A Tick's Quest: The Effects of Climatic Stress on Wild Ticks

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Introduction

Ticks transmit more disease than any other arthropod vectors in North America and Europe. From 2004 to 2018, almost 600,000 cases of tick-borne diseases were reported in the United States, and annual numbers are increasing (Centers for Disease Control and Prevention 2019). There are many factors that influence the spread of tick-borne diseases, including **questing,** a host-seeking behavior in which a tick climbs vegetation and stretches its front legs to latch onto a passing host (Estrada-Peña and de la Fuente 2014). Therefore, understanding questing behavior is crucial for informing how to mitigate the spread of infectious tick-borne pathogens.

The lone star tick (*Amblyomma americanum*) has been historically prevalent in the southeastern United States, however it has expanded its geographic range both northward and westward over the last 50 years (Monzón et al. 2016). This indicates that lone star tick populations are establishing in areas where climatic conditions are more stressful than in their historic range, and stressful climatic conditions have been shown to affect the questing of ticks (Perret et al. 2004, Nielebeck et al. 2023). This is the first experiment on the effects of climatic stress on questing behavior in wild populations of lone star ticks from recently expanded areas.

This experiment aims to investigate whether sex or geographic origin affects questing behavior and the ability to survive stressful conditions.

Methods

- We collected lone star ticks at six sites across New York, New Jersey, and Oklahoma. We separated ticks by geographic origin and sex for the duration of the study.
- We filled 48 plastic containers with 6 plastic tubes each, drilling holes in the caps for air and using one bamboo skewer per tube to simulate natural terrain. We then placed one tick in each tube (**Figure 1**).
- We split each group (NY/NJ Male, NY/NJ Female, OK Male, and OK Female) equally into three relative humidity (RH) categories: 32%, 58%, and 84%.
- We used Boveda 2-way humidity packets to control RH.
- We placed all containers in an environmental chamber programmed to cycle between 25°C and 35°C daily with a 15:9 light-to-dark photoperiod to simulate summer.
- We checked all ticks daily for 30 days when the temperature was 35°C, recording if they were alive and questing.
- We recorded the mass of each tick at the beginning of the experiment when they were fully hydrated, and again on the day of death from dehydration.

Figure 1: Airtight bin filled with tubes, skewers, ticks, RH packet, and a HOBO temp/RH logger. Photo from Kim et al. 2022

Discussion

We found that relative humidity had a significant effect on survivorship, consistent with our previous studies (Kim et al. 2022, Nielebeck et al. 2023). However, when comparing survivorship of ticks from different geographic origins, we observed that Oklahoma males are hardier than New York/New Jersey males.

Interestingly, Oklahoma females – not males – had a higher dehydration tolerance than any other group, being able to tolerate tolerate ~3% more dehydration. Further research is necessary to investigate potential factors responsible for these sex- and region-specific differences in hardiness and dehydration tolerance.

When examining host-seeking behavior, males quested almost twice as frequently as females in both OK and NY/NJ. This discovery is relevant to public health because more questing results in more disease spread (Estrada-Peña and de la Fuente 2014). More research is needed to determine the mechanistic causes and epidemiological implications of behavioral differences between male and female ticks.

We found no evidence that wild lone star ticks increase the rate of questing behavior as they get closer to death. Our results contradict those of Nielebeck et al. (2023) who conducted a similar study on three species of colony-reared ticks. The rate of questing as ticks approach death varies with temperature as well as whether a tick was bred in captivity. This indicates that ticks grown in a laboratory could exhibit different behavioral phenotypes or could be evolving different genotypes than wild ticks (Monzon et al. 2016), potentially due to the optimal conditions of the facility compared to the more stressful conditions encountered in nature.

