Factors influencing fine-scale spatial distribution of questing hard ticks

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Abstract

Hard ticks (Acari: Ixodidae) are important vectors of disease and threaten public health. Increasing tick-borne disease (TBD) cases indicate a need for effective management.

Understanding tick spatial distribution can inform management and encounter risk. This study examines the most influential factors affecting questing ticks on a 1-m scale.

Tick-host temporal occurrence, microclimate, vegetation, and tick density was sampled. The predictor variables were analyzed with generalized linear mixed models.

The results will provide insights to tick spatial ecology at a biologically relevant scale. This study contributes to improved targeted strategies for reducing ticks and TBDs.

Methods

Study Region

- 20-ha of non-barren pitch pine-oak forest (Fig. 3)
- *Quercus*-dominated overstory with few *Pinus rigida* and an understory of *Gaylussacia baccata* and *Vaccinium pallidum*
- Infrequent fire regime
- High density of deer and other wildlife

Figure 3. Study forest contains a *Quercus*-dominated pitch pine-oak canopy in the Central Pine Barrens of New York

Sampling Design

- 8 plots, 3m x 15m in size (Fig. 4)
- Cameras captured host presence at each plot for 14 days (Fig. 5)
- Vegetation was sampled on a 1m x 1m scale over the 15m plot (Fig. 6)
- Microclimate data was collected passively with iButtons (Fig. 7)
- Tick drags were conducted, and all nymph and adult ticks were recorded (Fig. 8)

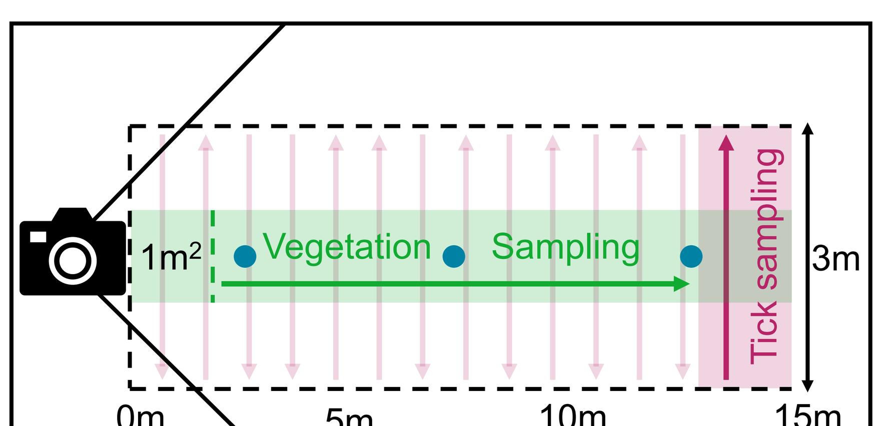

Figure 4. Visualization of plot sampling design. Vegetation sampling was conducted in the inner 1m² of the plot, while tick dragging was completed across 3m² meters, and microclimate was collected every 5m. The camera captured wildlife motion across the entire plot.

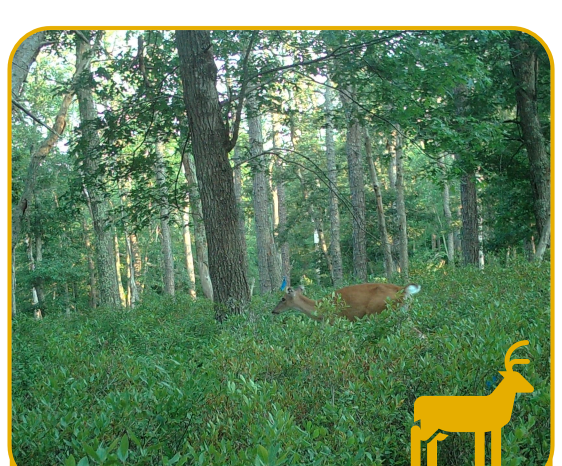

Figure 5. The temporal occurrence of hosts, like this white-tailed deer, were recorded using trail cameras at each plot

Figure 6. Over 11 vegetative variables were measured: canopy cover, shrub cover, and max. vegetation height

Figure 7. iButtons were deployed to passively record microclimatic conditions on a 2-day rotational schedule

Statistical Analysis

Generalized linear mixed model with a negative binomial distribution → **Set of 10 candidate models** → **Model selection with AIC**

Dependent variable Number of ticks

12 Independent predictor variables

Figure 8. Ticks were sampled using a cotton drag and checked and recorded separately for each 3m drag at each plot.

