Summer 7-21-2022

Victory for the vectors? Cilmatic stress decreases tick survival but increases host-seeking behavior

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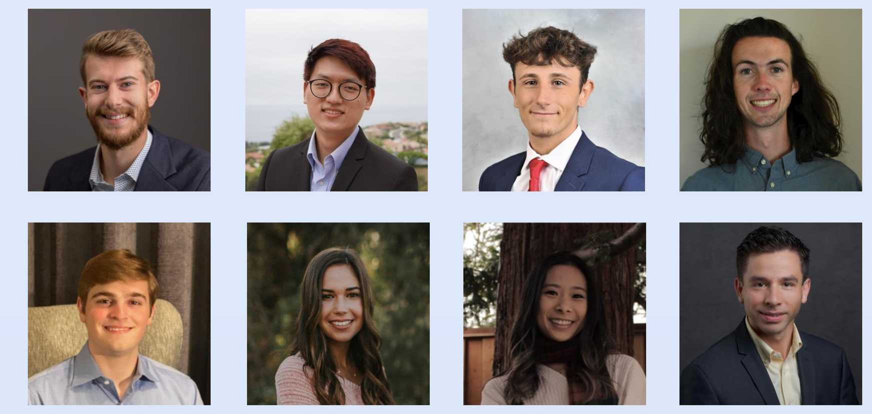


Introduction

Ticks are vectors of many diseases and their expansion into new areas is likely fueled by climate change[1,2]. However, it is unknown how ticks will fare in these new environments where they experience stressful climatic conditions. Therefore, we used a novel method to simulate climatic stress and evaluate the survival, behavior, and physiology of individual ticks belonging to three species - the lone star tick (*Amblyomma americanum*), the American dog tick (*Dermacentor variabilis*), and the black-legged tick (*Ixodes scapularis*).

These three species are the most medically important vectors of tick-borne pathogens in North America[1,3]. The lone star tick is a vector of several pathogens, such as ehrlichiosis and tularemia, and is the most frequent tick found attached to humans in the eastern United States. The American dog tick is the primary vector of the bacterium that causes Rocky Mountain spotted fever. The black-legged tick is the main vector of the bacterium that causes Lyme disease, the most common tick-borne disease in the United States.

To better understand how climatic stress affects the behavior and physiology of ticks, we conducted two stress experiments to assess how ticks respond in a variety of climatic conditions.

- **Hypothesis 1: Climatic stress reduces tick survivorship but enhances tick host-seeking behavior, especially as ticks experience increasingly life-threatening levels of water loss.**
- **Hypothesis 2: *I. scapularis* ticks have a lower dehydration tolerance (DT) or a higher net transpiration rate (NTR), thus accounting for their lower survivorship.**

