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Effect of floor type on survival of *Amblyomma maculatum* and *Amblyomma americanum* (Acari: Ixodidae)

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ABSTRACT: Exposure to ticks (Acari: Ixodidae) puts humans and their companion animals at risk of tick bites and potential pathogen transmission. Bites often occur when humans encounter ticks outdoors, but there may also be a risk in the home given the propensity of ticks to hitchhike on clothes and pets. We assessed survival of two tick species widely distributed across the southeastern United States, *Amblyomma maculatum* Koch and *A. americanum* Linnaeus, on different types of flooring commonly found in residential homes. We placed ticks individually onto one of five different types of flooring (tile, wood, vinyl, short pile carpet, and long pile carpet; n = 180 total, 36 ticks per species per floor type). Ticks were contained in plastic cups fixed in place on each floor type to reduce movement and/or escape and promote tick contact with the flooring. Survival was assessed as a function of the interaction between species and floor type. We found that *A. maculatum* ticks survived for significantly longer periods of time than *A. americanum* (median survival/mean survival) on vinyl (22.5/25.4 vs. 11.5/10.4 d), wood (18.5/16.1 vs. 11.0/12.2 d), tile (21.0/20.4 vs. 6.5/7.33 d) and short pile carpet (20.0/20.8 vs. 10.5/10.8 d), but *A. americanum* lived longer overall on long pile carpet (13.0/10.4 vs. 13.0/14.9 d). Our findings help clarify expected tick survival following entry into the home, and how floor type can mediate in-home tick exposure. Furthermore, this work emphasizes the necessity of performing tick checks, wearing protective clothing, and applying appropriate acaricides to people and pets to prevent tick transportation into the home. ***Journal of Vector Ecology* 51 (1): 12-21. 2026.**

Keyword Index: Gulf Coast tick, household exposure, household tick survival, lone star tick, tick survival.

INTRODUCTION

Tick-borne disease cases are rising in the United States, more than doubling in the last 20 years (Eisen et al. 2017; Centers for Disease Control and Prevention 2019; Rodino et al. 2020). While this increase is partly due to better diagnostics, routine surveillance, and increased awareness (Eisen et al. 2017), it has also been attributed to anthropogenic factors like habitat degradation, landscape fragmentation, and an increasing wildlife-urban interface (Allan et al. 2003; Stein et al. 2008; Diuk-Wasser et al. 2021). Certainly, continued alteration of tick habitats is expected to increase tick encounter rates (Stein et al. 2008; Diuk-Wasser et al. 2021), but tick encounter rates may also increase as a result of humans spending more time recreating outdoors, particularly with companion animals (Jones et al. 2018; Mead et al. 2018; Curtis et al. 2020; Keesing et al. 2022). As the potential for encounter rates outside increase, we risk transporting these hitchhiking ticks indoors. As such, it is important to understand how, if at all, the life histories of ticks may change after being transported indoors.

The bulk of the tick lifespan is spent off-host, and thus tick survival can be impacted by a variety of environmental factors while outdoors (Apanaskevich and Oliver 2014). The effects of temperature and humidity on desiccation appear to be the most important abiotic drivers of tick survival (Apanaskevich and Oliver 2014; Sonenshine and Roe 2014). Ticks exhibit behavioral adaptations to avoid adverse conditions by sheltering in leaf litter, in rotting vegetation, or buried under stone and soil (Apanaskevich and Oliver 2014). They will remain in these protected microhabitats until conditions are suitable for host seeking or dispersal (Maupin et al. 1991; Ginsberg 2014; Sabet et al. 2024). While ticks may have evolved numerous ways to avoid mortality within the natural environment, it is not understood how certain tick species survive, and for how long they may survive, within a built, indoor environment.

Ticks that are brought into the home on pets or clothing will inevitably detach; this may be due to feeding to repletion (Waladde and Rice 1982), repellency due to acaricide application (Bissinger and Roe 2010; Prullage et al. 2011; Pages et al. 2014), or mechanical removal (intentional or accidental). Once detached, if unfed ticks are not immediately killed, they may seek another host until one is found, or until they die (Piesman 1991; Wang et al. 1999; van Duijvendijk et al. 2016; Tahir et al. 2020). Interestingly, *Rhipicephalus sanguineus* Latreille sensu lato thrives in indoor environments, and can even colonize the home (Uspensky and Ioffe-Uspensky 2002). Due to the unique ecology of *R. sanguineous*, the longevity of this tick in indoor conditions and its developmental thresholds at a variety of extreme conditions have been evaluated (Koch and Tuck 1986; Dantas-Torres et al. 2012; Tian et al. 2023).

The ability of other tick species to persist in microclimates within the home is unclear.