Introduction

- The three most prevalent hard ticks (Acari: Ixodidae) on Long Island are the lone star tick, deer tick, and dog tick (Fig. 1).
- These three species are responsible for most of the increasing number of TBD cases[1].
- Many studies have explored the distribution of ticks and TBDs across regional scales.
- However, few have explored what factors determine fine-scale tick spatial distribution.

Figure 1. From left to right: the Lone Star tick (*Amblyomma americanum*), American Dog tick (*Dermacentor variabilis*), and Deer tick (*Ixodes scapularis*). Image credit: CDC

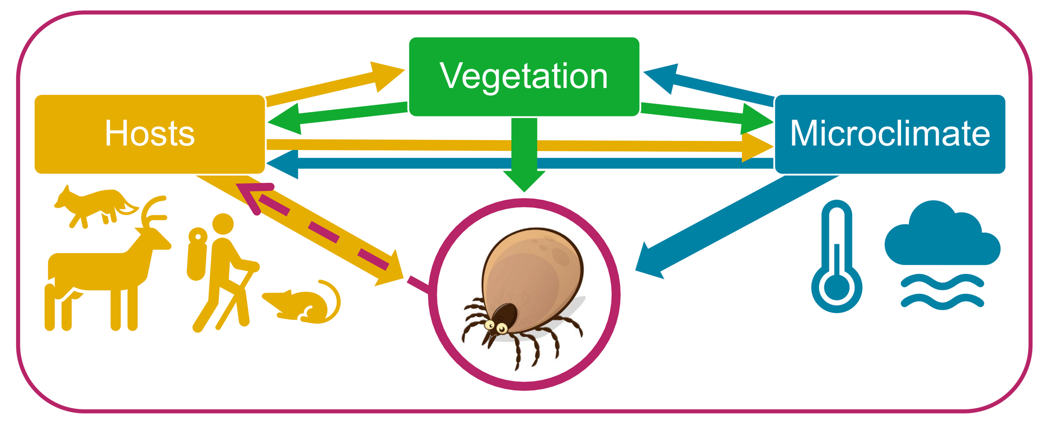

Figure 2. Tick ecology is shaped by host availability, vegetation structure, and microclimatic conditions.

- Tick distribution is related to tick survival, ecology, and questing behavior (Fig. 2).
- Tick populations thrive on high abundances of hosts like mice and deer, humid environments, and mild winters.

Objective

Determine the relative influence of tick-host temporal occurrence, microclimatic conditions, vegetative structure that affect tick questing to understand the spatial distribution of ticks on a fine scale (1-m resolution)

Results

15 predictor variables were used to develop 10 candidate models, and the null model with 1m² plots as a random effect was the most parsimonious model (Table 1).

Variation in tick abundance may be attributable to site-level random effects (Fig. 9).

Table 1. Model results of ten candidate models used to determine the influence of predictors on tick abundance on a fine scale; df is degrees of freedom; logLik is log likelihood

Model #	df	logLik	AICc	Delta AICc	Weight
null	3	-123.44	253.22	0.00	1
2	8	-127.37	272.92	19.71	0
6	9	-126.11	272.99	19.77	0
3	9	-126.13	273.03	19.81	0
4	8	-127.52	273.23	20.01	0
5	9	-127.20	275.16	21.94	0
8	6	-131.33	275.89	22.68	0
7	6	-132.45	278.14	24.93	0
1	11	-126.67	279.52	26.31	0
global	17	-124.77	294.28	41.06	0

Figure 9. Predicted mean number of ticks with subplot-level error bars for each site, demonstrating how each site differs in the number of ticks compared to the overall mean (red horizontal line)

Discussion

Understanding the relative influence of factors that influence the fine-scale spatial distribution of ticks can help inform targeted management strategies for ticks.

The interpretability of the results is limited by the high model complexity and low amount of data sampled. However, this study offers a methodology and integrative approach to better understand tick ecology.

Future work should expand on the methods created here and apply them in various landscapes and regions to determine the applicability of the results on a broader scale. Other landscape metrics and like distance to nearest water source or deer trails can be considered to understand fine-scale tick spatial distribution.

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