# 2019
# WEST VIRGINIA MOSQUITO AND TICK SURVEILLANCE REPORT

WEST VIRGINIA Department of Health & Human Resources
BUREAU FOR PUBLIC HEALTH

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## MOSQUITO SURVEILLANCE

### INTRODUCTION

The West Virginia Mosquito Surveillance Program (WVMSP) began in 2007 and involves the efforts of both state and local partners. The WVMSP's objective is to identify mosquitoes that are infected with or are capable of transmitting mosquito-borne diseases. The secondary objective is to determine the geographic distribution of mosquitoes that are known to transmit diseases to humans and animals. Data collected on mosquitoes can guide mosquito control methods and activities. Monitoring for new, invasive mosquito species and species that are known to transmit emerging mosquito-borne diseases (e.g. chikungunya, Zika) is another function of the WVMSP.

Mosquito-borne diseases under surveillance in West Virginia are shown in Table 1. Mosquitoes collected through the season are tested for the following arboviruses: La Crosse Virus (LACV), West Nile virus (WNV), St. Louis encephalitis virus (SLEV), and Zika virus (ZIKV), which replaced Eastern Equine Encephalitis (EEE) virus in 2017.

**Table 1. Mosquito-borne diseases under surveillance in WV and their vectors.**

| Disease | Vector |
|---|---|
| La Crosse Encephalitis (LAC) | *Aedes triseriatus, Aedes japonicus, Aedes albopictus* |
| West Nile Virus Infection (WN) | *Culex* species |
| Malaria | *Anopheles* species |
| Dengue/Chikungunya/Zika Virus Disease (ZIK) | *Aedes aegypti*, Aedes albopictus* |
| Eastern Equine Encephalitis (EEE) | *Aedes*, *Coquillettidia*, and *Culex* species |
| St. Louis Encephalitis (SLE) | *Culex pipiens, Culex quinquefasciatus** |

*Species has not been found in West Virginia

LAC is the predominant mosquito-borne disease in West Virginia and has the highest incidence in the southern part of the state. The severe (neuroinvasive) form of LAC occurs in children under the age of 16. WNV was added to mosquito surveillance after a nationwide outbreak that started in New York in 1999. The highest number of WNV (N=9) was reported in 2012. Surveillance for ZIK in mosquitoes was initiated in response to the ZIK outbreak in Central and South America during 2015-2016. Although no locally acquired human cases of ZIK have occurred in West Virginia, ZIK could be established in the local mosquito population following mosquito blood feeding on human hosts who have the virus in their blood. Surveillance for arboviruses and other mosquito-borne diseases is important in understanding the public health impact of these diseases and monitoring for changes in disease activity, particularly because arboviral outbreaks are difficult to predict.

Mosquito surveillance involves use of different techniques to trap mosquitoes based on the species of interest, life stage, and other characteristics. For example, *Culex* spp. mosquitoes are drawn to gravid traps while *Aedes* spp. are drawn to carbon dioxide emitting light traps and Bio Gent (BG) Sentinel traps. Attractants such as carbon dioxide ($CO_2$), chemical lures, and light are often used. Table 2 shows the types of mosquito traps used by WVMSP during 2019.

**Table 2. Mosquito traps used by WVMSP during the 2019 mosquito surveillance season.**

| Type of Trap | Trap Characteristics | Mosquito Target |
|---|---|---|
| Gravid Trap / Frommer Trap / Reiter Trap | Collects gravid mosquitoes searching for site to deposit eggs | *Cx. pipiens*, *Cx. restuans*, *Ae japonicus* |
| Light Trap (with dry ice) | Light used to guide mosquitoes into trap. Dry ice (carbon dioxide) mimics vertebrate host. | *Ae. aegypti*, Ae. albopictus*, *Ae. triseriatus*, *Coquillettida perturbans*, *An. quadrimaculatus*, *An. punctipennis* |
| BG Sentinel Trap (with octenol or BG Lures) | Visual and olfactory; air convention currents mimic vertebrate host. | *Ae. aegypti*, Ae. albopictus*, *Ae.triseriatus* |

*Species has not been found in West Virginia

Following failures to manage local transmission of Zika virus disease due to adulticide resistance, public health officials became more interested in monitoring pesticide resistance in local mosquito populations. The Asian tiger mosquito is a competent mosquito vector for endemic (LAC) and non-endemic (yellow fever, dengue fever, chikungunya, Zika virus disease). Therefore, the Asian tiger mosquito (*Aedes albopictus*) is an invasive mosquito species of public health concern in West Virginia. Adult *Ae. albopictus* mosquitoes are active from May to October throughout West Virginia, have preferential breeding close to humans and adult females have a broad host feeding range including humans. Populations of *Ae. albopictus* throughout the continental United States are resistant to different pesticides including malathion, bifenthrin and etofenprox.

This report summarizes the combined efforts of state and local public health officials in West Virginia during the 2019 mosquito surveillance season.

**METHODS**

The West Virginia Department of Health and Human Resources (DHHR), Bureau for Public Health conducted mosquito surveillance activities from May to October 2019 for arbovirus detection and *Aedes albopictus* monitoring. Four local health departments (LHDs) were actively involved in mosquito surveillance in 2019: Cabell-Huntington Health Department (HD) (1 surveyor), Kanawha-Charleston HD (1 surveyor), Monongalia County HD (3 surveyors), and Wheeling-Ohio HD (1 surveyors).

The Bureau for Public Health provided resources to participating LHDs (i.e. mosquito surveyors, surveillance equipment, microscopes, mosquito identification training, mosquito identification expertise, educational materials), served as a central depository for mosquito surveillance results, and conducted mosquito surveillance in counties not actively monitored by a LHD. State responsibilities were performed by the state public health entomologist, one vector surveillance intern, and two microbiologists in the West Virginia Office of Laboratory Services (OLS).

Mosquito surveillance activities were modified due to the 24$^{th}$ World Scout Jamboree held during July 22 – August 2, 2019 at the Summit Bechtel Family National Scout Reserve in Fayette County. The World Scout Jamboree was one of the largest mass gatherings in the state's history with approximately 50,000 scouts attending from 138 countries and visitors on-site. Because Summit Bechtel is located in a high LAC incidence region, adult mosquito surveillance was focused in Fayette County and neighboring Nicholas and Raleigh counties from May through July. Due to distance, semi-regular sampling was conducted in Hampshire, Jackson, Mercer, Mingo, Pendleton, Randolph, Wetzel, and Wood counties from August through October. LHD partners conducted regular, weekly mosquito trapping in Cabell, Kanawha, Marion, and Ohio counties and semi-regular sampling in Doddridge, Harrison, Monongalia, Preston, Taylor, and Wayne counties.

