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Short Communication

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Low Abundance of Three Tick Species in the Piedmont of North Carolina

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Abstract

Multiple species of ticks, including *Ixodes scapularis* (Say, Ixodida:Ixodidae), *Amblyomma americanum* (L., Ixodida:Ixodidae), and *Dermacentor variabilis* (Say, Ixodida:Ixodidae), occur in high and increasing abundance in both the northeast and southeast United States. North Carolina is at the nexus of spread of these species, with high occurrence and abundance of *I. scapularis* to the north and *A. americanum* to the south. Despite this, there are few records of these species in the Piedmont of North Carolina, including the greater Charlotte metropolitan area. Here, we update the known occurrence and abundance of these species in the North Carolina Piedmont. We surveyed for ticks using cloth drags, CO_2 traps, and leaf litter samples at a total of 79 sites within five locations: Mecklenburg County, South Mountains State Park, Stone Mountain State Park, Duke Forest, and Morrow Mountain State Park, all in North Carolina, during the late spring, summer, and fall seasons of 2019. From these surveys, we had only 20 tick captures, illuminating the surprisingly low abundance of ticks in this region of North Carolina. Our results indicate the possibility of underlying habitat and host factors limiting tick distribution and abundance in the North Carolina Piedmont.

Key words: North Carolina, tick abundance, tick survey

Two of the most important determinants of human tick-borne disease (TBD) risk are tick occurrence and abundance; ticks must occur in a region for them to act as pathogen vectors and the probability of pathogen transmission increases, in part, as a function of tick abundance. In the eastern United States, *Ixodes scapularis* Say and *Amblyomma americanum* L. are the most abundant tick species encountered by humans (Trout Fryxell and Vogt 2019). *Ixodes scapularis*, the vector of Lyme disease, is present in both the Northeast and Southeast United States, but densities of *I. scapularis* are typically higher in the Northeast (Bishopp and Trembley 1945, Eisen et al. 2016). The predominant tick species of the Southeast is *A. americanum* (Merten and Durden 2000). *Dermacentor variabilis* Say, the American dog tick, is widespread in both northeastern and southeastern states and has a distribution that overlaps that of *I. scapularis* (Merten and Durden 2000).

Interestingly, the Piedmont of North Carolina, a region of high human population density, is situated in an apparent gap in the distribution of *I. scapularis* to the Northeast and *A. americanum* to the East and Southeast (Diuk-Wasser et al. 2006, Eisen et al. 2016). Previous surveys indicated that few *D. variabilis* were present in the central and western areas of North Carolina (Diuk-Wasser et al. 2006). North Carolina also has fewer reported counties with *I. scapularis* than states to the north and south, especially in the Piedmont region between the mountains and coastal plain (Eisen et al. 2016). As a result, there are relatively few reports of these vectors in the North Carolina Piedmont, leaving North Carolina with considerably fewer Lyme disease cases than states to the north, including nearby Virginia (Lantos et al. 2015). Trends in vector spread, however, suggest that patterns of tick distribution and abundance may have changed or will change rapidly in the near future (Diuk-Wasser et al. 2006, Lantos et al. 2015, Eisen et al. 2016), and there is evidence of increasing incidence of Lyme disease in northern North Carolina and ehrlichiosis in central North Carolina (NC Division of Public Health 2019a,b).

In response to the above trends, we aimed to update and document patterns of tick presence and abundance in the Piedmont of North Carolina. We focused our surveys on an area of perceived low tick abundance (Town of Davidson, Mecklenburg County, Davidson, NC) and sought to confirm and explore the boundaries of this low tick abundance within the piedmont of North Carolina.

Materials and Methods

We visited multiple locations within the Piedmont of North Carolina during late spring, summer, and fall of 2019 (Fig. 1). We focused our data collection in suburban Mecklenburg County

(Davidson, NC) and conducted surveys to the west (South Mountains State Park, Burke County), north (Stone Mountain State Park, Wilkes and Alleghany Counties), northeast (Duke Forest, Durham County), and east (Morrow Mountain State Park, Stanley County). The summer season corresponds to the larval and nymphal life stages of *I. scapularis*, adult life stage of *D. variabilis*, and adult, larval, and nymphal life stages of *A. americanum* (Ostfeld and Keesing 2000, Goddard and Zhou 2007). We selected sites at each of these five locations haphazardly to sample different habitat types, forest structures, fields, and field edges with road access. In addition to these geographically extensive surveys, we also sampled intensively in Davidson to determine whether previous observations by our research of low tick densities were the result of low sampling effort.

