Ticks and the Restoration of Oak Woodlands and Savanna in Tennessee: A One- Health Perspective

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Abstract

Eastern North America contains myriad biodiverse ecosystems that depend on periodic wildland fire in order to persist. However, fire suppression by humans has threatened the viability of many of these habitats by initiating changes in abiotic environmental conditions that precipitate the establishment of new plant species, ones that are more tolerant of shady and moist conditions— taxa that displace the previous floral community. The reintroduction of disturbance events (such as burning and selective thinning) into these landscapes, which include ecosystems such as the Oak woodlands and savannas of Appalachia and the Pine Barrens of the North Atlantic Coast, has a demonstrated capacity to promote the regeneration of pre-mesophication communities. Furthermore, these management strategies may reduce tick populations by creating abiotic conditions that are unsuitable for the survival of these arthropods, known vectors of disease to humans. We sought to examine how fire, ignited during different seasons in varying habitat, influenced *Amblyomma americana* (lone star tick) populations in oak dominated areas situated in the Catoosa Wildlife Management Area (Tennessee, USA). Five treatments were considered: no fire or mechanical management (1), growing season burns in oak woodland (2) and savanna (3), dormant season burns in oak woodland (4) and savanna (5). Ticks were collected by dragging $1m^2$ pieces of cloth along 100m transects within treatments and then identified to species. Results indicate that burning in the growing season may in some cases decrease tick populations. Additionally, we are actively investigating the relationship between burn frequency and tick populations on Long Island (New York, USA) in the Central Pine Barrens Region. This research contributes to efforts by Brookhaven National Laboratory and the Department of Energy to promote sustainable environmental stewardship, as incentivizing burning to decrease tick populations as a public health measure could increase public acceptance of fire as a conservation strategy.

Introduction

Mesophication and the Decline of Pyrophytic Ecosystems in Eastern North America

Natural communities that are adapted to disturbance events such as periodic low to moderate intensity wildland fire are located throughout the eastern part of North America. These fire dependent—or pyrophytic—associations include threatened and rare ecosystems such as the myriad types of oak forests, woodlands, and savannas that characterize the broader Appalachian region[1] and the North Atlantic Coastal Pine Barrens.[2] However, since the arrival of European settlers, the implementation of novel land management paradigms has threatened the survival of many of these ecosystems.[3] In these areas, fire exclusion is thought to have contributed to a significant decline in both species diversity and richness.[1,3] Fire suppression is believed to be a leading driver of community change in many pyrophytic ecosystems through a process known as 'mesophication'.[3] This hypothesis postulates that fire exclusion initiates a cascading series of changes (i.e., a positive feedback loop) that facilities the survival of plant species that are adapted to more mesic and shady (rather than xeric and sunny) conditions by promoting moist and shaded microclimates. Management strategies such as controlled burn and canopy thinning can work to reverse this process.

On Moisture and Microclimates: Considering Ticks within the Context of Mesophication

Many tick (parasitic arthropods that are known vectors of microorganisms that can cause disease in humans) species could benefit from the environmental conditions that result from mesophication.[4] Ticks are highly vulnerable to desiccation in relatively dry environments.[5] As the abiotic environment in ecosystems that are undergoing mesophication becomes progressively moister and more shaded, microclimate conditions that are favorable to tick existence may expand accordingly.[4] Indeed, the range of many tick species, including *Amblyomma americanum* (the lone star tick), is believed to have dramatically increased in recent years.[6] Mesophication could be playing a role in driving this spread.[4] Conversely, in habitats that have experienced frequent fire (i.e., several burns in the same area), tick populations may decline [7]— a reduction that may buffer humans from tickborne illnesses by decreasing the likelihood that humans encounter a tick carrying a pathogenic microorganism.[8]

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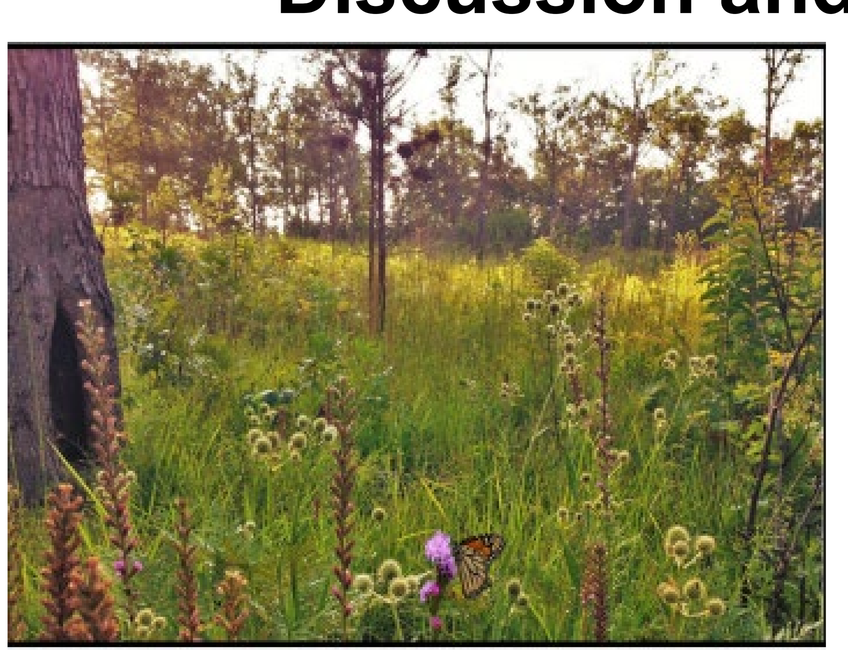
Discussion and Conclusions