Adult mosquitoes were predominantly collected using gravid traps and $CO_2$ emitting light traps. Additional mosquito surveillance methods were employed to better monitor *Aedes albopictus* activity, detect *Aedes aegypti*, and reduce damage to mosquitoes caused by the collection process. Bio Gent Sentinel traps with BG lure were utilized regularly throughout the surveillance season in Cabell and Doddridge counties. To monitor *Aedes albopictus* activity, Bio Gent Sentinel traps with BG lure were also utilized opportunistically in Hampshire, Harrison, Kanawha, Marion, Mingo, Monongalia, Pendleton, Preston, Randolph, Taylor, Wayne, and Wood counties. To reduce damage to mosquito samples, Frommer traps and Reiter traps were also used in Kanawha County. LHDs regularly submitted mosquito samples with the associated collection information to the Bureau for Public Health throughout the summer. Geographic, temporal, collection method, identification, and test result data were stored in an Epi Info 7 database.

Following collection from field sites, adult mosquitoes were prepared for arboviral testing at OLS. Mosquitoes were identified and sorted into pools (groups) based on date of collection, collection location, and genus (average of 26.5 adult mosquitoes per mosquito pool). Due to recent concerns about ZIK competent mosquitoes, the Asian tiger mosquito, *Ae. albopictus*, was tested separately from other mosquito species.

Due to an unforeseen loss of two OLS microbiologists in June, OLS testing was limited to mosquito samples collected from Fayette County from May 28 through July 8. Pools consisting of 10-50 adult female mosquitoes were screened for WNV, SLEV, LACV, and ZIKV (male mosquitoes do not actively transmit arboviral diseases) using real-time reverse transcription polymerase chain reaction (RT-PCR). This assay amplifies and detects arboviral ribonucleic acid (RNA).

The Kanawha-Charleston HD and DHHR's Office of Epidemiology and Prevention Services evaluated malathion, bifenthrin, and prallethrin efficacy on adult *Ae. albopictus* collected from three Kanawha County surveillance sites and one neighboring Putnam County surveillance site using the Centers for Disease Control and Prevention (CDC) Bottle Bioassay. The CDC Bottle Bioassay technique is a surveillance tool used for detecting insecticide resistance in a vector population.

**Table 3. Diagnostic doses and times used for technical grad active ingredients used in CDC Bottles Bioassays on *Ae. albopictus*.**

| Insecticide | Final Concentration per Bottle (Diagnostic Dose) | Diagnostic Time | Reference |
|---|---|---|---|
| Bifenthrin | 15 µg | 30 minutes | (Richards *et al*. 2017) |
| Malathion | 400 µg | 30 minutes | (CDC, 2020) |
| Prallethrin | 0.05 µg | 120 minutes | (CDC, 2020) |

Specifically, bottles were coated with initial doses of malathion, bifenthrin, and prallethrin according to guidance provided by the CDC (2020) and Richards *et al.* (2017, 2019) to detect insecticide resistance. These insecticides were chosen based on a 2016 survey of private and public pesticide applicators in West Virginia certified in mosquito pest management that showed they were the most common active ingredients used in mosquito control. Furthermore, these pesticides, malathion (organophosphate), bifenthrin (Type I pyrethroid), and prallethrin (Type I pyrethroid), represent a diversity of chemistries with different modalities. Field-collected adult mosquitoes were put into treatment bottles and observed for two hours. Resistance was determined by the percentage of mosquitoes that died (mortality rate) at the pre-determined threshold time during those two hours. To compensate for mortality caused by acetone, mosquito mortality was monitored for two hours in a control bottle coated with acetone.

Arboviral results were provided to the Bureau for Public Health and participating LHDs for their jurisdiction by OLS. Arboviral test results were reported to CDC by the Bureau for Public Health through ArboNET, a national mosquito surveillance reporting system, within three days of confirmation, and later to CDC through MosquitoNET. Results from pesticide efficacy trials were also reported to the CDC through ArboNET. Pool infection rates were examined for each mosquito genus weekly to relate incidence of infection with a population indicator. The WNV minimum infection rate (MIR) for *Culex* mosquitoes was determined weekly using the following equation:

$$MIR = \frac{virus\ positive\ mosquito\ pools}{total\ number\ of\ mosquitoes\ tested} \times 1{,}000$$

## RESULTS

From May 28 to October 17, 2019, WVMSP conducted mosquito surveillance at 60 localities in 21 counties (Figure 1 and Appendix A); a total of 14,645 adult mosquitoes was collected. None of the mosquito pools tested positive for WNV, SLEV, LACV, or ZIKV.

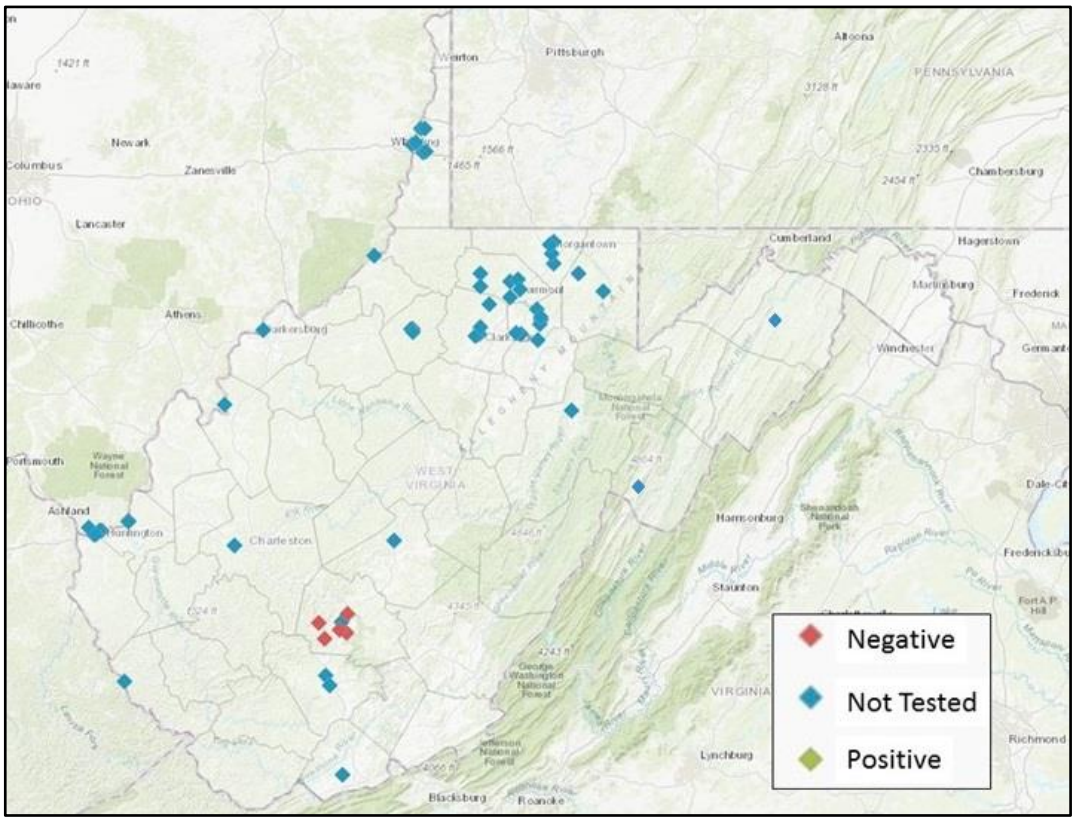


**Figure 1. Locations under active mosquito surveillance in West Virginia, 2019. 'Positive' means mosquito sample tested positive for virus responsible for WN, LAC, SLE or ZIK. 'Negative' means virus responsible for WN, LAC, SLE or ZIK was not detected in the mosquito sample.**

Complete *Aedes albopictus* mortality was achieved within 35 minutes of pesticide application for all three pesticides from the three surveillance sites in Kanawha County and one surveillance site in Putnam County (Figs. 2-5). *Aedes albopictus* from all surveillance sites would be classified as 'malathion resistant,' since these mosquitoes suffered <90% mortality within the 30-minute diagnostic time (CDC, 2020). Conversely, the single population of *Aedes albopictus* from South Charleston in Kanawha County was the only population examined shown to be 'developing resistance' to bifenthrin (Richards *et al*. 2016).