Two commonly found ticks in the southeastern United States are the Gulf Coast tick (*Amblyomma maculatum* Koch) (Paddock and Goddard 2015; Sabet et al. 2023) and the lone star tick (*A. americanum* Linnaeus) (Childs and Paddock 2003; McClung and Little 2023). Both ticks feed readily on a wide array of animals, including various bird species and mammals. The Gulf Coast tick is a known vector of two pathogens of medical and veterinary importance: *Rickettsia parkeri* Lackman et al. (Rickettsiales: Rickettsiaceae), a spotted fever rickettsiosis (Paddock et al. 2004), and *Hepatozoon americanum* Vincent-Johnson et al. (Eucoccidiida: Haemogregarinidae), an apicomplexan parasite that causes American canine hepatozoonosis in canids (Mathew et al. 1998; Ewing and Panciera, 2003). The lone star tick is able to transmit a variety of pathogens, including the causative agents of Bourbon virus disease (*Thogotovirus bourbonense* Articulavirales: Orthomyxoviridae), Heartland virus disease (*Heartland bandavirus;* Hareavirales: Penuiviridae), ehrlichiosis (*Ehrlichia chaffeensis* Anderson et al. and *E. ewingii* Andrerson et al.; Ricketssiales: Ehrlichiaceae), and tularemia (*Francisella tularensis* [McCoy & Chapin] Dorofeev; Beggiatoales: Francisellaceae) (Hopla 1955; Anziani et al. 1990; Ewing et al. 1995; Goddard and Varela-Stokes 2009; Godsey et al. 2016). Several rickettsial organisms also have been found in lone star ticks, including *Rickettsia ambloymmatis* Karpathy et al.; Rickettsiales: Rickettsiaceae (also known in the literature as *Rickettsia amblyommii*) (Jiang et al. 2010; Breitschwerdt et al. 2011; Wright et al. 2015). In addition, Alpha-gal syndrome may be triggered from tick bites, including the bite of lone star ticks. This is an allergic response in humans to the alpha gal (galactose-α-1,3-galactose) sugar molecule found in mammalian products (Commins et al. 2011).

There are a multitude of ways that a tick may reach an untimely end within a home. As a starting point to explore this idea and to understand one potential limiting factor to tick longevity in residential homes, we assessed the survival of *A. maculatum* and *A. americanum* on five types of flooring commonly found in residential homes: vinyl, tile, wood, short pile carpet, and long pile carpet.

MATERIALS AND METHODS

Female *A. maculatum* (n = 90; three replicates of 30) and *A. americanum* (n = 90; three replicates of 30) ticks were ordered from the Tick Rearing Facility at Oklahoma State University. Until use, and for the duration of the experiment, ticks were kept at ambient temperature and relative humidity (~23°C, ~42% relative humidity (RH); measured using Onset HOBO logger; HOBO® Data Loggers, Bourne, Massachusetts, USA); ticks were used within 3 hours of receipt. Upon purchase, ticks were around 3 months old and unfed. Ticks were assigned randomly to one of five different types of flooring: long pile carpet (Stainmaster Hiking Trail Indoor Carpet #S9354-133-S, Stainmaster®, Centerville, Louisiana, USA), short pile carpet (Stainmaster Natureweave indoor/outdoor carpet, #MBL4N490144L, Stainmaster®, Centerville, Louisiana, USA), wood (Stainmaster Vienna Basin Oak, #56237, Stainmaster®, Centerville, Louisiana, USA), tile (Venatino Polished Marble stone, #354384, Satori Tile®, Vista, California, USA), and vinyl flooring (Style Selections Mosaic Vinyl, #A5005041, Style Selections®, Charlotte, North Carolina, USA). Flooring was obtained in bulk 1 week prior to the start of the experiment and was kept throughout the duration of the experiment and all replicates. Flooring was disposed of at the end of a replicate, and new flooring was used for the beginning of a new replicate. Experimental ticks were kept on the laboratory bench throughout the duration of the experiments, and confined individually onto substrates by placing a small plastic container on top of each substrate to prohibit dispersal and ensure the tick remained close to the flooring while also permitting the tick to walk around. These containers resembled cups; one end of the container was sealed and the other end was open. They were placed with the open side down on each floor type to enclose each tick, and were weighed down using crafting clay. Containers measured 5 cm tall with a diameter of around 3.5 cm. Holes were made at the top of the plastic container to ensure ticks were able to respire without escaping the container. Ticks were visually monitored for survival approximately daily. If a tick appeared immobile, it would be stimulated with human breath for 10 s and was considered dead if unresponsive. See Figure 1 for a visual schematic of the experimental design. Additionally, control *A. maculatum* (n = 20; two replicates of ten) and *A. americanum* (n = 20; two replicates of ten) were placed individually in containers on plastic trays and held either on the laboratory bench or were placed into a growth chamber (22 °C with ~85% RH) to track survival during the last two replicates; there was a limited number of ticks during the first replicate and thus there was not a control group. Control ticks helped ensure that experimental ticks were dying due to the treatment, rather than a confounding variable affecting the whole cohort. Data related to survival of ticks within the growth chamber were not included in final analyses.