At each survey site, 4–19 of which were nested within each location (Fig. 1, Table 1), we laid a 100-m transect and recorded GPS location data for the start and end of the transect, the direction of the transect, temperature, weather, time, if the site had recently been burned, a brief description of understory composition, and elevation. We sampled on days without rain, except for rain overnight at South Mountains on 8 July, light rain at three sites on 9 July at South Mountains, and rain during surveys of Morrow Mountain on 23 November.

Tick Surveys

We used three methods to sample ticks at each site: drag sampling (Falco and Fish 1988), CO_2 trapping (Falco and Fish 1992), and leaf litter collection (Chilton and Bull 1993). We used tick drags and CO_2 traps to survey for questing ticks. We used Berlese funnels to survey for ticks in the leaf litter and topsoil of forest sites, as previous studies have shown that *I. scapularis* may be present in leaf litter when not questing (Chilton and Bull 1993).

For drag sampling, we made 1 m^2 cloth tick drags following Russell and Jain-Sheeha (2015). At each site, we dragged twice in parallel along a 100-m transect with at least 5 m between the two drags, thereby covering 200 m^2 at each site. While dragging, we wore white coveralls to easily see ticks and checked the drag cloth and coveralls every 20 m. We collected any ticks we found and placed them into Whirl-Paks with 70% ethanol for preservation and later identification to the species level using a dissecting microscope, taxonomic keys (e.g., Keirans and Litwak 1989), and consultation with colleagues.

We constructed CO_2 traps following Falco and Fish (1992). We placed CO_2 traps at 33- and 66-m marks of select sites and collected them the following day. At select sites, we also collected leaf litter and soil samples to be run through Berlese funnels to determine whether ticks were present in leaf litter or topsoil (Chilton and Bull 1993, Tietjen et al. 2019).

Results

From three sampling methods for surveying ticks (cloth drags, CO_2 traps, and leaf litter collection) across four locations in North Carolina in the summer and five locations in the fall, we captured a total of 20 ticks. Of these 20 captures, all were adult *D. variabilis*, except for one capture of *I. scapularis* larvae (n = 204) and one capture of *A. americanum* larva (n = 1) found in leaf litter (Table 1). Although *Ixodes affinis* Neumann (Acari: Ixodidae) occurs in North Carolina and is difficult to distinguish from *I. scapularis* in the larval stage, *I. affinis* is restricted to the coastal plain in North Carolina, a different ecoregion that is >250 km from the capture site of *I. scapularis* in our study (Harrison et al. 2010).

Nineteen of the captures were in the summer season, and only one *A. americanum* larva was found from a Davidson site in the fall (from leaf litter extraction using Berlese funnels). Of the 19 captures from the summer, all were collected by cloth drag and CO_2 trapping, with no ticks found in leaf litter samples (Table 1).

Discussion

The highest number of tick captures per amount of effort was at Stone Mountain State Park, which is located near the southern