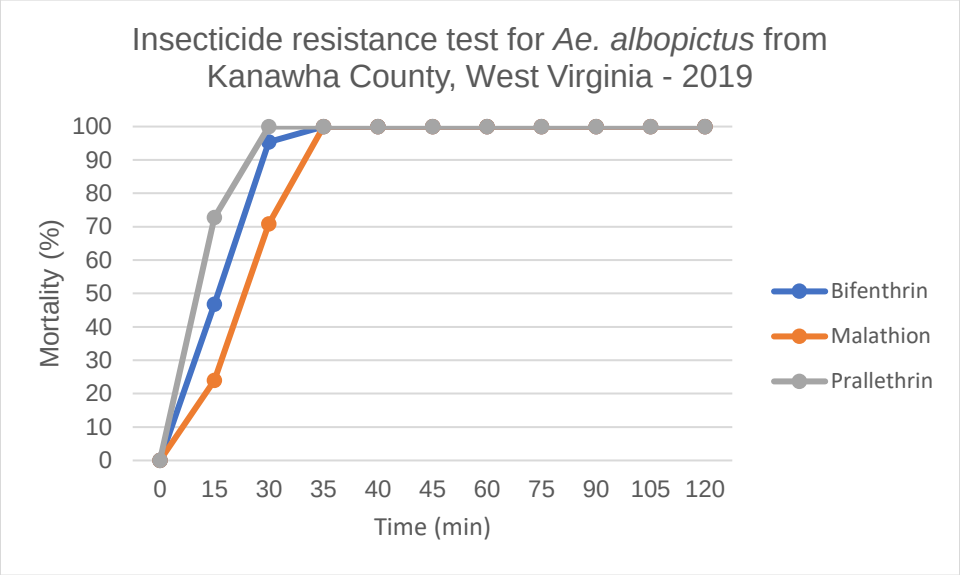


**Figure 2. Insecticide resistance test using CDC Bottle Bioassay for *Ae. albopictus* from South Charleston, Kanawha County for technical grade active ingredients.**

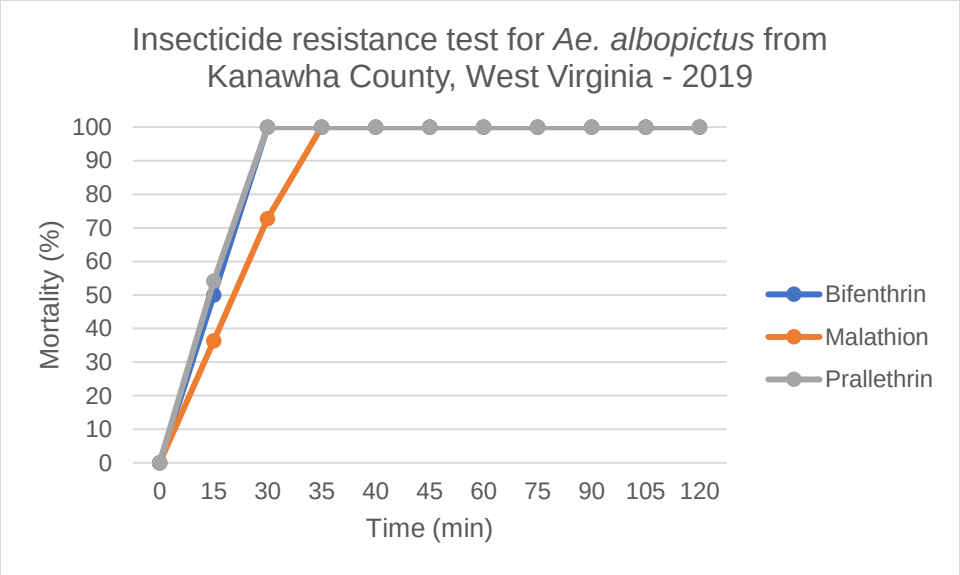


**Figure 3. Insecticide resistance test using CDC Bottle Bioassay for *Ae. albopictus* from Mill Creek, Charleston, Kanawha County for technical grade active ingredients.**

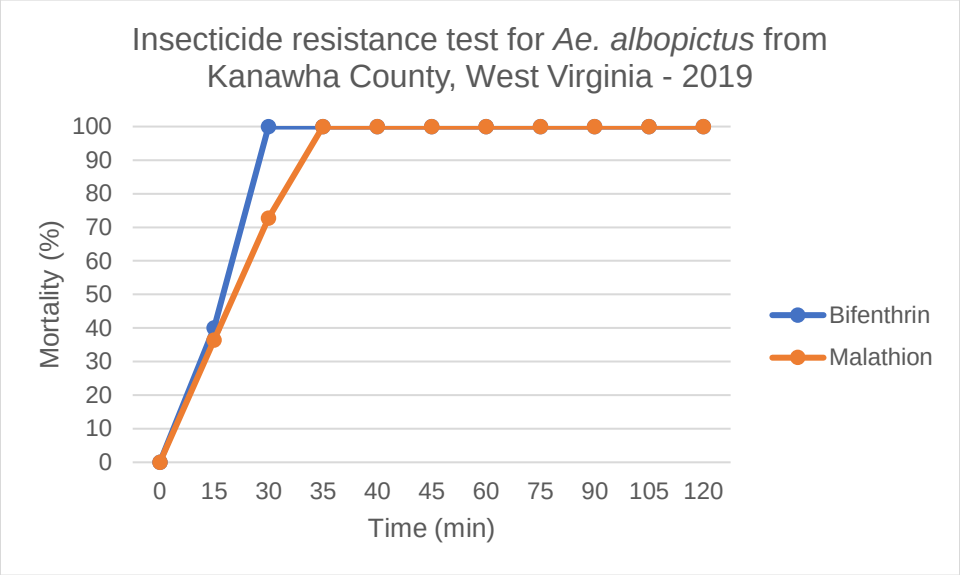


**Figure 4. Insecticide resistance testing using CDC Bottle Bioassay for *Ae. albopictus* from West Side, Charleston, Kanawha County for technical grade active ingredients.**