Data were analyzed using R Statistical Software (v4.4.1, R Core Team 2022) via R Studio (RStudio Team 2020). Kaplan-Meier survival curves were generated in R using the *survival* (Therneau 2024a) and *survminer* (Kassambara et al. 2021) packages. Otherwise, data were visualized using *ggplot2* (Wickham 2016). To analyze survival, we used a mixed-effects Cox proportional hazards model fit via the *coxme* package (Therneau 2024b) with tick species (*A. maculatum* and *A. americanum*), floor type (vinyl, tile, wood, short pile carpet and long pile carpet), and their interaction as predictors. Significance was determined by an alpha value of 0.05 ($\alpha = 0.05$). A term for replicate was fit as a random intercept to account for any differences among the three replicates. Analysis of deviance was performed using a type III sums of squares to assess the strength of the interaction. Pairwise comparisons were performed using the *emmeans* package (Lenth 2023).

A generalized linear mixed-effects model using a Poisson error structure and log link function was fit via the *lme4* package (Bates et al. 2015) to assess the effect of tick

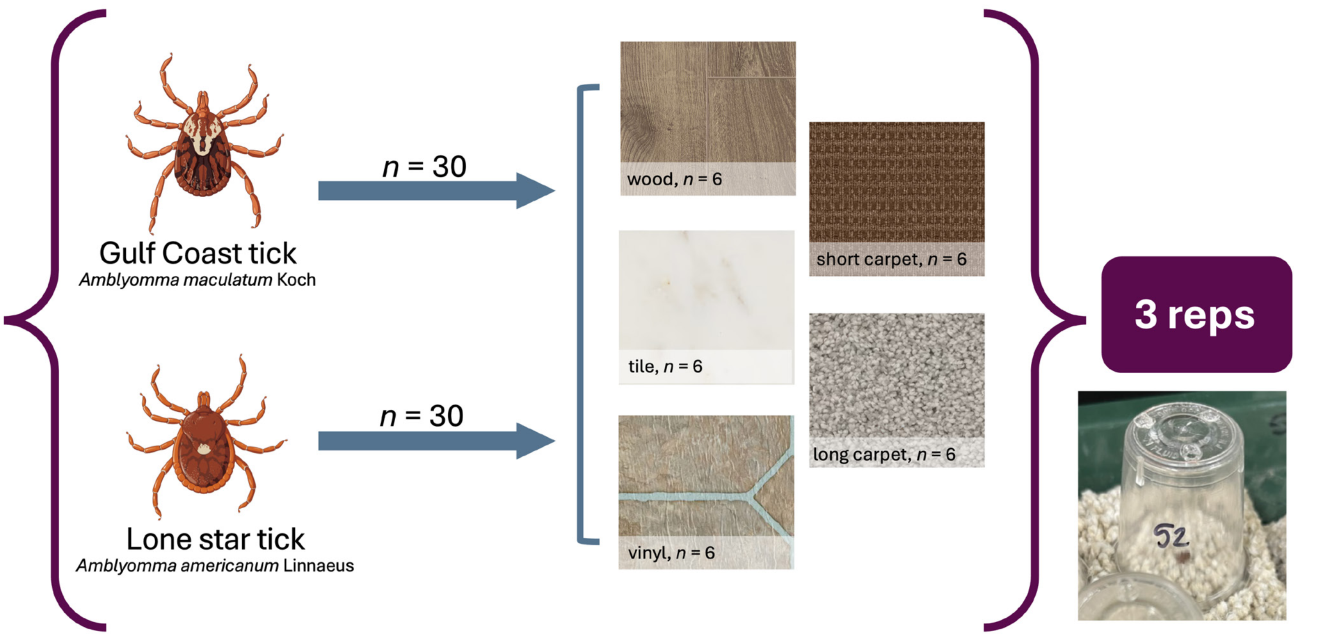

Figure 1. Graphical representation of the experimental design. Thirty *Amblyomma maculatum* and thirty *A. americanum* were placed individually onto either wood, tile, vinyl, short pile carpet, or long pile carpet. A control was placed onto the laboratory bench. This was replicated three times, resulting in a total of 90 ticks per species. Ticks were assessed approximately daily for survival, visually with breath stimulation. See image of a tick within a container on the long pile carpet.

species, floor type, and their interaction on the number of days survived; a term for replicate was fit as a random intercept. Analysis of deviance was conducted using a type III sums of squares test (Fox and Weisberg 2019), and pairwise comparisons were conducted using the *emmeans* package (Lenth 2023) on statistically significant ($\alpha < 0.05$) terms. We conducted both a traditional survival analysis as well as a mixed-effects model to compare conclusions and robustness of results.