Methods

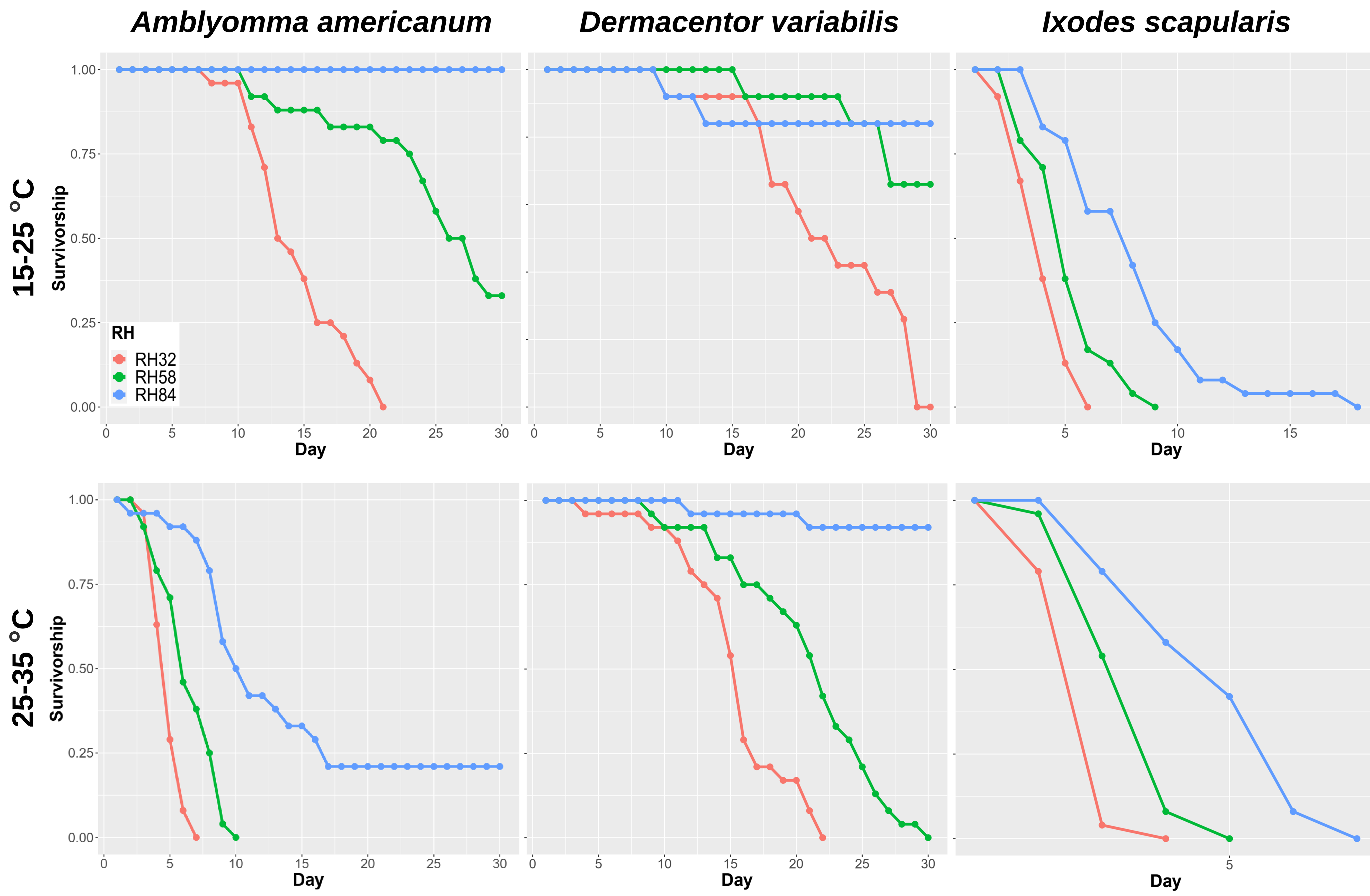
Experimental:

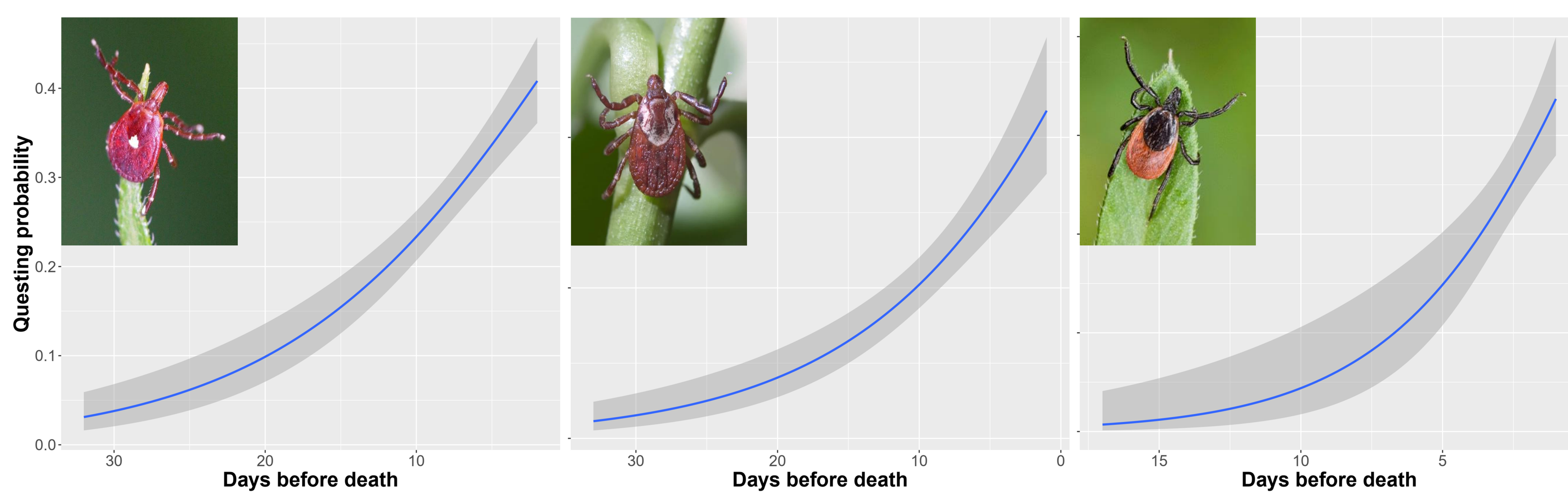
We invented a novel method of manipulating the climate of individual ticks by placing a tick into a plastic cylinder and placing six cylinders with a humidity pack into an airtight container. We used 144 adult female ticks of each species, subdivided into six climate groups (n = 24) corresponding to three relative humidity (RH) treatments (32%, 58%, and 84%) and two temperature treatments (15-25 °C and 25-35 °C). We exposed the ticks to these conditions and checked the ticks daily for 30 days to assess their survivorship and questing behavior, which is when a tick is perched with its front legs outstretched to latch on to a host. In a second experiment, we placed 18 ticks of each species in a 32% RH and 35 °C environment. We assessed and weighed the ticks every 3 hours from 7 AM to 6 PM until all ticks died.