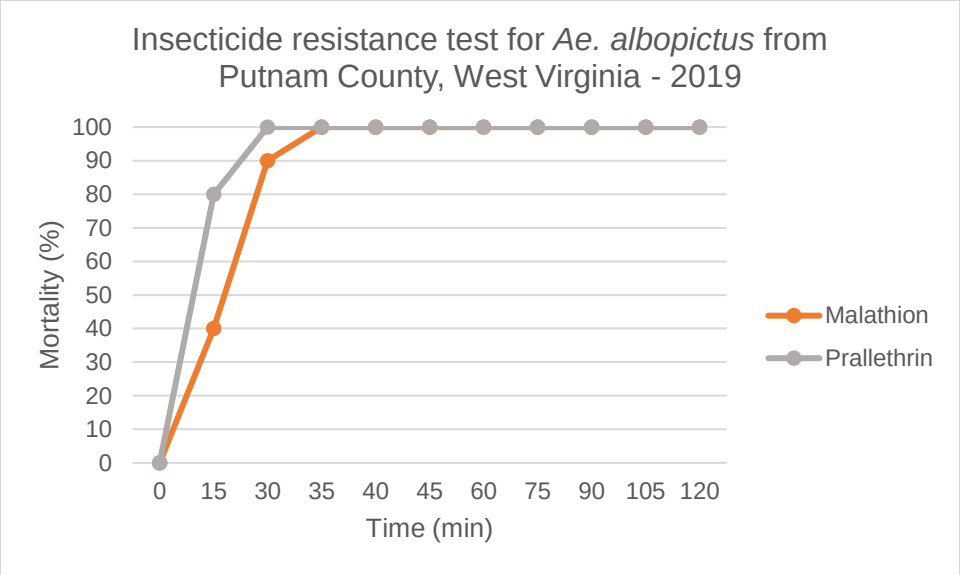


**Figure 5. Insecticide resistance testing using CDC Bottle Bioassay for Ae. albopictus from Eleanor, Putnam County for technical grade active ingredients.**

## DISCUSSION

Low arboviral infection rates in mosquitoes resulted in few human arboviral diseases in 2019. West Nile virus infection rates in *Culex* species during the 2019 mosquito surveillance seasons were comparable to the low rates from other years when human incidence of West Nile encephalitis was low (2008-2011, 2013-2018). Furthermore, the low LACV infection rate in mosquitoes resulted in few human LAC cases in 2019.

Under the thresholds proposed by Richards *et al.* (2017) and CDC (2020), *Ae. albopictus* was classified as 'resistant' to malathion, with one population 'developing resistance' to bifenthrin. These thresholds, however, were not meant to be definitive and instead were developed as guidelines (CDC 2016, 2020). The diagnostic time should be between 30 and 60 minutes (CDC 2016); if the diagnostic time was extended five minutes to 35 minutes, *Ae. albopictus* from all localities would be classified as 'susceptible' to both malathion and bifenthrin. For example, *Ae. albopictus* from Brunswick Co., NC were 'possibly resistant' to bifenthrin based upon 85% mortality at a 12.6 µg/ml pesticide diagnostic dosage and a 30-minutes diagnostic time (Richards *et al.* 2017). In a follow-up study, Richards *et al.* (2019) found *Ae. albopictus* from Brunswick Co., NC were 'susceptible' to bifenthrin based upon 100% mortality at the same 12.6 µg/ml pesticide diagnostic dosage and modified 40 minutes diagnostic time. If the *Ae. albopictus* from Brunswick Co., NC from Richards *et al.* (2019) were classified based upon the previous 30 minutes diagnostic time, this mosquito species would have been classified as 'possibly resistant' based upon <90% mortality at 30 minutes.

Preventing mosquito bites reduces the risk of mosquito-borne disease.

- Wear protective clothing such as long sleeves, pants, and socks. Use insect repellant that contains DEET, picaridin, IR3535, or oil of lemon eucalyptus on exposed skin and clothing when outdoors.
- Be aware of the times of day when mosquitoes are most active. For many mosquitoes, peak hours are dusk and dawn. LAC-transmitting mosquitoes are active during the day.
- Ensure that window and door screens are intact to keep mosquitoes outside of homes. Remove breeding sites around the home (e.g. any containers that can accumulate water).
- Check with your healthcare provider when traveling abroad to learn more about mosquito-borne diseases found in that area of the world.

The Zoonotic Disease Program sincerely thanks the many public health partners who contributed to mosquito-borne disease surveillance across the state whose efforts provided much of the data summarized in this report. Mosquito surveillance partnerships with LHDs enhanced the collection duration, geographic surveillance area, mosquito collection abundance, and public health outreach in communities.

**REFERENCES**

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## 2019 TICK SURVEILLANCE SUMMARY

### INTRODUCTION

The West Virginia Tick Surveillance Program (WVTSP) was initially developed in 2011 to ascertain the distribution of the blacklegged tick (*Ixodes scapularis*) and the infection rate of human pathogens transmitted by this tick species throughout West Virginia. Surveillance objectives include classifying population establishment, estimating the human pathogen infection rate, estimating the density of host-seeking nymphs and adults (infected and non-infected), and documenting the host-seeking seasonal phenology of *I. scapularis* throughout the state. Following the recent increase in state spotted fever group rickettsiosis (SFGR) human cases, the program has increased efforts to document the biology of competent SFGR tick vectors in West Virginia and invasive tick species (e.g. Asian longhorned tick *Haemaphysalis longicornis*) detected through the network of animal health agencies, human public health partners, local veterinarians, and academic colleagues developed through the WVTSP.

Tick-borne diseases of human health concern in West Virginia are shown in Table 4. Competent tick vectors for the most common tick-borne diseases, including Lyme disease and SFGR, are active in the state.

**Table 4. Possible tick-borne diseases by causative agent based on tick vectors found in West Virginia.**

| Tick-borne Disease[a] | Pathogen(s) | Tick Vectors Present in WV |
|---|---|---|
| Lyme disease | *Borrelia burgdorferi*<br>*Borrelia mayonii* | Blacklegged tick (*Ixodes scapularis*)[b] |
| Rocky Mountain spotted fever and other spotted fever rickettsioses | *Rickettsia rickettsii*<br>(and other spotted fever group Rickettsia) | American dog tick (*Dermacentor variabilis*)<br>Brown dog tick (*Rhipicephalus sanguineus*)<br>Lone star tick (*Amblyomma americanum*)<br>Gulf Coast tick (*Amblyomma maculatum*) |
| Ehrlichiosis | *Ehrlichia chaffeensis*<br>*Ehrlichia ewingii*<br>Panola Mountain *Ehrlichia* sp.<br>*Ehrlichia muris eauclairensis* | Lone star tick (*Amblyomma americanum*)<br>Gulf Coast tick (*Amblyomma maculatum*)<br>Blacklegged tick (*Ixodes scapularis*) |
| Anaplasmosis | *Anaplasma phagocytophilum* ha | Blacklegged tick (*Ixodes scapularis*) |
| Babesiosis | *Babesia microti*<br>and other *Babesia* spp. | Blacklegged tick (*Ixodes scapularis*) |
| Tick-borne Relapsing fever[c] | *Borrelia miyamotoi* | Blacklegged tick (*Ixodes scapularis*) |
| Powassan virus disease[c] | Powassan virus | Groundhog tick (*Ixodes cookei*)[d]<br>Blacklegged tick (*Ixodes scapularis*) |
| Tularemia | *Franciscella tularensis* | American dog tick (*Dermacentor variabilis*)<br>Lone star tick (*Amblyomma americanum*) |

[a] Other tick-borne diseases, including but not limited to Colorado tick fever, tick-borne encephalitis, and Crimean-Congo hemorrhagic fever, may result from travel to regions where these illnesses are endemic.
[b] *Ixodes scapularis* is also commonly referred to as the deer tick.
[c] Although circulating in neighboring states, this tick-borne disease has not been detected in West Virginia.
[d] *Ixodes cookei* does not have an official common name. Names that have been used include the groundhog tick, woodchuck tick, and the American castor bean tick.

