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# Dead deer do tell tales: infestation of road-killed white-tailed deer by juvenile *Ixodes scapularis* (Ixodida: Ixodidae) ticks

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## Abstract

The white-tailed deer (*Odocoileus virginianus*) contributes indirectly to the enzootic circulation of the Lyme disease pathogen, *Borrelia burgdorferi* by serving as the primary reproductive host for adult-stage blacklegged ticks (*Ixodes scapularis*). The role of white-tailed deer as a host for juvenile life stages is less well understood, in part because their periods of activity typically fall outside of most white-tailed deer hunting seasons. We inspected 22 road-killed deer for all stages of blacklegged ticks in Rutland County, Vermont from May to August in 2020, 2021, and 2024. Adult-stage blacklegged ticks were found attached to ten deer in May and early June. Larval-stage ticks, including ones that were partially engorged, were found on 3/5 deer inspected by hanging the head, hide, and legs over water for approximately 24 hours. We directly observed 7 nymphal-stage ticks attached to one additional deer. This study adds to a growing body of evidence that the role of juvenile feeding on white-tailed deer may be underestimated and demonstrates that the study of road-killed deer may improve our understanding of how populations of blacklegged ticks are maintained among wildlife communities.

### Keywords

*Ixodes scapularis* ; *Odocoileus virginianus* ; feeding behavior

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## Introduction

The blacklegged tick (*Ixodes scapularis*) is the primary vector of Lyme disease spirochetes in the eastern United States. The role of white-tailed deer (*Odocoileus virginianus*) as key hosts for the adult life stage of the blacklegged tick is well-established, in part due to a fall peak in adult tick activity coinciding with hunting seasons facilitating extensive sampling of hunter-killed deer (Halsey et al. 2018). In a review and meta-analysis of 116 studies examining host relationships for the blacklegged tick, Halsey et al. (2018) reported across all studies 13,950 individual deer examined for the presence of the blacklegged tick, with only the adult life stage reported. It is unclear if this is due to the absence of juvenile ticks (i.e., larvae and nymphs) infesting deer, or a sampling bias due to collections occurring in late autumn during hunting seasons when the adult life stage is active, and the juvenile life stages generally are not.

Feeding by juvenile ticks is of particular interest because pathogens acquired by these life stages can be transmitted to humans or recirculated among wildlife. While white-tailed deer are believed to be poor reservoirs for Lyme disease spirochetes (Kurtenbach et al. 1998, 2002, Nelson et al. 2000), they play an important role in tick population dynamics by serving as hosts for the adult life stage; by comparison, understanding of their contributions to feeding juvenile life stage ticks is quite poor. In a comprehensive survey, Telford III et al. (1988) received an out-of-season permit to shoot 19 white-tailed deer during the peak in larval activity in September 1986, on Hog and Naushon Islands, Massachusetts. An average of 342 larval blacklegged ticks were collected from each deer, suggesting potentially high larval tick burdens. Piesman et al. (1979) similarly report 688 larval and 232 nymphal blacklegged ticks collected from 16 white-tailed deer shot on Naushon and Nantucket Islands, Massachusetts. Stafford III et al. (1996) removed an unspecified number of larval and nymphal blacklegged ticks from immobilized deer in Bridgeport, Connecticut, many of which were described as being engorged. In Ontario, Canada, Watson and Anderson (1976) found all 3 life stages of blacklegged ticks on white-tailed deer, each with distinct anatomical preferences for feeding location on the deer. Finally, LoGiudice et al. (2003) sampled deer shot under a depredation permit issued to a farmer in Dutchess County, New York, during the seasonal peak in larval activity, but reported few fully engorged larvae were collected. Incidentally, molecular analysis of adult and nymphal-stage ticks reveals the presence of *Babesia odocoilei* (Armstrong et al. 1998, Landesman et al. 2019), a blacklegged tick-borne pathogen of white-tailed deer (Milnes et al. 2019), providing additional potential evidence of feeding in a prior (i.e., nymphal or larval) life stage.

Blacklegged tick populations have become widespread in Vermont (Serra et al. 2013), a state with one of the highest *per capita* rates of Lyme disease reported in humans (https://www.cdc.gov/lyme/data-research/facts-stats/surveillance-data-1.html). As a result of Vermont Fish and Wildlife's Venison for Vermonters wild game meat donation program, numerous roadkill deer are collected, processed, and distributed to local food shelves throughout the year, including during spring and summer when juvenile stages of blacklegged ticks are more active. Perhaps because ticks are known to detach from hosts following host death (e.g., Tsunoda 2014), road-killed deer appear to have received less attention to identify the presence of tick infestations. However, if road-killed deer maintain

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infestations for a period of time after death sufficient for researchers to examine carcasses for ticks, it may be possible to better illuminate the role of deer as a host for juvenile ticks. Here we report our observations from 19 road-killed deer from 2020 as well as 2 additional deer from 2021 and one from 2024 that were opportunistically sampled to determine if blacklegged tick infestations could be detected within the timeframe of collection after death.