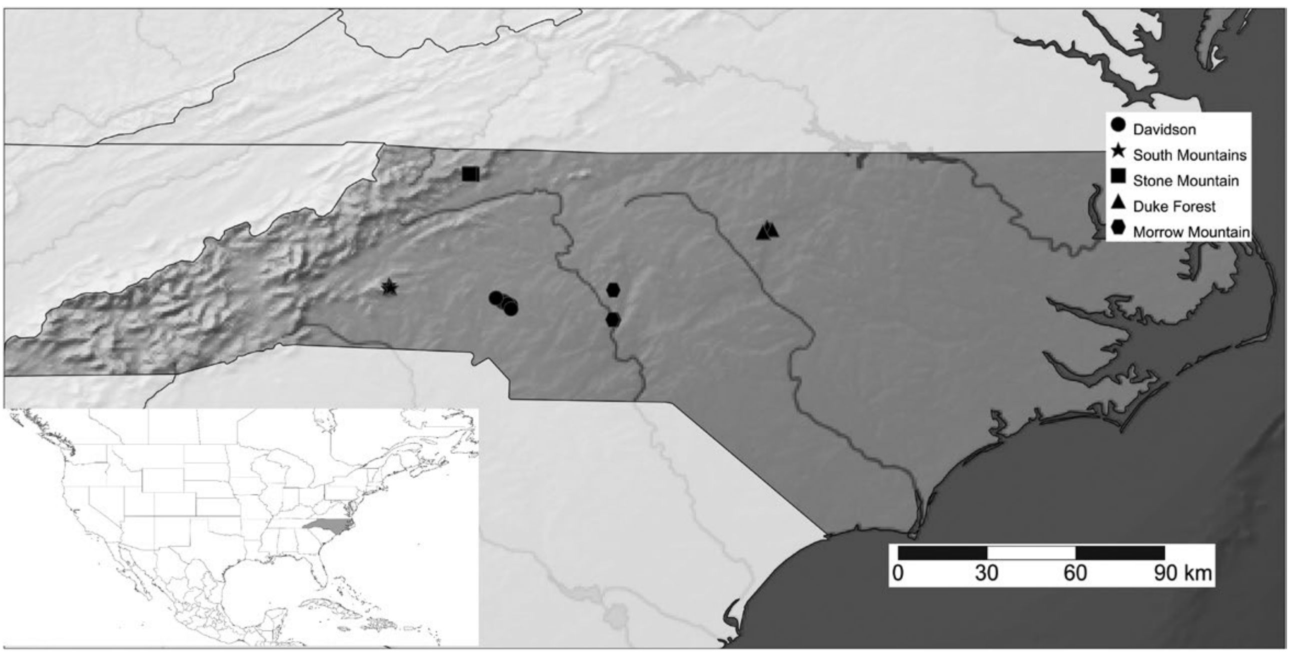

Fig. 1. Map of survey locations for tick sampling in the Piedmont of North Carolina. Each cluster of symbols represents a location as described in Table 1, with individual symbols representing sites, some of which overlap at this scale.

Table 1. Survey effort and tick captures for this study

		Summer 2019			Fall 2019		
		Cloth drags	CO_2 trap-nights	Leaf litter samples	Cloth drags	CO_2 trap-nights	Leaf litter samples
Davidson, Mecklenburg County	Effort	19	16	6	18	16	6
	Dermacentor variabilis	6 (adult)	3 (adult)				
	Amblyomma americanum						1 (larva)
South Mountains SP, Burke County	Effort	10	8	2	4	8	3
	Dermacentor variabilis	1 (adult)	2 (adult)				
Stone Mountain SP, Wilkes & Alleghany Cos.	Effort	9	8	4	4	8	4
	Dermacentor variabilis	4 (adult)	1 (adult)				
	Ixodes scapularis (presumed; see text)	204 (larvae)					
Duke Forest, Durham County	Effort	7	4	2	4	4	3
	Dermacentor variabilis	1 (adult)					
Morrow Mountain SP, Stanley County	Effort	NA	NA	NA	4	0	4
	No captures						

Each drag was 200 m^2, and each leaf litter sample was ca. 1 liter of material. NA (not applicable).

border of Virginia. Stone Mountain was also the only location of an *I. scapularis* capture (a single cluster of larvae; Table 1), which could be the evidence of the southward movement of *I. scapularis* from Virginia into North Carolina proposed by Lantos et al. 2015.

Although not found in our surveys, *Ixodes affinis* Neumann is a tick species widespread through the northeastern and southeastern United States (Kohls and Rogers 1953) and was reported in 2010 to be abundant in counties in coastal North Carolina (Harrison et al. 2010). Smith et al. (2010) reported high abundances of *A. americanum* in Chatham County, NC, which is a neighboring county of Durham County, where we surveyed at Duke Forest. However, we only had one tick capture of *D. variabilis* in Durham County and no captures of *A. americanum*, suggesting that although locally abundant, their distribution is patchy. Recent incidence of ehrlichiosis in this part of the North Carolina Piedmont suggests that this tick species is firmly established, however (NC Division of Public Health 2019a).