## METHODS

In addition to passive tick submissions from citizens, human patients, feral swine, and animal carcasses, the WVTSP developed the following special programs to monitor tick activity across the state.

*2019 World Scout Jamboree Tick Surveillance*

West Virginia hosted the 24th World Scout Jamboree during July 22 – August 2, 2019 at the Summit Bechtel Family National Scout Reserve in Mount Hope. The World Scout Jamboree was one of the largest mass gatherings in the state's history with 50,000 scouts and day visitors on-site. Jamboree participants were instructed to visit their camp medical facility when they recovered a tick on themselves. Medical facilities at each base camp were supplied with tick submission kits including Ziploc bags, submission forms, and microcentrifuge tubes with alcohol. Submission forms included a protocol for tick removal and submission, collecting locality, collection date, patient's name and patient's base camp/program medical facility name. Public health teams collected the submitted ticks and delivered them to the state public health entomologist. The ticks were tested for human pathogens by the Tick-Borne Disease Laboratory at the Army Public Health Command at the Aberdeen Proving Ground in Edgewood, Maryland.

*West Virginia Veterinary Tick Submission Project (WVVTSP)*

The WVVTSP started in 2013 as a sentinel surveillance system for tick-borne diseases. Initially, veterinarians from clinics across the state (and one in Pennsylvania) were asked to mail ticks found on their animal clients to the Zoonotic Disease Program. For each submission, a form that collected information about the animal host (e.g. host species, host residence county, tick-borne disease testing history of host, tick prevention utilized by host) and date of collection was enclosed with each tick submission. In 2016, a separate submission form was developed to collect 4DX SNAP test results for tick-borne diseases detected in veterinary canine patients.

*Active Tick Surveillance*

Since 2012, an unexplained cluster of human Lyme disease cases has been developing in southwestern Virginia. State health partners from surrounding states (Kentucky, North Carolina, Tennessee, Virginia, West Virginia) monitored tick activity in this region. Tick drags were conducted at Bluestone Wildlife Management Area, East River Mountain Scenic Overlook, Little Beaver State Park, Moncove Lake State Park, and Pipestem Resort State Park in southeastern West Virginia from June – December 2019.

## RESULTS

The most common and widely distributed ticks in West Virginia were blacklegged ticks (*Ixodes scapularis*) and American dog ticks (*D. variabilis*) (Table 5; Figs. 6, 9). During the past few years, lone star ticks (*A. americanum*) and the invasive Asian longhorned ticks (*H. longicornis*) have expanded their distribution across the state (Table 5; Fig. 7). There are no established populations of Gulf Coast ticks (*A. maculatum*) in West Virginia (Table 5; Fig. 8). In 2019, a single Gulf Coast tick was recovered from a dog and a single Gulf Coast tick was recovered from a pig.

**Table 5. Data from passive tick surveillance activities (WVVTSP, 2019 World Scout Jamboree, West Virginia Feral Swine Project, health care facility submissions, citizen submissions, and animal carcass retrieval).**

| Tick Species | # of Ticks Identified | Animal Species From Which Tick was Removed | # of Counties With Tick Species |
|---|---|---|---|
| *Amblyomma americanum* | 47 | Cat, Dog, Human | 11 |
| *Amblyomma maculatum* | 2 | Dog, Pig | 2 |
| *Dermacentor variabilis* | 345 | Cat, Dog, Horse, Human, Pig | 26 |
| *Dermacentor albipictus* | 38 | Deer | 1 |
| *Haemaphysalis leporispalustris* | 5 | Rabbit | 1 |
| *Haemaphysalis longicornis* | 46 | Cat, Dog | 6 |
| *Ixodes cookei* | 15 | Cat, Dog | 4 |
| *Ixodes dentatus* | 11 | Rabbit | 1 |
| *Ixodes scapularis* | 454 | Cat, Dog, Human | 34 |
| **Total** | **963** | | |