RESULTS

Over the course of this study, survival was checked daily for all ticks, resulting in 4,639 individual observations (assuming dead ticks were not re-observed after death). Of these observations, 88% (n = 4,093) were of ticks that were sitting on top of the flooring, in full contact; 7.8% of observations (n = 366) were ticks considered "active", meaning that they were either waving their forelegs, walking along the surface of the flooring, or moving vertically in the containers. The remaining observations were the final observations per tick, or the observation of mortality. Average survival of *A. maculatum* (n = 90) during the experiment was (mean ± SE) 18.6 ± 1 d with 50% of *A. maculatum* individuals surviving for ≥18 days. Average survival of *A. americanum* (n = 90) was 11.0 ± 0.7 d, with 50% of *A. americanum* surviving ≥10 d. Mean survival of *A. maculatum* was longest on vinyl (25.4 ± 2.7 d) and shortest on long pile carpet (10.4 ± 1.2 d) (Table 1). Similarly, 50% survivorship of *A. maculatum* was highest on vinyl (22.5 d) and shortest on long pile carpet (13.0 d) (Table 1). Mean survival of *A. americanum* was longest on long pile carpet (14.9 ± 2.5 d) and shortest on tile (7.33 ± 1.2 d) (Table 1). This was similar to 50% survivorship of *A. americanum*, which was longest on long pile carpet (13.0 d) and shortest on tile (6.5 d) (Table 1). Details on average survival period and 50% survivorship across all five floor types and the control are provided in Table 1. All humidity chamber control ticks survived for over a month, confirming that survivorship was not compromised based on purchasing cohort. Despite not having a formal control for replicate one, survival was statistically comparable across all replicates.

Survival was assessed using a Cox proportional hazards model, with a significant interaction found between floor type and species (χ^2 = 56.04, df = 5, $p < 0.0001$); the main effects for tick species (χ^2 = 27.45, df = 1, $p < 0.0001$) and floor type (χ^2 = 44.17, df = 5, $p < 0.0001$) were also statistically significant. *Amblyomma americanum* had an increased risk of death on tile ($z = -6.23$, $p < 0.0001$; Figure 2A), vinyl ($z = -6.38$, $p < 0.0001$; Figure 2B), wood ($z = -2.81$, $p = 0.18$; Figure 2C), and short pile carpet ($z = -4.61$, $p = 0.0003$; Figure 2D) as compared to *A. maculatum*. Survival on long carpet, however, was associated with a decreased risk of death for *A. americanum* compared to *A. maculatum* ($z = 3.49$, $p = 0.024$) (Figure 2E). For ease of visual comparison, the survival times on different floor types are provided on species-specific panels (Figure 3) in addition to the flooring-specific panels (Figure 2) described above. There was a slight violation of the proportionality assumption ($p = 0.024$), but this was deemed minor; the plot is provided for reference (10.5281/zenodo.16328774). All pairwise comparisons are listed in 10.5281/zenodo.16328774.

When analyzing the effects of tick species and floor type

Table 1. Kaplan-Meier survival analysis of mean survival ± standard error and 50% survival of *Amblyomma maculatum* and *Amblyomma americanum* on tile, vinyl, wood, short pile carpet, long pile carpet, and the control at laboratory conditions in days. In total, 180 ticks were used to assess survival; 90 ticks per species.

	Amblyomma maculatum, *n* = 90		*Amblyomma americanum*, *n* = 90	
	Mean survival in days ± standard error	50% survival in days	Mean survival in days ± standard error	50% survival in days
Tile	20.4 ± 1.63	21.0	7.33 ± 1.20	6.5
Vinyl	25.4 ± 2.71	22.5	10.4 ± 0.88	11.5
Wood	16.1 ± 1.99	18.5	12.2 ± 1.12	11.0
Short pile carpet	20.8 ± 1.80	20.0	10.8 ± 1.19	10.5
Long pile carpet	10.4 ± 1.21	13.0	14.9 ± 2.46	13.0
Control	21.8 ± 1.44	24.0	11.6 ± 0.77	11.5