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Methods

Study Site

- Tick sampling occurred at the Catoosa Wildlife Management Area (CWMA—Tennessee, USA), a 32,374 ha parcel administered by the Tennessee Wildlife Resources Agency (TWRA). For a complete description of the environmental conditions and ecological community present at the site, see Vander Yacht et al. 2017 [y] and Vander Yacht et et al. 2020.[x]

Sample Design

- Sampling activities took place at 20 plots (50- acres each) that were divided into two replicates of five distinct treatment categories (plots were randomly assigned to treatments):
  1. Control—a stand that was not subject to prescribed fire or mechanical thinning.
  2. FaW—Growing season burn/ woodland : an area that was thinned to a basal area of 60 f^2 $acre^{-1}$ and burned (x3 times) during the growing season (October 2010, 2012, 2014).
  3. FaS—Growing season burn/ savanna : an area that was thinned to a basal area of 30 f^2 $acre^{-1}$ and burned (x3 times) during the growing season (October 2010, 2012, 2014).
  4. SpW— Dormant season burn/woodland: an area that was thinned to a basal area of 60 f^2 $acre^{-1}$ and burned (x3 times) during the dormant season (March 2011, 2013, 2015).
  5. SpS—an area that was thinned to a basal area of 30 f^2 $acre^{-1}$ and burned (x3 times) during the dormant season (March 2011, 2013, 2015).
- Mechanical treatment (consisting of overstory thinning) was implemented in late 2008. This operation selectively targeted fire-intolerant species (such as *Acer* spp. and *Liquidambar styraciflua*) while safeguarding pyrophytic taxa (including *Quercus* spp., *Carya* spp., and *Pinus echinata*).
- Ticks were sampled at each plot three times (once during the first week of June, July, and August) in 2014, 2015, and 2016.
  - 2014 samples were obtained one year after the second fire treatment and one year prior to the third burn.
  - 2015 samples were obtained one year after the third fire treatment.
  - 2016 samples were obtained two years after the third fire treatment .
- Ticks were sampled by dragging $1m^2$ pieces of cloth along 100m long transects that were established within the plots (area that was sampled did not include a $50m^2$ buffer around the edge of the unit). Between 6-9 transects were sampled per plot.
  - Ticks identified to species and recorded taxonomically by instar (and, if adult, sex).
  - Temperature and relative humidity values that were present at the start and end of the survey were noted.

Statistical Analysis

- *A. americanum* count data (individuals per 100m transect) was aggregated by treatment (i.e., all ticks that were collected during each sampling event in FaS plots were compiled in the same bin, with each transect coded as a unique and independent sample).
- Utilizing R Studio, normality was assessed within treatments by employing a Shapiro-Wilk test on the distribution for each age class of *A. americanum* (as well as the total number of ticks). Neither the number of individuals within any age class nor the total amount of ticks for each treatment was found to be normally distributed. Thus, the distribution of each of these categories was compared, by year, with a Kruskal-Wallace test. If a significant result was identified, Dunn's test was used as a post hoc analysis to identify where significant difference occurred.

Results

Growing Season Burns

- Significant decrease in number of *A .americanum* ticks collected between 2014 and 2016 in both woodland (FaW: Dunn's Test— Z=2.795172, P<0.05) (Table 2) and savanna (less (FaS: Dunn's Test— Z=2.5323644, P<0.05) (Table 3).
  - FaW total decrease: 67%; FaS total decrease: 79%
- Significant decrease in number of *A. americanum* nymphs collected between 2014 and 2016 in woodland (FaW: Dunn's Test—Z=3.163524, P<0.01) (Table 2).
  - FaW nymph decrease: 64%
- Significant decrease in number of *A. americanum* nymphs collected between 2015 and 2016 in savanna (FaS: Dunn's Test—Z=2.5356539, P<0.05) (Table 3).
  - FaS nymph decrease: 59%

Dormant Season Burns

- Significant decrease in number of *A. americanum* ticks collected between 2015 and 2016 in woodland (SpW: Dunn's Test— Z= 2.5035271, P<.05) (Table 4).
  - SpW nymph decrease: 54%
- Significant increase in number of *A. americanum* larvae collected between 2015 and 2016 in savanna (SpS: Z=-2.4094010, P<0.05) (Table 5)
  - SpS larvae increase: 1653%
- Significant increase in number of *A. americanum* larvae collected between 2014 and 2016 in savanna (SpS: Z= -2.7536012, P<0.05)
  - SpS larvae increase: 3122%