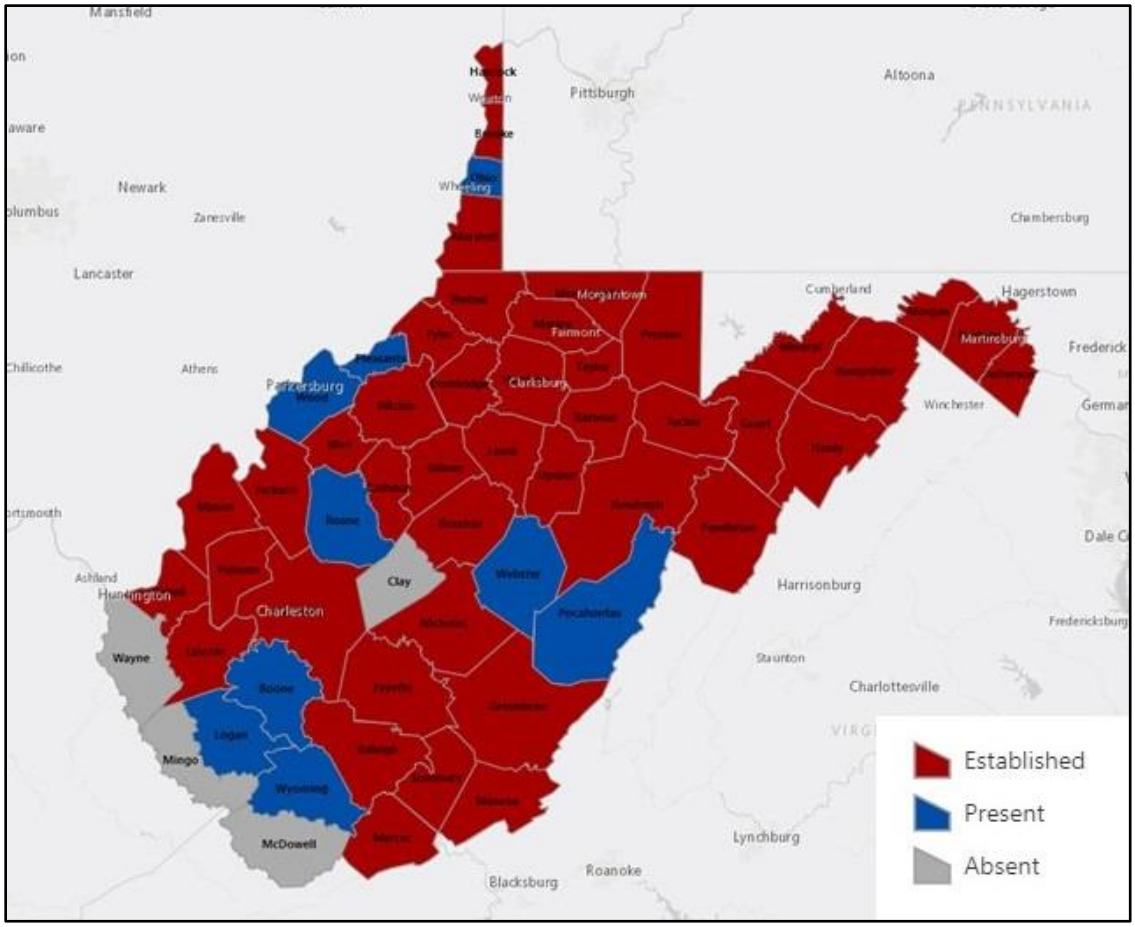


**Figure 6. Counties where *Ixodes scapularis* has been identified in West Virginia.**

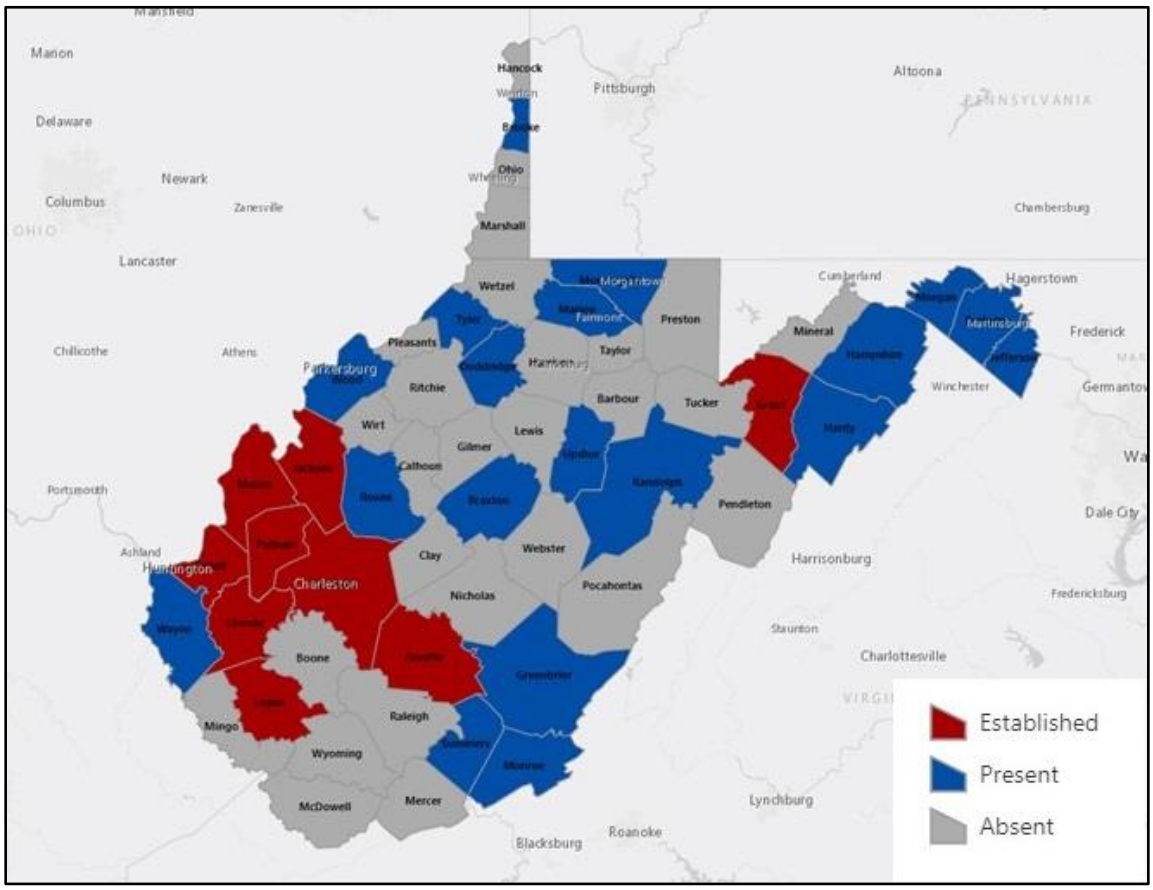


**Figure 7. Counties where *Amblyomma americanum* has been identified in West Virginia.**

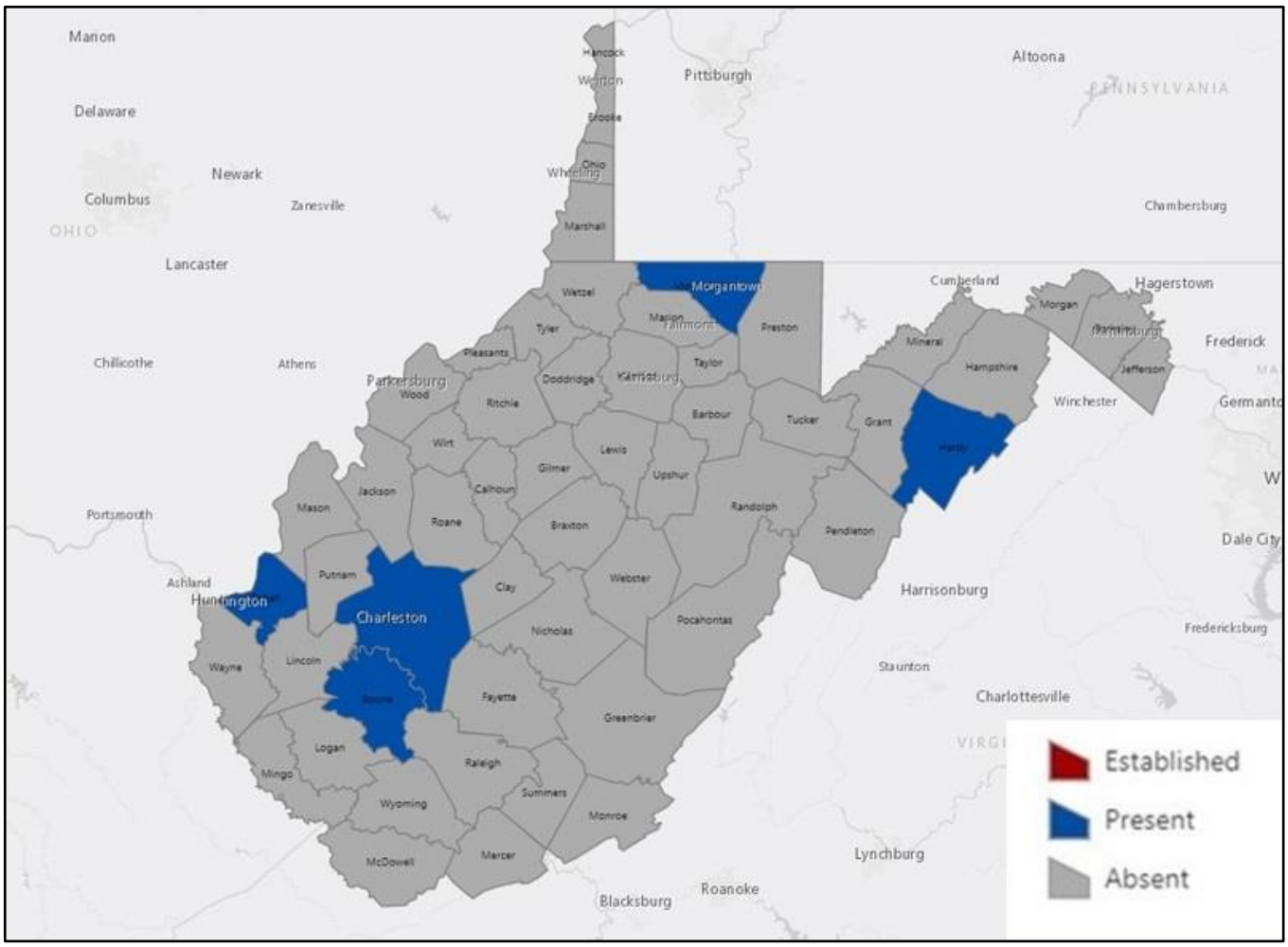


**Figure 8. Counties where *Amblyomma maculatum* has been identified in West Virginia.**

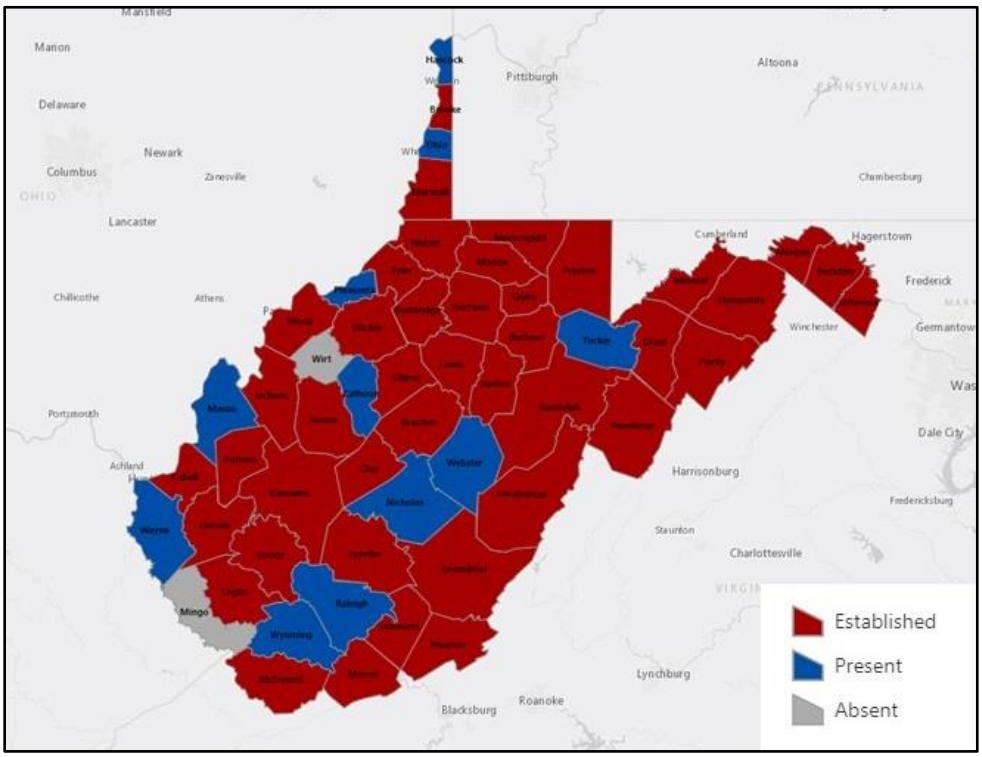


**Figure 9. Counties where *Dermacentor variabilis* has been identified in West Virginia.**

*2019 World Scout Jamboree Tick Surveillance*

None of the 70 ticks recovered from World Scout Jamboree participants contained pathogenic *Borrelia*, *Ehrlichia*, or *Rickettsia* species. One of the 64 American dog ticks (*D. variabilis*) was infected with *Rickettsia montanensis*. *Rickettsia amblyommatis* was detected in both lone star tick (*A. americanum*) nymphs. Human pathogens were not detected in the four blacklegged ticks (*I. scapularis*).

*WVVTSP*

Lyme disease (*B. burgdorferi*) infection was more prevalent in canines from the eastern half of the state (Table 6). In southeastern West Virginia, most dogs showed previous infection with Lyme disease. The percentage of dogs previously infected with Lyme disease was 100.0% (Nimitz), 90.0% (Jumping