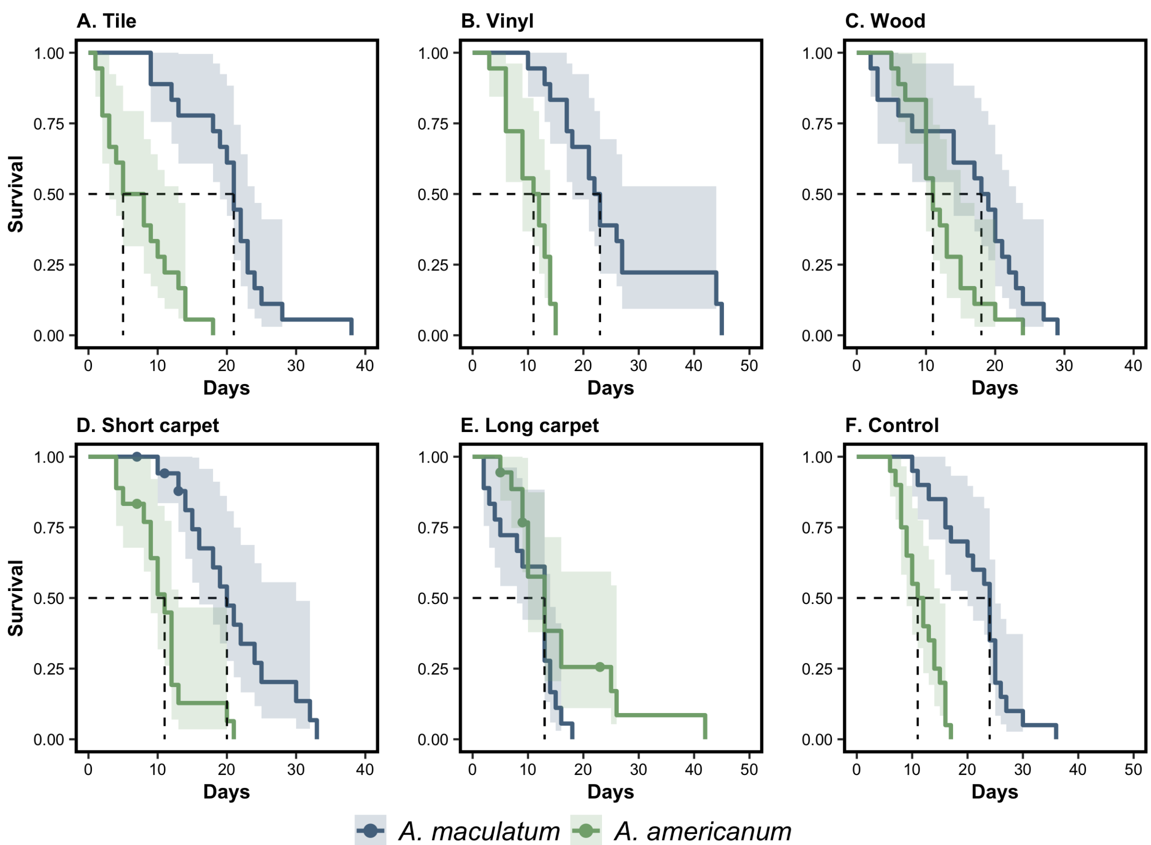

Figure 2. Kaplan-Meier curves depicting survival of *Amblyomma maculatum* and *A. americanum* on (A) tile, (B) vinyl, (C) wood, (D) short pile carpet, (E) long pile carpet and (F) on the laboratory bench (control). Points refer to censored ticks—those that escaped the enclosure. Dashed lines denote time points associated with 50% tick survivorship. Survival of *A. maculatum* was longer on tile, vinyl, wood, short pile carpet, and in the control, but survival of *A. americanum* was longer on long pile carpet.

