Allegheny County Health Department: Vector Control Program Summary and Community Outreach & Education Plan

by

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Allegheny County Health Department: Mosquito-Borne Disease Control Program Summary and Community Outreach & Education Plan

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Abstract

The purpose of this essay is to summarize the vector-borne disease surveillance efforts of the Vector Control Program (VCP), specifically the Mosquito-Borne Disease Control Program (MBDCP) at the Allegheny County Health Department (ACHD). The three main areas of research discussed in this essay are West Nile virus (WNV) surveillance, testing, and data reporting, the invasive Asian tiger mosquito and the threat of it becoming a nuisance to the greater Pittsburgh area, and ticks and associated disease surveillance conducted in conjunction with the Pennsylvania Department of Environmental Protection (PADEP).

Throughout the completion of the practicum in the summer of 2020, it was noted the VCP's outreach and education materials and efforts were limited. In addition to the program summary, this essay will also propose an outreach and education plan to integrate in to the VCP in attempt to educate elementary to middle-school aged students about the importance of environmental vectors and their associated illnesses. This plan will specifically focus on mosquito and tick vectors and illnesses while engaging children in active surveillance in a county park. The public health significance of this work is to help understand and track vector-borne diseases in Allegheny County as well as benefit the public through immersive education.

Table of Contents

Acknowledgements ix

1.0 Vector Control Program Summary 1

1.1 History of West Nile Virus 2

1.1.1 West Nile Virus Transmission Cycle 3

1.1.2 West Nile Virus Clinical Manifestation and Treatment 4

1.1.3 West Nile Virus Surveillance Efforts in Pennsylvania 5

1.1.3.1 Adult Trapping and Collection 7

1.1.3.2 Larval Surveillance 9

1.1.4 West Nile Virus Surveillance Findings in Allegheny County 11

1.1.5 Asian Tiger Mosquito Surveillance 12

1.1.5.1 Trapping and Collection 14

1.2 Tick and Associated Disease Surveillance 15

1.2.1 Tick Species and Diseases 16

1.2.1.1 Lyme Disease Background, Clinical Manifestations, and Treatment 17

1.2.1.2 Anaplasmosis Background, Clinical Manifestations, and Treatment 19

1.2.1.3 Babesiosis Background, Clinical Manifestations, and Treatment 20

1.2.2 Collection and Testing 21

1.2.3 Species and Pathogen Findings: 2019 and 2020 Data 22

1.3 Prevention Measures 25

2.0 Community Outreach and Education Plan Overview 26

2.1 Target Audience and Stakeholders 26

2.2 'Backyard Bugs Summer Activity Week' 27

2.3 Program Limitations 30

3.0 Conclusion 31

Appendix A 32

Bibliography 37

List of Tables

Table 1: Pathogen percentages for fixed sites in 2019 and 2020.. 23

List of Figures

Figure 1: West Nile Virus Transmission Cycle ("West Nile Virus Transmission", 2018)..... 4

Figure 2: Open gravid trap (left). Removable netted container with trapped mosquitoes (right). Curry, A. (2020). Gravid trap and trapped mosquitoes. [Photograph]. Allegheny County Health Department.. 8

Figure 3: WNV gravid trap sites 2020. (Red = WNV+, Green = WNV-). Lamonte, L. (2020). WNV Fixed Gravid Trap Sites. [Powerpoint slide]. Allegheny County Health Department.. 12

Figure 4: CDC projection of Aedes albopictus geographical range and likelihood of survival. (CDC", 2020).. 14

Figure 5: BG Sentinel trap set up with dry ice container. Curry, A. (2020). Gravid Trap. [Photograph}. Allegheny County Health Department. 15

Figure 6: Dragging method for tick collection. Lamonte, L. (2020) A. Curry dragging ticks [Photograph]. Allegheny County Health Department... 22

Figure 7: Tick dragging sites and positive location names (Red = Lyme +, Black = Lyme -). Lamonte, L. (2020). 2020 Lymee Positive Tick Drag Parks [Powerpoint Slide]. Allegheny County Health Department.. 24