Age Class	2014- 2015	2015- 2016	2014- 2016
AA—Total	Z: 0.6007051 P: 1.0000000	Z: 0.9848384 P: 0.9741104	Z: 1.5959406 P: 0.3315062
AA—Larvae	Z: -1.20626137 P: 0.6831502	Z: 1.29805197 P: 0.5828084	Z: 0.09239251 P: 1.0000000
AA—Nymph	Z: 1.8934829 P: 0.1748810	Z: -0.3375015 P: 1.0000000	Z: 1.5661846 P: 0.3519162
AA— Adult (M)	Z: 1.0538914 P: 0.8757979	Z: -0.5458114 P: 1.0000000	Z: 0.5114117 P: 1.0000000
AA—Adult (F)	Z: 2.07327125 P: 0.09867438	Z: -0.07364123 P: 1.00000000	Z: 2.07327125 P: 0.11444113

Table 1: Dunn's Test results comparing population differences between years for *A. americanum* ticks (by instar/ total) found in Control areas. Red/bold= significant difference.

Age Class	2014- 2015	2015- 2016	2014- 2016
AA—Total	Z: 1.753575 P: 0.23851019	Z: 1.041597 P: 0.89279562	**Z: 2.795172 P: 0.01556164**
AA—Larvae	Z: 0.87812950 P:1	Z: -0.80035232 P: 1	Z: 0.07777718 P:1
AA—Nymph	Z: 1.799644 P: 0.21575083	Z: 1.363881 P: 0.21575083	**Z: 3.163524 P: 0.00467614**
AA— Adult (M)	Z: -0.9729824 P: 0.9916862	Z: 1.6088873 P: 0.3229229	Z: 0.6359050 P: 1.0000000
AA—Adult (F)	Z: 1.0513474 P: 0.8792972	Z: -0.5400102 P: 1.0000000	Z: 0.6091150 P: 1.0000000

Table 2: Dunn's Test results comparing population differences between years for *A. americanum* ticks (by instar/ total) found in FaW areas. Red/bold= significant difference

Age Class	2014- 2015	2015- 2016	2014- 2016
AA—Total	Z: 0.7266249 P: 1.00000000	Z: 1.8010364 P: 0.21509143	**Z: 2.5323644 P: 0.03398885**
AA—Larvae	Z: -0.4456359 P: 1.0000000	Z: 1.4872734 P: 0.4108278	Z: 1.0387531 P: 0.8967587
AA—Nymph	**Z: 2.5356539 P: 0.03367128**	Z: -0.2521796 P: 1.00000000	Z: 2.2998865 P: 0.06436396
AA— Adult (M)	Z: 0.3801326 P:1	Z: 0.4830054 P:1	Z: 0.8655984 P:1
AA—Adult (F)	Z: 1.2629635 P: 0.6198069	Z: -0.7694343 P: 1.0000000	Z: 0.5017038 P: 1.0000000

Table 3: Dunn's Test results comparing population differences between years for *A. americanum* ticks (by instar/ total) found in FaS areas. Red/bold= significant difference

Age Class	2014- 2015	2015- 2016	2014- 2016
AA—Total	Z: -0.9486065 P: 1.00000000	**Z: 2.5035271 P: 0.03688868**	Z: 1.5361345 P: 0.37351622
AA—Larvae	Z: -1.5850312 P: 0.3388777	Z: 1.2737052 P: 0.6083037	Z: -0.3427158 P: 1.0000000
AA—Nymph	Z: 0.9140167 P: 1.0000000	Z: 1.1315597 P: 0.2578196	Z: 2.0636776 P: 0.1171449
AA— Adult (M)	Z: -0.67012760 P:1	Z: 0.65195401 P:1	Z: -0.03144473 P:1
AA—Adult (F)	Z: 0.6637981 P: 1.0000000	Z: 0.7903536 P: 1.0000000	Z: 1.4672975 P: 0.4268854

Table 4: Dunn's Test results comparing population differences between years for *A. americanum* ticks (by instar/ total) found in SpW areas. Red/bold= significant difference

Age Class	2014- 2015	2015- 2016	2014- 2016
AA—Total	Z: 0.2693384 P:1	Z: -0.9229077 P: 1	Z: -0.6535693 P: 1
AA—Larvae	Z: -0.3442001 P: 1.00000000	**Z: -2.4094010 P: 0.04793619**	**Z: -2.7536012 P: 0.01768306**
AA—Nymph	Z: 0.9997325 P: 0.9523199	Z: -0.3810301 P: 1.0000000	Z: 0.6187024 P: 1.0000000
AA— Adult (M)	Z: -0.7007625 P:1	Z: 0.1039707 P:1	Z: -0.5967918 P:1
AA—Adult (F)	Z: -1.5275161 P: 0.37989816	Z: -0.6960305 P: 1.00000000	Z: -2.2235467 P: 0.07853688

Table 5: Dunn's Test results comparing population differences between years for *A. americanum* ticks (by instar/ total) found in SpS areas. Red/bold= significant difference

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