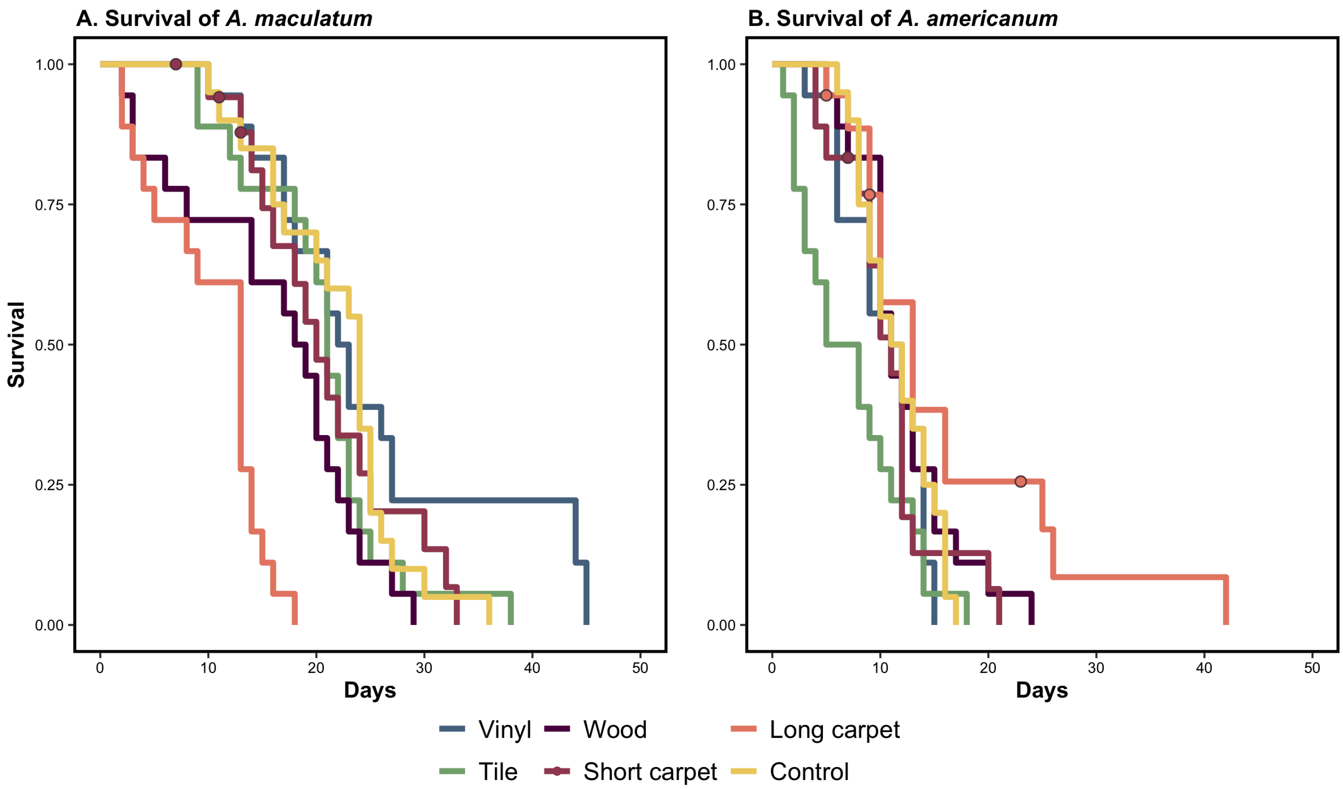

Figure 3. Kaplan-Meier curves depicting an analysis of survival of (A) *Amblyomma maculatum* and (B) *A. americanum* on different floor types (vinyl, tile, wood, short pile carpet, long pile carpet, and on the laboratory bench [control]). Points refer to censored ticks—those that escaped the enclosure, n = 8.