Figure 8: Culex species life cycle and description. ("Mosquito Life Cycle", n.d.)................ 33

Figure 9: Tick lifecycle. ("How ticks spread disease | CDC", 2020)..................................... 34

Figure 10: IPM pyramid generated by Penn State. Adapted from CHAPTER 3 BEST PRACTICES FOR PESTICIDE USE. Adapted with permission............................. 35

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1.0 Vector Control Program Summary

The ACHD Vector Control Program conducts surveillance, including abundance and geographical spread, of both vectors and pests and their associated diseases. This includes both the Mosquito-Borne Disease Control Program and surveillance of tick species and their associated pathogens. The ACHD Housing and Community Environment Program (HCEP) also enforces Article VI of the Allegheny County health code to both prevent and manage vector and pest infestations. Both health code enforcement and community education are used to regulate complaints from the public in attempt to diminish or eliminate environmental conditions that breed these vectors (ACHD, 2021).

The most common vectors of public health significance are mosquitoes and ticks. The best way to control these vectors is to ensure maintenance of yards and recreational areas. The VCP can respond to complaints filed to the HCEP. Not only does the VCP respond to public complaints but conducts mosquito and tick surveillance through trapping and control via pesticide application during the summer months to maintain a healthy community. This program also works closely with and is funded by the Pennsylvania Department of Environmental Protection (PADEP). The VCP sends vector samples to the PADEP for disease testing, as well as reports location data in order to determine where vector-borne diseases are prevalent within the community.

1.1 History of West Nile Virus

West Nile virus, a member of the family Flaviviridae, was first isolated from a woman of the West Nile District of Uganda in 1937 during a yellow fever epidemiologic study (Chancey et al., 2015). Her serum was inoculated in mice and the resulting virus showed similarity to two other members of the Flaviviridae family rather than yellow fever. These included both St. Louis encephalitis and Japanese B encephalitis viruses. The pathologies noted in the earliest cases were involved in the central nervous system, suggesting the virus' neurotropic nature (Sejvar, 2003). In the 1950's, WNV was discovered in birds within the Nile delta region, while other epidemic outbreaks were continuing to arise in Israel and the Mediterranean basin. A seroprevalence study completed in Egypt in the 1950's showed that WNV caused more symptomatic illness in young children than it did older children and adults, suggesting it as n early-childhood illness (Sejvar, 2003). Although later the virus was discovered WNV can affect all age groups. This same study also discovered the prevalence of WNV neutralizing antibodies within birds, especially crows, and that WNV causes severe and often fatal illness in horses. A few years prior to the discovery that WNV can infect multiple species, Egyptians were able to determine that mosquitoes of the genus *Culex* were the primary vector of WNV after examining many other arthropods (Sejvar, 2003).

West Nile virus was discovered in the United States in New York in 1999 (Sejvar, 2003). This cluster of cases that included severe encephalitis was accompanied by a new high fatality rate in birds in the New York City area. The mechanism in which WNV arrived in the United States in unknown, however, the genomic sequences from U.S. samples were similar to those in an outbreak in Israel at the same time. By 2002, the United States recorded the largest outbreak of WNV in the world with approximately 4,200 cases, 2,400 instances of meningoencephalitis, and 284 deaths

(Sejvar, 2003). Currently, WNV remains the leading cause of mosquito-borne disease in the continental United States.

1.1.1 West Nile Virus Transmission Cycle

The WNV life cycle occurs mostly in birds and *Culex* species mosquitoes (Figure 1). Birds are known as the amplifier host. An amplifier host provides a biological environment where WNV can replicate rapidly within cells in the blood stream to create high levels of virus in order to be transmitted through a bite by a vector species (*Culex* mosquitoes). Approximately seven days after the mosquito becomes infected, it can infect birds and other organisms when obtaining a blood meal. The cycle between mosquito and bird often branches out to humans and horses which are dead end hosts, any organism in which viral replication does not occur. This means the levels of WNV remain too low for transmission to occur from horses or humans. In horses, WNV can be deadly as it causes encephalitis in many infections. Humans however will be asymptomatic 80% of the time (Koblischke et al., 2020). The cycle begins in the late spring to early summer months and will continue through the fall season. WNV can survive the winter months by hibernating within adult *Culex* mosquitoes who find shelter until the warmer months arrive.

