Mark and recapture analysis of mammal density and its impact on tick prevalence and the spread of Lyme disease

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Abstract

Lyme disease (LD) is the most common vector-borne disease in North America; it is transmitted to humans primarily by the nymphal stage of blacklegged ticks (*Ixodes scapularis)*. In the eastern U.S., persistence of Lyme disease depends mostly on white-footed mice (*Peromyscus leucopus*) as they are common hosts for larval and nymphal blacklegged ticks and are highly competent reservoirs of the LD agent, *Borrelia burgdorferi* (Levi et al. 2012). We attempted to test 3 hypotheses: 1) that white-footed mice densities are positively associated with *Ixodes* tick densities; 2) that white-tailed deer densities are only correlated with *Ixodes* tick population densities when deer densities are low and 3) that red fox densities are negatively associated with small mammal densities. We collected relevant data in BNL's Pine Barrens ecosystem. We used live traps for small mammals (2048 trap nights), uniquely marked and removed ticks from captured mice, and collected ticks by flagging each site. Ticks were categorized by species and life stage. We used camera traps to monitor the abundance of other mammals such as deer and red fox. We found that there was a significant positive linear relationship between the density of mice and amount of nymphal *Ixodes* at each site. Therefore, if coyotes were to emerge in Long Island and prey on red foxes, it is expected that there would be an increase in the density of white-footed mice and in the amount of *Ixodes* ticks.

Introduction

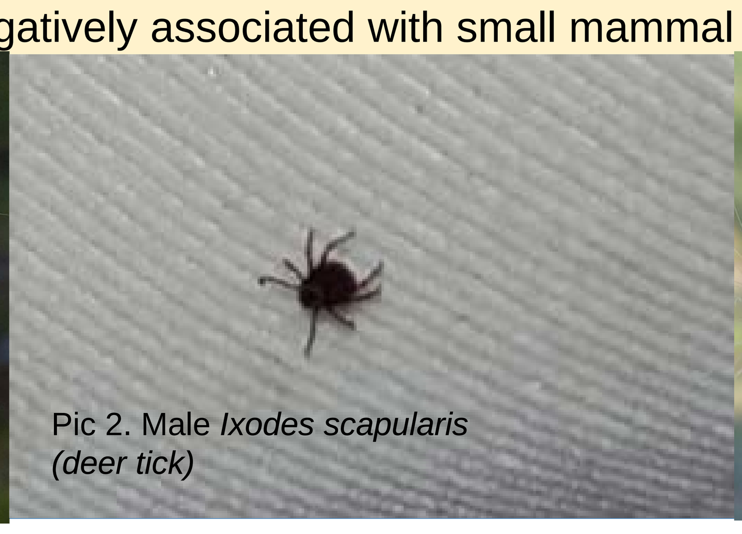
Increasing medical cases in northeastern United States indicate that Lyme disease (LD) is the most common tick-borne disease in the country. LD is transmitted to humans primarily by the nymphal stage of blacklegged ticks (*Ixodes scapularis*), these ticks also feed on a wide variety of birds, mammals, and lizards. It is important to understand the dynamics of ecological systems that affect tick populations and the LD agent, *Borrelia burgdorferi*, if we are to reduce LD cases in humans.

This research project involves testing Levi et al. (2012)'s hypotheses involving the relationships between coyotes, deer, red fox, small mammals, Ixodes ticks, and LD. We did this by measuring the abundance of white-footed mice, *I. scapularis* ticks, white-tailed deer, and red fox at four plots at BNL. In particular, we examined the relationship between the numbers of *I.scapularis* ticks at different life cycle stages found on white footed mice populations.

Hypotheses:

H_1: White-footed mice populations are positively associated with *Ixodes* tick population densities.
H_2: White-tailed deer densities are only correlated with *Ixodes* tick population densities when deer densities are low.
H_3: Red fox densities are negatively associated with small mammal densities.