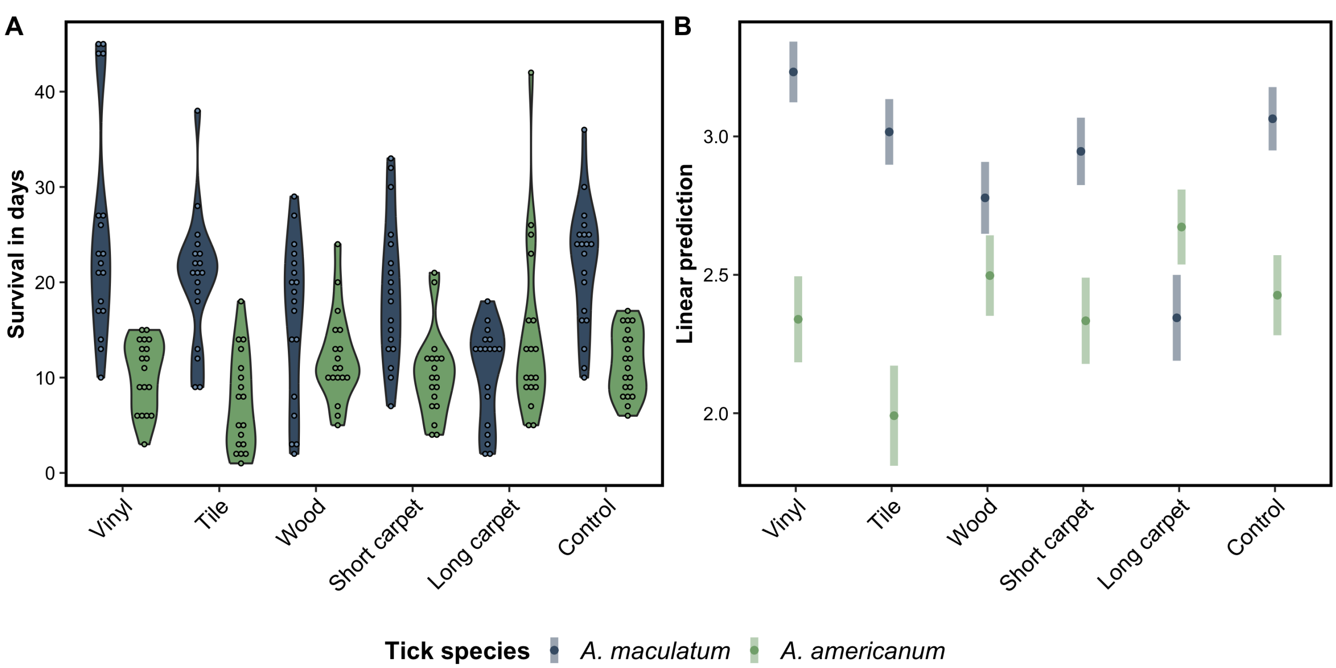

Figure 4. (A) Violin plot showing survival (d, y-axis) of *Amblyomma maculatum* and *A. americanum* on different floor types (x-axis). (B) Estimated marginal means of survival time (d, y-axis) as a function of the interaction between floor type (x-axis) and tick species. Each vertical bar indicates a 95% confidence interval, estimated using a generalized linear mixed-effects model. Compared with *A. maculatum*, *A. americanum* lived longer on long pile carpet ($z = -3.43$, $p = 0.02$), while *A. maculatum* lived longer on tile ($z = 10.12$, $p < 0.0001$), vinyl ($z = 10.29$, $p < 0.0001$), wood ($z = 3.14$, $p = 0.05$), and short pile carpet ($z = 6.72$, $p < 0.0001$) compared to *A. americanum*.

on days survived using a generalized linear mixed-effects model, we found a significant interaction between the two predictors ($\chi^2 = 132.17$, df = 5, $p < 0.0001$). *Amblyomma maculatum* lived longer, compared to *A. americanum*, on tile ($z = 10.12$, $p < 0.0001$), vinyl ($z = 10.29$, $p < 0.0001$), wood ($z = 3.14$, $p = 0.074$), and short pile carpet ($z = 6.72$, $p < 0.0001$) (Figure 4B). On long pile carpet, however, *A. americanum* lived longer ($z = -3.43$, $p = 0.02$) (Figure 4B). The two modeling frameworks, a Cox proportional hazards model looking at instantaneous hazard of mortality at daily time steps and a generalized linear mixed-effects model comparing mean survival times, yielded equivalent conclusions regarding the effects of flooring on tick survival.

DISCUSSION

With the proliferation of the wildland-urban interface, interactions between humans and ticks have increased (Diuk-Wasser et al. 2021). Increased exposure to these arthropods can exacerbate risks of adverse outcomes, including disease transmission (Oztoprak et al. 2008). It is possible that one mechanism for tick exposure is tick intrusion into the home (Oztoprak et al. 2008; Renvoisé et al. 2012; Banović et al. 2021; Buczek et al. 2024), wherein a tick is moved inside—on a companion animal or clothing—prior to feeding. If ticks are able to enter the home through these indirect mechanisms of movement, it becomes important to understand the length of time ticks would then be able to persist in the home. We assessed the survival of two tick species, *A. maculatum* and *A. americanum*, on different types of flooring, finding that 50% of all ticks lived longer than 13 d in indoor environmental conditions.

Ambylomma maculatum survived longer than *A. americanum* on vinyl, tile, wood, and short pile carpet, while *A. americanum* lived longer on long pile carpet (Figure 4). As tick movement was limited and ticks were only exposed to the laboratory environment, we believe that mortality was due to desiccation. The reversed pattern of survival time on long pile carpet—on which *A. americanum* outlived *A. maculatum* on average—was perplexing. The mechanism is unclear, but it appears the microenvironment shifted to favoring *A. americanum*. Rates of water loss and retention vary between the tick species (Hair et al. 1975; Sigal 1990; Yoder and Benoit 2003), and it is possible that differing moisture availability in the long carpet affected survival; e.g., the carpet could have retained moisture, but whether that moisture was available to ticks, versus remaining in the air in the container, is unknown. If moisture was retained in the long pile carpet, *A. americanum* may have had better success in water uptake and replenishing lost water stores compared to *A. maculatum*. Adult *A. maculatum* have the ability to store more water, and to retain that water, which may have contributed to their longer survival on other floor types (Yoder et al. 2008). While we observed most ticks being sedentary (see results), we do not know if there was a behavioral difference triggered by the difference in floor type. Anecdotally, we did notice that some ticks in the long pile carpet appeared to be positioned with their mouthparts down in the carpet, and their hindlegs sticking out, as if trying to burrow or feed, but this behavior was not quantified. Notably, this study used only unfed ticks, but fed ticks can have higher rates of water retention (Yoder et al. 1997) which may suggest that blood engorged ticks dropping from hosts in the home could live even longer, although this has only been investigated for replete ticks. The survival of partially fed ticks in homes warrants future investigation, especially since interrupted feeding can result in accelerated pathogen transmission to a secondary host (Shih and Spielman 1993; Tahir et al. 2020). Water retention abilities of fed versus unfed ticks have been investigated in other tick species (Yoder et al. 1997; Heath 2016), but it has not been investigated in *A. maculatum*.