It is important to note that WNV cannot be transmitted via coughing, sneezing, or through physical contact. Handling infected or dead birds with gloves or another protective barrier between you and the animal also poses no risk for transmission. Eating properly cooked infected birds or animals cannot transmit WNV. However, in a very small number of instances, WNV transmission has been documented in exposures in laboratory settings, blood transfusion and organ donations, as well as vertically in the womb or after birth during breast feeding (Koblischke et al., 2020)

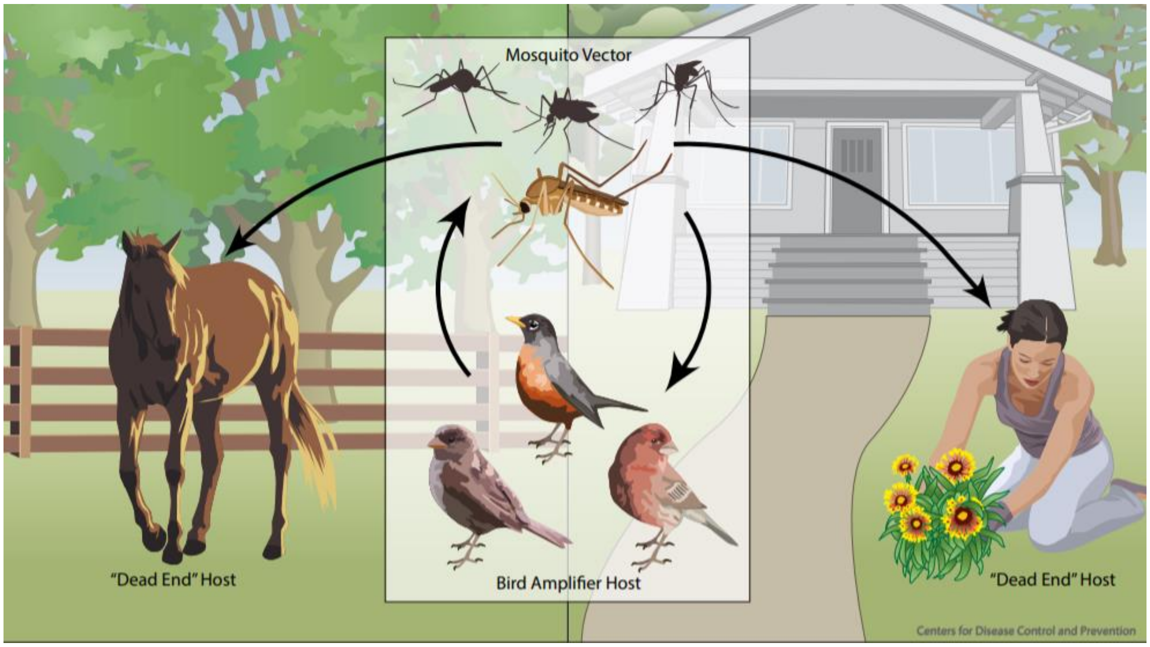

Figure 1: West Nile Virus Transmission Cycle ("West Nile Virus Transmission", 2018).

