33.61 and 55.95%. However, an *F*-test showed that these differences were not statistically significant ($F_{2, 12} = 2.82$; $P = 0.46$).

Discussion

The significantly more abundant but less variable round 1 tick rates for 1993–2004 suggest that round 1 tick data will be reliable as a starting point for estimating future tick abundance. In particular, when round 1 nymphal tick rates are averaged over a number of years, this historical figure is likely to be sufficiently stable for use as a baseline for seasonal modeling efforts. It seems, based on these data, that tick abundance rates are more similar each year at the beginning of the season before weather conditions less conducive to tick activity and survival exert their influence. In contrast, we observed a greater degree of variability in round 2 nymphal tick abundance, suggesting that these rates might be an important indicator of above-average annual nymphal tick rates in comparison with June tick abundance; however, this result was not statistically significant. It is therefore important that, depending on the use of the observation, care be taken to choose either round 1 or 2 tick abundance measurements, as appropriate for the intended use. Certainly, measurements from either collection round should not be used interchangeably for the same purpose.

Recent work has suggested that interannual variability in the abundance of nymphal *I. scapularis* are determined by biotic factors such as host availability (Ostfeld et al. 2006). There also is evidence suggesting that predetermined factors such as photoperiod have a large impact on the timing of tick emergence (Belozero et al. 2002). It seems likely that within-season variability in nymphal tick abundance should be attributed to factors influencing the tick environment over a shorter time frame. We suggest that the reason that round 2 nymphal *I. scapularis* activity in southern New England forests is less than in round 1 is that these ticks will likely be exposed for a longer duration to a greater range of more hostile prevailing weather conditions, including warmer temperatures and sub-optimal atmospheric moisture, resulting in unfavorable

conditions for tick survival. Conditions in New England may be relatively cool in June (30-yr climate average: June, 19.3°C; July, 22.6°C) with lower dew-points, in which case tick populations will have a greater chance of survival. However, a dry, hot July might restrict tick populations even within what is considered ideal habitat on a national scale (Estrada-Pena 2002, Brownstein et al. 2003). Host populations, particularly deer, are able to withstand more variable weather conditions because of their greater mobility and larger physical reserves. Ticks, however, are restricted to small areas, and they may quickly be susceptible to desiccation or fungal growth (Bunnell et al. 2003). Ticks in the latter part of the season may be more susceptible to suboptimal survival conditions (e.g., <82% humidity; Stafford et al. 1998, Rodgers et al. 2007), and longer periods of drought may permanently reduce yearly tick populations (Jones and Kitron 2000). If lack of moisture or other environmental stressors do not result in tick mortality, ticks might instead retreat into quiescence and not actively quest, and thus not be available for collection (Perret et al. 2003).

These results are based purely on statistical pattern matching, and ideally, future work will record weather conditions at each site to provide evidence of late-season weather variability and its influence on variation in nymphal *I. scapularis* abundance. Many complex interactions and dynamics can result in changes in tick abundance from temporal microclimatic variations to longer term, slowly changing factors such as land use and landscape fragmentation. In addition, resulting tick-transmitted disease, the ultimate focus of these types of studies, is the product of many complex social factors (Barbour and Fish 1993). However, these data suggest that variable late-season nymphal tick abundance may be worthy of further exploration by using environmental covariates such as relative humidity. Previous work has acknowledged that spatial variation in nymphal *I. scapularis* populations throughout Rhode Island is significant (Rodgers and Mather 2006), and this work adds to our knowledge that the sample timing, in addition to sample location, is an important consideration.

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