## Methods

A total of 19 road-killed deer (adults and juveniles, defined as less than 1 year old) were collected from state highways in Rutland County, VT (Fig. 1) in 2020 and visually inspected for blacklegged ticks while being processed for donation to local food shelves. Time since death for deer was known for most of the deer through roadside reporting or direct dispatch of the animal. In cases where the time since death was unknown, it was estimated with guidance from Oates et al. (1984). For deer subjected to visual inspection, it is only nymph or adult life stages that could be detected. However, 2 deer collected in 2020, 2 in 2021, and 1 in 2024, were inspected for larvae by hanging the head, hide, and legs over a pool of water for 17 to 48 hours (Fig. 2; Telford III et al. 1988). Larvae collected from the pool were identified and assessed for degree of engorgement using a dissecting microscope. Hides were rolled inside out to retain as many larvae as possible until the deer could be hung. The individual deer head, hide, and legs collected in 2024 were stored in a refrigerator for approximately 9 hours, until it could be hung. Potential differences in tick burdens between adult and juvenile deer were analyzed by one-way ANOVA.

## Results

In 2020, attached blacklegged adults were found on 10 of the first 12 white-tailed deer collected (to June 21) and then on no other deer (Table 1). Time since death for deer with attached adults ranged from 0.25 hours to > 24 hours. For the deer with attached ticks, adults had a higher average number of ticks (8.5 per animal) than juveniles (2.4 per animal); however, this difference was not statistically significant ($F = 1.82$, $P = 0.19$, df = 1).

We found 7 nymphs attached to a spotted fawn (JS; Table 1) in July 2020 that had been dead for 8 hours at the time of inspection. Two partially engorged nymphs were attached near the eye and one partially engorged nymph was attached to the cheek (Fig. 3a). The remaining ticks were flat and attached to the cheek, ears (2; Fig. 3b), or inside of the rear thigh. This deer was not checked for larvae. By the following morning (7 AM) 2 of these nymphs remained attached. We found blacklegged larvae on 3 of the 5 deer that were hung over water. The number of embedded/unembedded larvae was 31/3, 5/1, and 10/6; these deer were collected in August 2020, May 2021, and August 2024 (Table 1). For deer that were inspected for larvae, the approximate time since death from when the deer died to when it was skinned ranged from 0.25 to 9 hours. An additional 1 to 2 hours passed from skinning until it the hides were hung over water.

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## Discussion

We found larval-stage ticks on 3/5 road-killed deer hung over water, as well as attached nymphs on one additional deer, providing further support that juvenile feeding on this host is more common than may be typically implied from the lack of literature on this topic. The 3 deer infested with larvae were collected during May, June, and August, corresponding to periods of larval activity in this region (Levi et al. 2015). Our study was constrained by the non-random distribution of age, sex, and month in which road-killed deer could be collected, and time since death, making a quantitative analysis for juvenile feeding impossible. Nymphal-stage feeding on deer may have been underestimated, since half of the inspected deer were collected outside the period of peak nymphal activity (Baldwin et al. 2022). Furthermore, we relied on visual roadside inspection to search for nymphs, which is challenging on adult deer with longer fur. Given these constraints and our observation of ticks remaining attached several hours after death, the actual number of feeding ticks may be higher than what was recorded.

The role of deer in the maintenance of tick populations is usually assumed to be due to feeding by adult blacklegged ticks (e.g., Halsey et al. 2018). This assumption for tick populations is supported by correlational analyses between adult tick abundance and the presence of deer scat or other estimates of deer abundance (e.g., Rand et al. 2003) and by deer exclusion studies (e.g., Stafford III 1993, Perkins et al. 2006). On the other hand, Huang et al. (2019) estimated, via mathematical modeling, that 29% of larval blacklegged ticks fed on white-tailed deer in one community. Furthermore, the direct observations reported here and elsewhere (e.g., Watson and Anderson 1976, Piesman and Spielman 1979, Telford III et al. 1988, Stafford III et al. 1996, LoGiudice et al. 2008) suggest that the focus on the role of deer as hosts only for adult blacklegged ticks may in part reflect a sampling bias (Halsey et al. 2018).

Juvenile feeding by blacklegged ticks on white-tailed deer suggests there may be additional means by which deer may impact transmission of the Lyme disease spirochete. For example, as a poor host for *Borrelia burgdorferi* (Kurtenbach et al. 1998, Nelson et al. 2000, Kurtenbach et al. 2002), white-tailed deer may, in some regions, deflect bloodmeals from reservoir-competent hosts (LoGiudice et al. 2003). At the same time, by increasing tick populations, white-tailed deer might increase the population of juveniles and thus the number of infected blacklegged ticks (Ratti et al. 2021). Modeling analyses indicate that the extent to which this occurs may depend on the degree of feeding preference of juvenile ticks for deer vs. reservoir-competent hosts (Ratti et al. 2021). The study of road-killed deer is a promising tool for improving our understanding of juvenile feeding behavior that could aid in the modeling of Lyme disease risk in ecological communities.