We assessed time-to-mortality in this study by imparting large constraints on tick movement, but there are certain behaviors that ticks exhibit when activity is not constrained that may affect their longevity. For example, both of these *Amblyomma* species are thought to exercise a mixture of both ambush and pursuit strategies for their host-seeking (Ginsberg and Ewing 1989; Goddard et al. 2011), and such efforts would certainly deplete lipid stores and lead to a faster demise. It may be more difficult and taxing on a given tick to employ a pursuit-style host-seeking strategy on one floor type over another (e.g., carpet ves. tile). Furthermore, it is possible that a host-seeking tick could be discouraged from pursuing a host on a floor type that is uncomfortable, irritating, or depleting to walk across. These variables will certainly affect time-to-mortality further and should be a potential avenue of further exploration.

The temperatures at which survival was assessed in this experiment are described as "ambient room temperature", and were around 21°C. This may reflect the ambient temperature in some homes, but not all, and certainly some homes—potentially due to availability of air conditioning, and location—may be at vastly different temperatures, and by extension, different relative humidity levels. Such variation in conditions would certainly impact tick survival by itself, as these are both determinants of tick survival (Apanaskevich and Oliver 2014).

It is possible that off-gassing of flooring can affect tick survival within the home. Off-gassing is of concern when materials for construction (like flooring) are kept or stored in areas or in packaging that limits air exchange, and is associated with new materials (Wallace et al. 1987; Guo et al. 2004). The materials used in this experiment were purchased from a home improvement store. Some materials (i.e., long pile carpet, short pile carpet, vinyl, and wood) were completely unsealed at the time of purchase, and the tile was packaged in a cardboard box with cut-out windows. These materials were obtained, unpackaged if relevant, and then kept in the laboratory unsealed for approximately a week prior to the start of the experiment. Replicates were performed sequentially, and the flooring was obtained in bulk at the beginning of the experiment, so no new materials were introduced during the study. While we do not believe off-gassing affected survival in our experiment, it certainly could affect tick survival within the home, particularly within a newly built home.

Importantly, this work underscores the necessity of performing routine tick checks, wearing protective clothing, and applying appropriate acaricide products to people and pets according to the label (Nasci et al. 2013). These measures may vary in specifics by location and based on the tick species present in the region but remain consistent in messaging: changes to human behavior can reduce the risk of tick encounters, and tick-borne disease (Nasci et al. 2013). Pet owners can apply similar tactics to protect their pets by using appropriate acaricide application (after consultation with their veterinarians) and routine tick checks (Kiss et al. 2012; Jones et al. 2018). By employing these various anti-tick measures, we can limit tick encounters outdoors, prevent ticks being brought into the home, and/or more quickly identify hitchhiking ticks and remove them.

Humans and, by extension, their companion animals are living in very close proximity to ticks, making understanding tick ecology in differing environments essential to mitigating tick encounters. Ticks are brought into residential homes through many different pathways and may end up staying in the home for a period of time. This study presents an initial exploration into how survival of ticks may vary within a home and is a starting point for further investigation. Our results show that floor type can influence longevity of two commonly encountered *Amblyomma* species. Making conscious decisions about floor-types in the home, particularly at entry points or high traffic areas, might help decrease tick survival. At the very least, this work underscores the necessity of using appropriate personal protection and pesticide application when entering tick habitats, and multiday vigilance afterwards, when ticks may have been transported into the home.

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Data Availability

Please refer to 10.5281/zenodo.16328774 for all supplemental materials, including data, R script, supplemental figures and documents, related to this manuscript.

Author Contributions

AS = conceptualization; data curation; formal analysis; investigation; methodology; visualization; writing — original draft; writing — review & editing. SFW = conceptualization; methodology; supervision; writing — review & editing. RP = writing — review & editing.

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