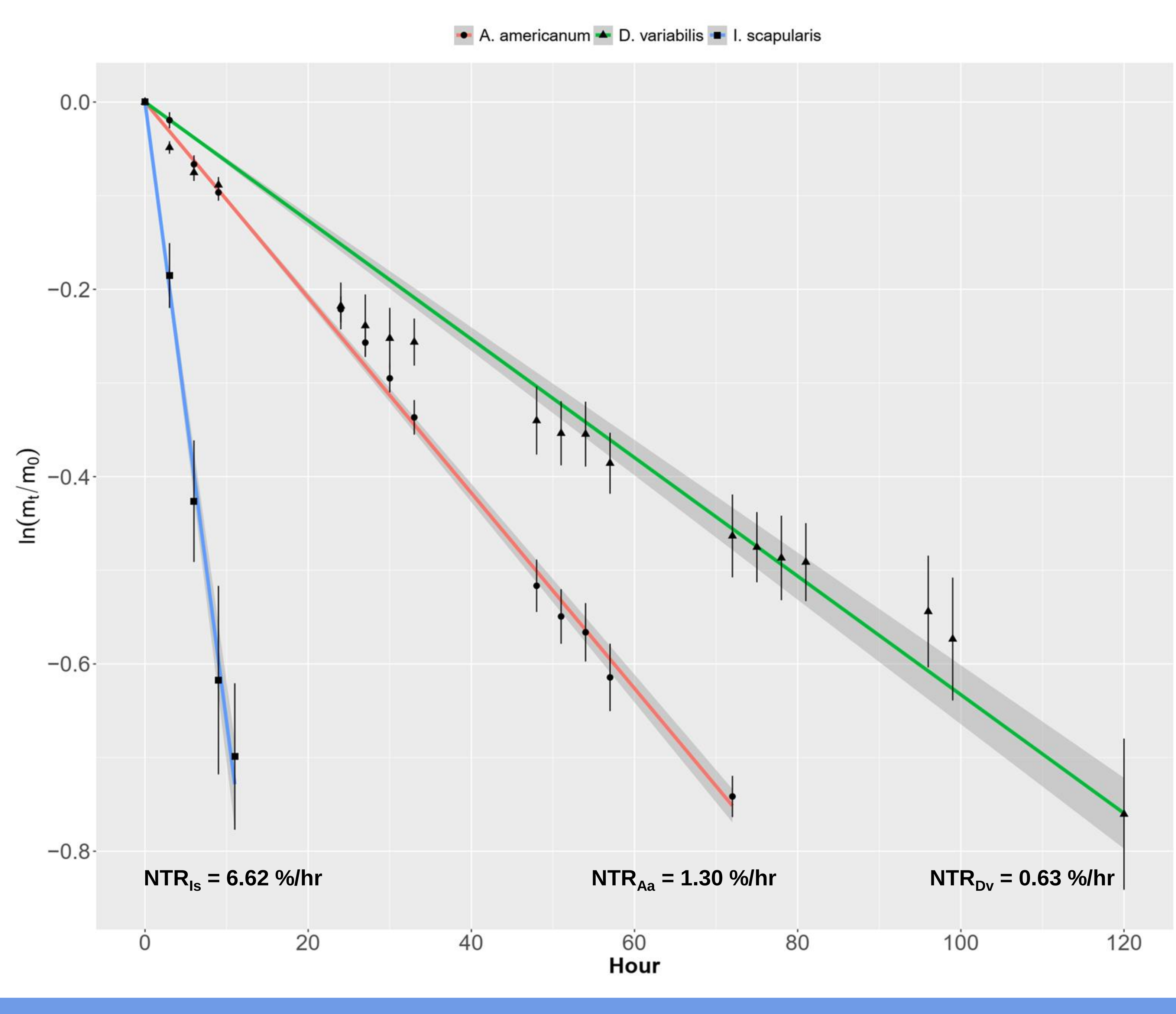
Analytical:

We conducted log-rank tests on each species to determine if survivorship differed among treatments, and logistic regression analyses to determine if questing frequency increased as ticks approached death. We also derived NTR from the slope of the linear regression of $\ln(m_t/m_0)$ against time, where m_t is water mass at any time t and m_0 is initial water mass[4]. We compared NTR among the three species with a test of equality of slopes.

Results







Top six panels: Survivorship decreased in hotter and less humid conditions. All pairwise comparisons showed significant differences in survivorship, except between 58% RH and 84% RH in *D. variabilis* at 15-25 °C (P = 0.445), between 32% RH and 58% RH in *D. variabilis* at 15-25 °C (P = 0.018), between temperatures in *D. variabilis* at 84% RH (P = 0.983), and between *A. americanum* and *D. variabilis* at 15-25 °C and 84% RH (P = 0.165).

Middle three panels: Probability of questing increased significantly (P < 0.001) as ticks of all three species approached death from dehydration.

Bottom panel: NTR of adult females exposed to 32% RH and 35 °C. All pairwise comparisons of NTR were statistically significant (P < 0.001).

Conclusions

Climatic stress decreases tick survival.

Our results show that both temperature and humidity strongly affect tick survival. Specifically, climatic stress experienced under hot and dry conditions increases tick mortality. The cause of death was dehydration; ticks of all three species reached functional death when they lost ~30% of body mass in water.

Climatic stress also increases tick host-seeking behavior.

Interestingly, ticks of all three species were more likely to quest as they approached death by dehydration. This suggests that ticks must balance their hydration status and time spent questing, but will quest more as they reach dangerous levels of dehydration in a desperate effort to obtain a blood meal. This highlights the complex interactions between climatic factors and the behavior and physiology of arthropod vectors of disease. Although climatic stress promotes the death of ticks, it also stimulates host-seeking behavior which may accelerate the spread of tick-borne illnesses.

***Ixodes scapularis* has a very high NTR.**

Ticks of all three species reached functional death when they lost ~51% of total body water content. Despite the absence of species differences in DT limit, *I. scapularis* ticks arrived at their limit much faster. Indeed, the rate of water loss in *I. scapularis* was approximately 5× faster than *A. americanum* and 11× faster than *D. variabilis*. This may be due to either higher cuticular or respiratory transpiration, as is typical of other species in the genus *Ixodes*[5]. Although the geographic distributions of the three species overlap broadly in the eastern half of the United States, the greater moisture requirements of *I. scapularis* constrain the breadth of microhabitats where it can survive[5].

Further investigations of ticks' behavioral and physiological responses to abiotic stress are necessary to develop robust models of how climate change will affect the geographic expansion of tick vectors and the transmission of tick-borne diseases.

References

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Acknowledgements

This project was funded by the National Science Foundation REU and REPS grant (award DBI-1950350), the Pepperdine Academic Year Undergraduate Research Initiative (AYURI), and the Natural Science Division of Pepperdine University. We thank Lee Kats, Helen Holmlund, David Green, Hassti Tirgardoon, Hyun Lim, and Sofia Monzón for their contributions to this project.