Branch), and 81.0% (Hinton) in southeastern West Virginia. A high percentage of dogs in northeastern West Virginia also showed previous infection with Lyme disease. Cities in northeastern West Virginia showing high Lyme disease infection in their dog populations include Salem (88.5%), Fairmont (83.3%), Clarksburg (80.0%), and New Milton (75.0%). Conversely, the Lyme disease infection amongst the dog populations residing in Cabell County and Hurricane was low.

Ehrlichiosis (*E. ewingii, Ehrlichia canis*) infection was more common in dogs from southwestern West Virginia (Table 6). The greatest percentage of dog patients with ehrlichiosis were residing in Culloden (80.0%), Hurricane (47.1%), and Milton (40.0%) in Cabell and Putnam counties. On the other hand, ehrlichiosis was seldom detected in dogs from northeastern (West Union (9.1%), Salem (3.8%), New Milton (0.0%), Clarksburg (0.0%)) and southeastern West Virginia (Hinton (9.1%), Jumping Branch (0.0%), Nimitz (0.0%)).

Very few dogs were infected with anaplasmosis (*Anaplasma phagocytophilum*, *Anaplasma platys*). There was no West Virginia region with a high anaplasmosis infection rate in their dog populations (Table 6). Lyme disease, ehrlichiosis, and anaplasmosis were not detected in dogs from the eastern panhandle (Table 6).