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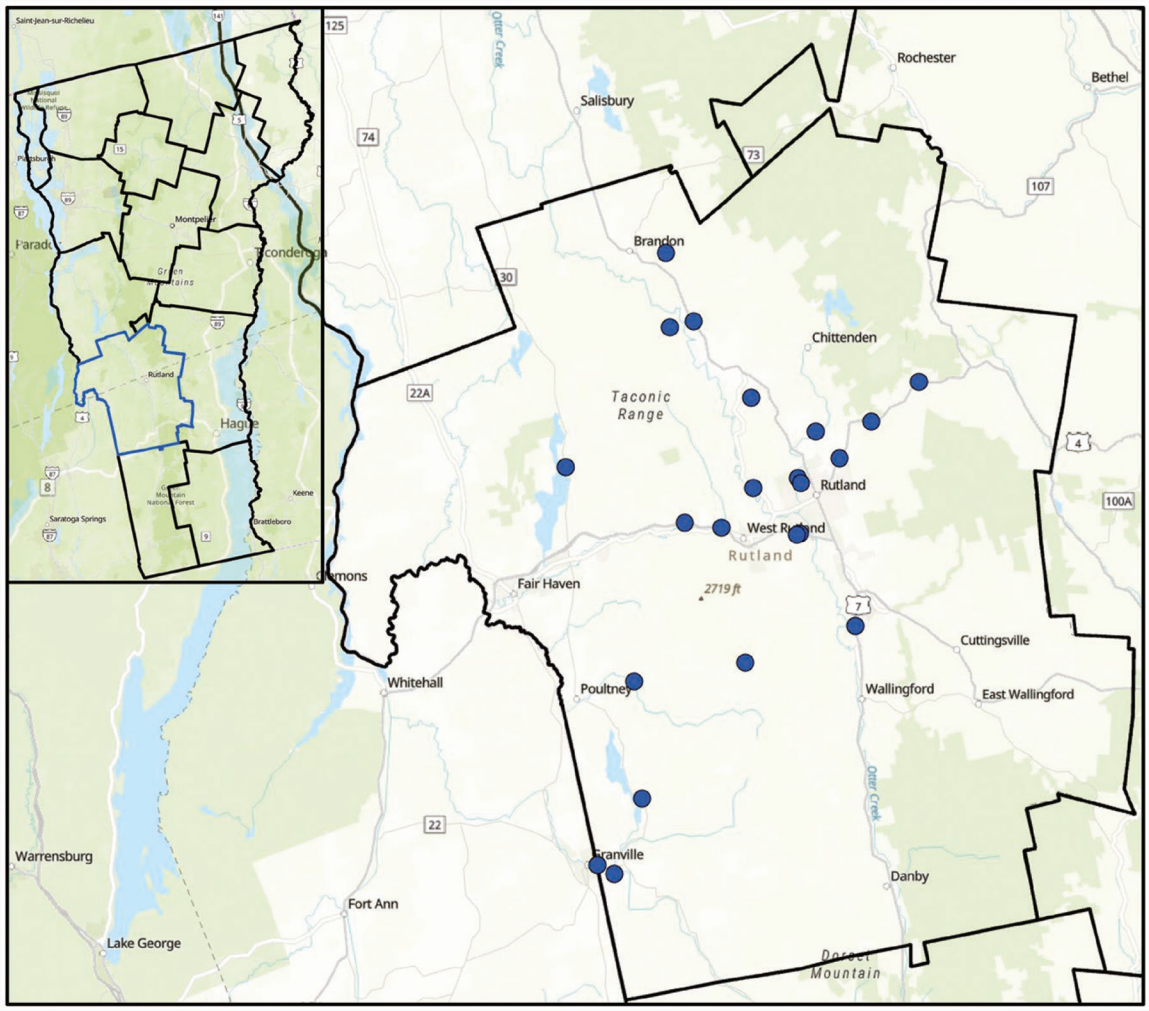



**Fig. 1.**
Location of road-killed deer collected in Rutland County, Vermont.

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**Fig. 2.**

Method for inspecting white-tailed deer (head, hide, and legs) for larvae. Inset: Partially engorged larvae, collected from this deer, under a dissecting microscope (13 August 2024).