Pic 1. *Peromyscus leucopus*


Pic 2. Male *Ixodes scapularis* (deer tick)


Pic 3. *Microtus pinetorum*

Methods

Study Area: Brookhaven National Laboratory, Long Island, New York
Study Period: June 14, 2016 to July 16,2016
Small Mammal Surveys:
At each of the four sites we established an 8x8 grid of Sherman traps spaced 5 meters apart, 64 traps per grid. Traps were baited with a peanut butter/oat mixture. Animals were trapped at each site over four consecutive nights during alternate weeks for a total of 8 days (or 512 trap nights/site, 2048 total trap nights). Traps were checked each morning, captured animals were weighed, sexed, and marked with individual ear tags. All attached ticks were removed and preserved. We collected ticks directly by flagging twice at each corner of the four sites for one minute intervals. The number and life stage of each tick species were later determined in the lab.

Camera Methods:
- 4 camera traps were set up at each site to monitor the appearance of other mammals
- Scented discs were used to attract mammals

Analysis:
- Program MARK Version 8.1, robust design model was used for a parameter estimate of white-footed mice abundance at each site (Cooch and White 2006).
- Program DENSITY Version 5.0 was used to predict the size of white-footed mice population within the surrounding hectare using the spatially explicit capture-recapture data collected (Efford 2012).
- Tick prevalence was assessed calculating the proportion of mice with at least one attached tick.


Pic 4. White-tailed deer (*Odocoileus virginianus*) captured on camera.


Pic 5. Example of tick flagging


Pic 6. Handling of *Tamias striatus* (eastern chipmunk)

Results

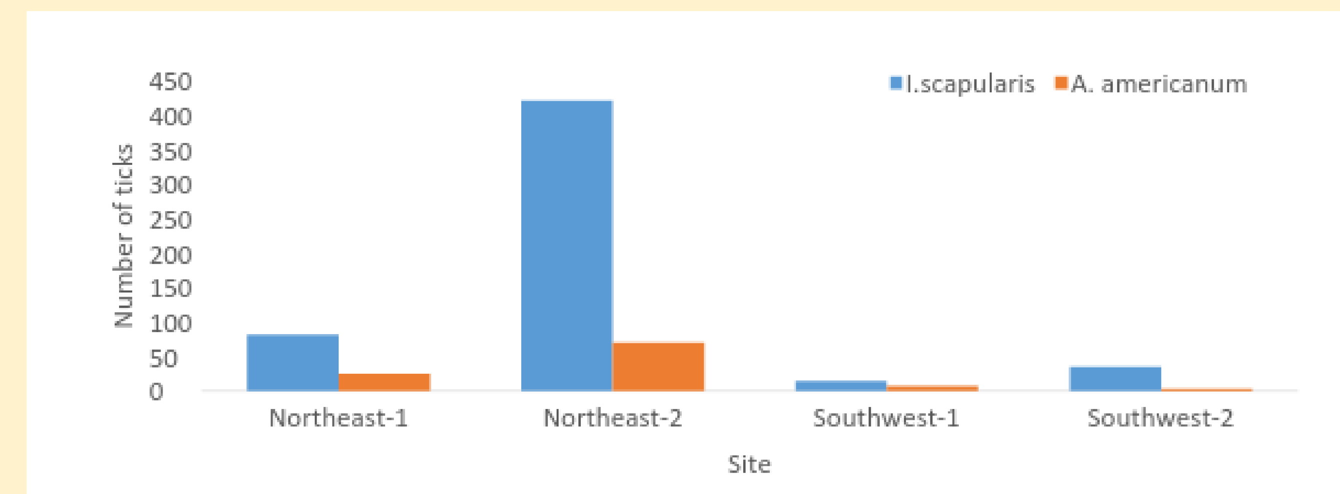


Figure 1 Number of ticks collected from captured mice by tick species (n=663).