**Table 6. Tick-borne disease infection rate amongst dogs reported through 2019 WVVTSP. (Note: Only zip code localities with three or more animal patient 4DX SNAP test results are listed. Co-infections in dog patients resulted in denominator discrepancies within zip code localities.)**

| City | Zip Code | County | Percentage of Dogs With Previous Anaplasmosis Infection | Percentage of Dogs with Previous Lyme Disease Infection | Percentage of Dogs with Previous Ehrlichiosis Infection |
|---|---|---|---|---|---|
| Culloden | 25510 | Cabell | 0 (0/5) | 0 (0/5) | 80.0 (4/5) |
| Hamlin | 25523 | Lincoln | 0 (0/3) | 100.0 (3/3) | 0 (0/3) |
| Hurricane | 25526 | Putnam | 6.3 (1/16) | 31.3 (5/16) | 47.1 (8/17) |
| Milton | 25541 | Cabell | 20.0 (1/5) | 20.0 (1/5) | 40.0 (2/5) |
| Scott Depot | 25569 | Putnam | 16.7 (1/6) | 66.7 (4/6) | 16.7 (1/6) |
| Hinton | 25951 | Summers | 9.5 (2/21) | 81.0 (17/21) | 9.1 (2/22) |
| Jumping Branch | 25969 | Summers | 10.0 (1/10) | 90.0 (9/10) | 0 (0/11) |
| Nimitz | 25978 | Summers | 0 (0/3) | 100.0 (3/3) | 0 (0/3) |
| Clarksburg | 26301 | Harrison | 0 (0/5) | 80.0 (4/5) | 0 (0/5) |
| New Milton | 26411 | Doddridge | 0 (0/4) | 75.0 (3/4) | 0 (0/4) |
| Salem | 26426 | Harrison | 0 (0/26) | 88.5 (23/26) | 3.8 (1/26) |
| West Union | 26456 | Doddridge | 9.1 (1/11) | 63.6 (7/11) | 9.1 (1/11) |
| Fairmont | 26554 | Marion | 0 (0/6) | 83.3 (5/6) | 0 (0/6) |
| Moorefield | 26836 | Hardy | 0 (0/5) | 0 (0/5) | 0 (0/5) |
| Petersburg | 26847 | Grant | 0 (0/3) | 0 (0/3) | 0 (0/3) |

*Active Tick Surveillance*

Blacklegged ticks (*I. scapularis*) were seldom collected through tick drags in southeastern West Virginia. No blacklegged ticks (*I. scapularis*) were collected from Bluestone Wildlife Management Area, Little Beaver State Park, Moncove Lake State Park, or Pipestem Resort State Park in southeastern West Virginia. Conversely, 19 female and 10 male blacklegged ticks were collected over 4500 $m^2$ examined in East River Mountain Scenic Overlook. At East River Mountain Scenic Overlook, 0.0042 blood feeding *I. scapularis* females were active each square meter and 0.0064 *I. scapularis* were active each square meter.

## DISCUSSION

The *Rickettsia* species infection rate in ticks collected from the 2019 World Scout Jamboree at the Summit Bechtel Family National Scout Reserve was comparable to results from other tick surveys conducted in West Virginia and neighboring Mid-Atlantic states**.** *Rickettsia rickettsii*, a highly pathogenic member of the SFGR and causative agent for Rocky Mountain spotted fever (RMSF), has not been found in ticks in West Virginia. Rickettsiae were not detected in *D. variabilis* collected through the previous 2013 Boy Scout Jamboree Tick Survey at Summit Bechtel Family National Scout Reserve.

One of 12 *D. variabilis* from the 2011-2012 Harper's Ferry and New River Gorge National Park Tick Surveys was infected with *R. montanensis*. And four of 93 *D. variabilis* collected through the 2014 WVVTSP were also infected with *R. montanensis*. Conversely, *R. amblyommatis* was detected in eight of 32 *A. americanum* collected through active tick drag or submitted through the WVVTSP in 2014. Despite the high incidence of SFGR in states neighboring West Virginia, *Rickettsia rickettsii* has seldom been detected in ticks from surrounding Mid-Atlantic states (Moncayo *et al*. 2010, Stromdahl *et al*. 2011, Gaines *et al*. 2014). Entomological evidence suggests other spotted fever group rickettsiae, not *R. rickettsii*, are the primary agents responsible for SFGR in this region. Other members of the spotted fever group rickettsiae, including *Rickettsia parkeri* (Paddock *et al.* 2008) and *Rickettsia amblyommatis* (Delisle *et al*. 2016) are pathogenic. Antibodies reactive to *R. rickettsii* detected by a serological test could result from infection with other spotted fever group rickettsiae (Vaughn *et al*. 2014).

The geographic distribution of tick-borne diseases in dogs complements the geographic distribution of tick-borne diseases in humans and the geographic distribution of their tick vectors. Like Lyme disease incidence in humans, most Lyme disease dog cases occurred in the eastern half of the state. Conversely, most ehrlichiosis cases in humans (*E. chaffeensis*, *E. ewingii*) and canines (*E. canis*, *E. ewingii*) occurred in southwestern West Virginia, mirroring the counties with established populations of lone star tick, *A. americanum*, a competent tick vector for both *E. chaffeensis* and *E. ewingii*.

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**Appendix A. Number of mosquito pools collected in each county during the 2019 mosquito surveillance season.**

| County | AA | AE | AN | CO | CX | OR | PS | TX | UR |
|---|---|---|---|---|---|---|---|---|---|
| Cabell | 106 | 1 | 0 | 0 | 36 | 0 | 0 | 0 | 4 |
| Doddridge | 6 | 7 | 2 | 0 | 9 | 0 | 0 | 0 | 0 |
| Fayette | 7 | 16 | 7 | 7 | 17 | 0 | 1 | 0 | 2 |
| Hampshire | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Harrison | 7 | 5 | 1 | 0 | 9 | 0 | 0 | 0 | 0 |
| Jackson | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| Kanawha | 16 | 9 | 0 | 0 | 14 | 0 | 0 | 0 | 0 |
| Marion | 8 | 9 | 1 | 1 | 10 | 0 | 0 | 0 | 0 |
| Mercer | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Mingo | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Monongalia | 3 | 9 | 2 | 0 | 7 | 1 | 0 | 0 | 0 |
| Nicholas | 0 | 8 | 7 | 6 | 75 | 0 | 6 | 0 | 4 |
| Ohio | 10 | 9 | 5 | 0 | 15 | 0 | 0 | 0 | 0 |
| Pendleton | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Preston | 1 | 5 | 2 | 2 | 5 | 0 | 2 | 0 | 1 |
| Raleigh | 3 | 7 | 2 | 0 | 21 | 0 | 1 | 0 | 0 |
| Randolph | 0 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Taylor | 2 | 4 | 2 | 0 | 8 | 0 | 0 | 0 | 0 |
| Wayne | 2 | 3 | 0 | 0 | 11 | 0 | 0 | 0 | 0 |
| Wetzel | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| Wood | 6 | 10 | 8 | 0 | 6 | 2 | 6 | 2 | 2 |
| Total | 183 | 111 | 43 | 16 | 248 | 3 | 18 | 2 | 13 |

AA=*Aedes albopictus*
AE=*Aedes* spp.
AN=*Anopheles* spp.
CO=*Coquillettidia* spp.
CX=*Culex* spp.
OR=*Orthopodomyia* spp.
PS=*Psorophora* spp.
TX=*Toxorhynchites* spp.
UR=*Uranotaenia* spp.