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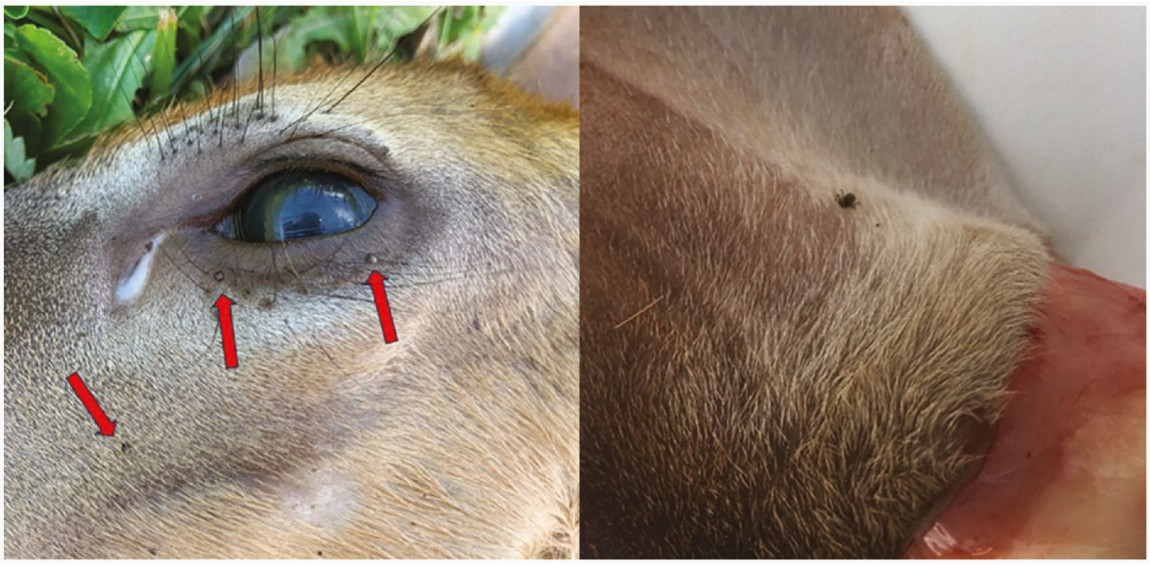


**Fig. 3.**
Partially engorged and flat nymphal-stage blacklegged ticks attached near the eye, cheeks (a) and ear (b) of a White-tailed deer (26 July 2020).

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**Table 1.**

Summary of date of collection, age/sex of deer, time since death (TSD, measured in hours); number of embedded adults, (AE), unembedded adults (AUE), nymphs and larvae (F/E = flat/embedded) ticks found on road-killed deer.

| Date | Age/Sex | TSD | AE | AUE | Nymphs F/E | Larvae F/E |
|---|---|---|---|---|---|---|
| 05/19/20 | A/F | >24 | 15 | 0 | 0 | HNH |
| 05/31/20 | A/F | 0.25 | 43 | 8 | 0 | HNH |
| 06/05/20 | Y/M | 1.00 | 8 | 1 | 0 | HNH |
| 06/05/20 | A/F | 10.00 | 18 | 3 | 0 | HNH |
| 06/05/20 | Y/F | 1.00 | 0 | 0 | 0 | HNH |
| 06/07/20 | Y/F | >24 | 2 | 0 | 0 | HNH |
| 06/07/20 | Y/F | 10.00 | 8 | 13 | 0 | HNH |
| 06/08/20 | Y/F | 1.00 | 4 | 0 | 0 | HNH |
| 06/13/20 | A/F | 2.00 | 5 | 2 | 0 | HNH |
| 06/14/20 | A/F | 12.00 | 10 | 3 | 0 | 0/0 |
| 06/16/20 | A/F | 6.50 | 0 | 0 | 0 | HNH |
| 06/21/20 | A/F | 2.00 | 3 | 0 | 0 | HNH |
| 07/09/20 | JS/F | 3.00 | 0 | 0 | 0 | HNH |
| 07/26/20 | JS/M | 8.00 | 0 | 0 | 0/7 | HNH |
| 08/03/20 | A/F | 1.50 | 0 | 0 | 0 | HNH |
| 08/10/24 | JS/F | 0.25 | 0 | 0 | 0 | HNH |
| 08/18/20 | A/F | >24 | 0 | 0 | 0 | HNH |
| 08/20/20 | J/F | 1.50 | 0 | 0 | 0 | HNH |
| 08/31/20 | A/F | 7.00 | 0 | 0 | 0 | 31/3 |
| 05/27/21 | A/M | 0.25 | NVI | NVI | 0 | 5/1 |
| 06/23/21 | A/F | 0.33 | NVI | NVI | 0 | 0/0 |
| 08/13/24 | A/F | 0.25 | 0 | 0 | 0 | 10/6 |

NVI = no visual inspection; HNH = hide not hung; J = juvenile; JS = spotted juvenile; Y = yearling; A = adult; M = male; F = female.

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