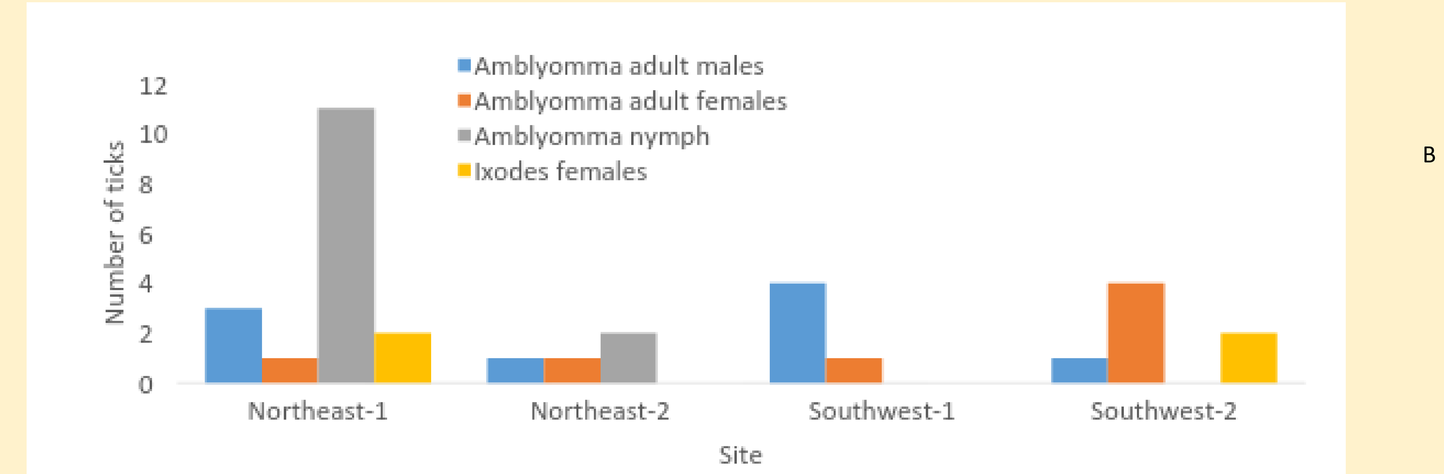


Figure 3 Number of Ticks collected by tick flagging categorized by tick species and tick life stage (n=33).