Results

We analyzed how survivorship of the ticks is affected by RH, sex, and location. RH had the expected effect of reducing survivorship with decreasing humidity. Although females of both locations had similar survivorship curves, male survivorship was always higher for OK populations compared to NY/NJ males **(Figure 2).**

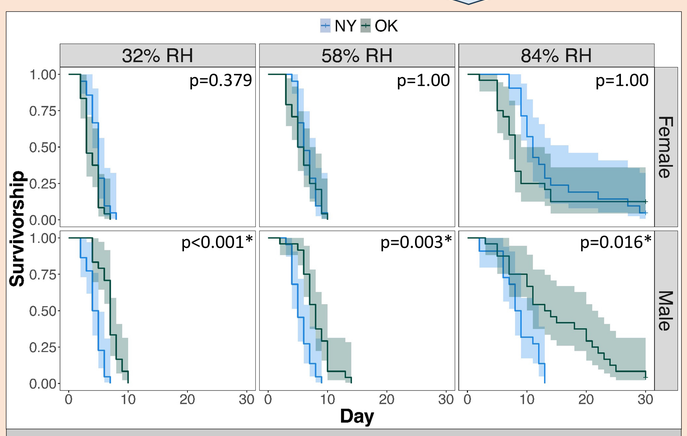

Figure 2: Comparison of survivorship of ticks between locations, organized by sex and relative humidity (RH). OK males survived stressful conditions longer than NY/NJ males.
* = p-values indicating significant difference at alpha = 0.05

Dehydration tolerance (DT) is calculated by dividing each tick's mass at the beginning of the experiment by its mass on the day it dies, representing its percent mass lost to dehydration at death.

Oklahoma females had a higher DT than both New York males and females, but were not significantly different from Oklahoma males **(Figure 3)**.

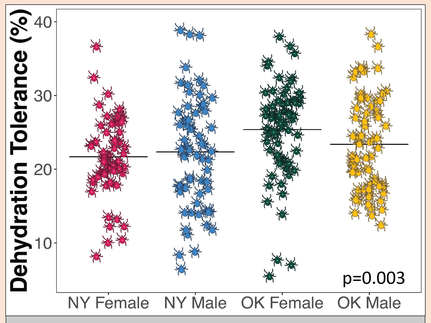

Figure 3: Dehydration tolerance by sex and location. Black lines indicate group means. Kruskal-Wallis p-value displayed.

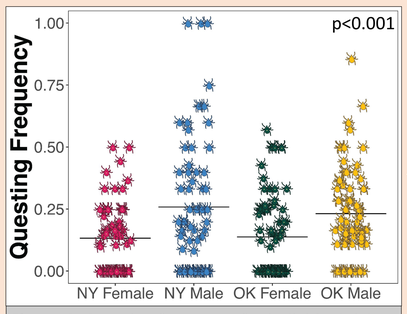

Figure 4: Questing frequency for individual ticks by location and sex. Black lines indicate group means. Kruskal-Wallis p-value displayed.

Questing frequency is the proportion of days each tick was observed questing.

Males quested more than females regardless of geographic origin (p<0.001), and location had no effect whatsoever (p=0.612) (**Figure 4**).

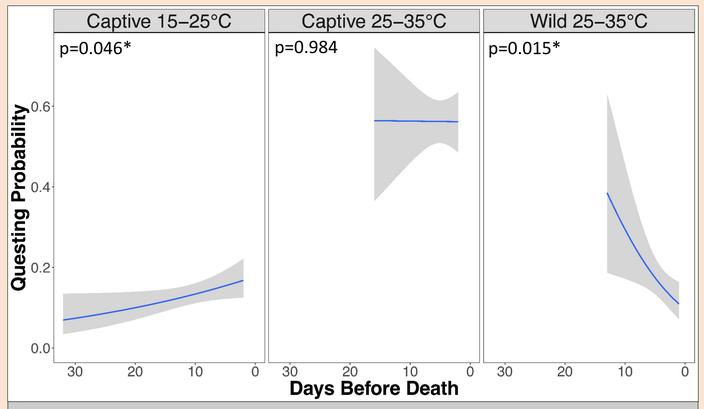

Figure 5: Probability that a female lone star tick quests as it approaches death. Left and middle panels plot data from Nielebeck et al. (2023). Right panel plots data from this study. Captive ticks were acquired from the Oklahoma State University Tick Rearing Facility; wild ticks were collected from three state parks in Oklahoma. Experimental temperature range is also noted above each panel.
* = p-values indicating significantly positive or negative relationships at alpha = 0.05.

Our data do not support the hypothesis that ticks quest more frequently as they approach death from dehydration stress. This contradicts the results of a similar experiment in this laboratory. Nielebeck et al. (2023) used captive ticks in two temperature ranges; we used wild-caught ticks in one temperature range.

When we partitioned the data from Nielebeck et al. (2023) by temperature range, only the ticks at the cooler range quested more frequently with increasing dehydration stress **(Figure 5)**.

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