Previous studies in 2006 and 2010 indicated low abundance of various tick species in the western Piedmont of North Carolina (Diuk-Wasser et al. 2006, Smith et al. 2010, Eisen et al. 2016). Our results confirm these findings, contradicting predictions of increasing tick abundances in the state (Harrison et al. 2010, Lantos et al. 2015), if only temporarily. This trend may indicate that there could be environmental factors, such as host community composition and/or habitat composition, that contribute to low tick densities in North Carolina. Habitat, host species, and climate are three factors that affect the presence of ticks (Ginsberg et al. 2019), and the parts of North Carolina surveyed in this study may have host and habitat compositions that do not support high tick abundances. Specifically, North Carolina has higher rodent and reptile diversity than states in the northeast United States, which could contribute to fewer ticks and the lower prevalence of TBDs such as Lyme disease (Ryan et al. 1998, 2000), despite a moderately increasing trend of Lyme in North Carolina, especially near the Virginia border (NC Division of Public Health 2019b).

Invasive plant species and mammal composition play important roles in the abundance of various tick species and the pathogens they carry (Keesing et al. 2006, Levi et al. 2012). The presence of invasive plant species, such as Amur honeysuckle (*Lonicera maackii,* Maximowicz, Dipscales:Caprifoliaceae) and Japanese barberry (*Berberis thunbergii,* De Candolle, Ranunculales: Berberidaceae), in forest understory can increase the abundance of *A. americanum* and *I. scapularis*, respectively (Allan et al. 2010, Williams et al. 2017). Amur honeysuckle increases tick abundance by altering the habitat of hosts, such as white-tailed deer (*Odocoileus virginianus*, Zimmermann, Artiodactyla: Cervidae) (Allan et al. 2010), and Japanese barberry changes the microclimate of the forest understory and provides access to hosts (Williams et al. 2017). We never recorded the presence of Amur honeysuckle (*Lonicera* sp.) or Japanese barberry (*Berberas* sp.) as significant components of the forest understory in the public lands in our surveys. However, several of the survey locations in Mecklenburg County have high densities of introduced olives (*Elaeagnus* sp., Rosales, Elaeagnaceae) and privets (*Ligustrum* sp., Lamiales, Oleaceae), which may provide similar habitats and resources as *Lonicera* and *Berberas*, so understory habitat alone may not explain the low tick abundances recorded in our study.

Mammal composition can also affect the abundance of ticks and predation dynamics of these mammals could contribute to the low tick abundance observed in this study (Levi et al. 2012). Researchers have shown that declines in red fox (*Vulpes vulpes*, L., Carnivora:Canidae) abundance due to increased abundance and predation by coyotes (*Canis latrans*, Say, Carnivora:Canidae) increased the density of *I. scapularis* nymphs and therefore the prevalence of Lyme disease (Levi et al. 2012). If these predation and mammalian host dynamics have not changed in North Carolina, the abundance of *I. scapularis* may remain low. However, similar to our assessment of understory shrubs, coyote populations have been expanding in North Carolina, so this factor by itself is unlikely to explain low tick abundances in the North Carolina piedmont. Furthermore, deer densities in the North Carolina Piedmont are among some of the highest in the state (NC Wildlife Resources Commission 2015), suggesting that hosts for adult ticks are not limiting. Changing dynamics of host and habitat composition clearly affect tick abundances (Keesing et al. 2006, Levi et al. 2012), but given the low abundance of ticks reported in our study and over the past decade in the North Carolina Piedmont (Diuk-Wasser et al. 2006, Smith et al. 2010, Eisen et al. 2016), these factors might maintain low tick abundance, with a similar effect on TBDs in this region.

Collectively, our results suggest that the distribution and abundance of two important tick species, *I. scapularis* and *A. americanum* are limited in parts of the Piedmont of North Carolina. We suggest that further monitoring of tick abundance and host and habitat composition over time may help clarify if ecological factors in the region are limiting the establishment of these important vector species in an otherwise suitable region.

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