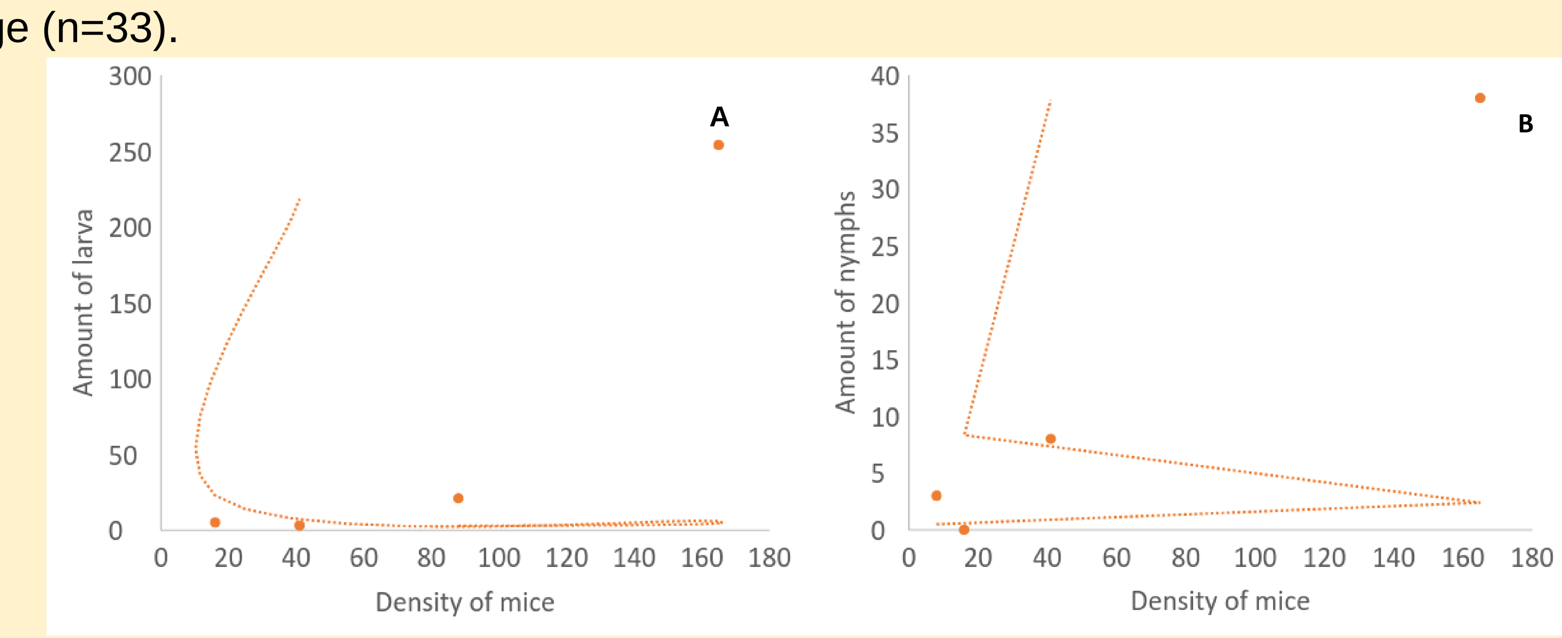


Figure 4 A. Amount of larva in relation to the density of mice at each site (R^2= 0.93, t(3) = 3.21, p = 0.08, n= 663). B. Amount of nymphs in relation to the density of mice at each site (R^2= 0.99, t(3) = 12.19, p = 0.007, n=663).

Abundance and Density:	**Tick prevalence:**
Northeast-1: 48; 88	27.45%
Northeast-2: 75; 165	47.88%
Southwest-1: 10; 16	21.74%,
Southwest-2: 26; 41	38.32%

Additionally, very few deer and no foxes were captured on camera.

Discussion

- The population of ticks found from flagging may not reflect ticks found on small mammals in the area.
- Density of mice in one hectare has a significant positive linear relationship with amount of *Ixodes* nymphs.
- Increase in coyote population may have indirect positive relationship with Lyme disease rates.
- Future studies should try to obtain data on deer and red fox populations relationship with tick density.

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References

Cooch, Evan, and Gary White. "Program MARK: a gentle introduction. D*ownloaded at http://www. phidot. org/software/mark/docs/book* (2006).
Efford, Murray G. "DENSITY 5.0: software for spatially explicit capture–recapture." *Department of Mathematics and Statistics, University of Otago, Dunedin, New Zealand http://www. otago. ac. nz/density* (2012).
Frank, Denise H., Durland Fish, and Fred H. Moy. "Landscape features associated with Lyme disease risk in a suburban residential environment." *Landscape Ecology* 13.1 (1998): 27-36.
Hersh, Michelle H., et al. "Reservoir competence of wildlife host species for Babesia microti." *Emerg Infect Dis* 18.12 (2012): 1951.
Lane, R. S., J. Piesman, and W. Burgdorfer. "Lyme borreliosis: relation of its causative agent to its vectors and hosts in North America and Europe." *Annual review of entomology* 36.1 (1991): 587-609.
Levi, Taal, et al. "Deer, predators, and the emergence of Lyme disease. *Proceedings of the National Academy of Sciences* 109.27 (2012): 10942-10947.
"Lyme Disease." Centers for Disease Control and Prevention. Centers for Disease Control and Prevention, 18 Nov. 2015. Web. Accessed 12 Apr. 2016. <http://www.cdc.gov/lyme/index.html>.
Maloney, Elizabeth. "What Every Primary Care Clinician Should Know About the Diagnosis of Lyme Disease." *The Taproot* 24.2 (2015).
Ostfeld, Richard S., Clive G. Jones, and Jerry O. Wolff. "Of mice and mast."*BioScience* 46.5 (1996): 323-330.
Roy-Dufresne, Emilie, et al. "Poleward expansion of the white-footed mouse (*Peromyscus leucopus*) under climate change: implications for the spread of Lyme disease." *PloS one* 8.11 (2013): e80724.
Tilly, Kit, Patricia A. Rosa, and Philip E. Stewart. "Biology of infection with *Borrelia burgdorferi*." *Infectious disease clinics of North America* 22.2 (2008): 217-234.
Way, Jonathan G., and Bradley N. White. "Coyotes, red foxes, and the prevalence of Lyme disease." *Northeastern Naturalist* 20.4 (2013): 655-665.