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1.1.2 West Nile Virus Clinical Manifestation and Treatment

West Nile virus often remains asymptomatic within 80% of infected individuals and leads to varying degrees of illness in the remaining 20% (WHO, 2017). The illness is either a mild West Nile fever or more severe manifestation known as neuroinvasive West Nile disease. West Nile fever can cause symptoms such as fever, body aches, headaches, nausea, vomiting, a skin rash normally on the trunk of the body, and swollen lymph nodes. Severe West Nile disease affects the central nervous system and can cause encephalitis and/or meningitis. Symptoms of severe West Nile disease include fever, disorientation, coma, tremors, muscle weakness, numbness, and paralysis (Petersen et al., 2013). Severe illness occurs more often in people over 60 years of age and those with underlying medical conditions such as cancer, diabetes, hypertension, and organ transplant recipients. About one in ten people who develop severe illness with central nervous system symptoms die. In order to determine a WNV infection, a healthcare provider must test for the virus through a WNV-specific IgM immunoassay using serum or cerebrospinal fluid (Petersen et al., 2013).

There are no known virus-specific treatments or vaccines currently available for WNV in humans. West Nile fever symptoms can be controlled through use of fever reducing medications, rest, and fluid intake. However, individuals with severe illness may need to be hospitalized to receive higher levels of care (Petersen et al., 2013).

As mentioned previously, WNV affects horses as well. WNV is the leading cause of arbovirus-causing encephalitis in horses across the United States with over 25,000 infections reported since 1999 (Swinker, 2015). In order to combat WNV in horses, the K-WN vaccine was developed and made available in 2001 (Seino et al., 2007). Since then, other vaccines have been developed and made available to treat equine WNV. As for WNV prevention in birds, the natural reservoir hosts of WNV, there are currently no approved vaccines (Jiménez de Oya et al., 2019). The need for vaccination in domestic birds and livestock is nearly zero due to the extremely low pathogenicity of the virus in these species (Jiménez de Oya et al., 2019). One main concern for developing a vaccine for birds is how herd immunity would be achieved in wild and captive birds, especially species most susceptible to infection (Jiménez de Oya et al., 2019).

1.1.3 West Nile Virus Surveillance Efforts in Pennsylvania

West Nile virus was discovered in Pennsylvania in 2000 soon after it arrived to the United States in 1999. Surveillance and control efforts were implemented in order to contain WNV as cases increased through 2003. Since 2000, the Pennsylvania Departments of Health, Environmental Protection (DEP), and Agriculture collaborated to develop an all-encompassing

WNV surveillance program (PADEP, 2019). This plan includes using the principles of Integrated Pest Management (IPM) (Appendix A), public education, habitat and breeding site reduction, surveillance, and control (PADEP, n.d.). Pennsylvania and participating counties conduct yearly mosquito and bird surveillance alongside monitoring for human and equine cases. The state budget includes funding for prevention and mitigation of the potential effects WNV has on Pennsylvania's residents. This funding allows the state to provide staffing and epidemiological infrastructures for controlling WNV.

The Department of Health (DOH) provides testing services to diagnose West Nile cases, as well as monitor for possible future cases. The DOH also provides education to healthcare workers statewide on the signs and symptoms of WNV. The Department of Agriculture (DOA) takes responsibility for monitoring animal populations for signs of WNV. Of note, the Pennsylvania state bird, the ruffed grouse, is heavily impacted by this virus. The Pennsylvania Game Commission in collaboration with the DOA track seasonal changes and intensities of WNV in ruffed grouse populations. The WNV Control Program website provides guidance on how to report dead birds, as this is one way to understand the prevalence of WNV in the environment. Some of the most common bird species affected by WNV in Pennsylvania include robins, crows, jays, owls, and raptors (PADEP, n.d.). The PADEP coordinates the MBDCP in the participating counties in order to have comprehensive mosquito control and surveillance throughout the state. In counties not funded with this program, PADEP conducts the surveillance. The MBDCP is a gold member of the Environmental Protection Agency's (EPA) environmental stewardship program, which allows for staffing at the county level to control for mosquitoes that spread WNV. The Pennsylvania DEP website provides yearly updates on WNV prevalence and control efforts by county, as well as information on how pesticides are used, and what the general public can do to eliminate mosquito breeding sites and habitat.

1.1.3.1 Adult Trapping and Collection

A gravid trap is used to collect the *Culex* species that transmits WNV. This trap is designed to attract gravid, or egg-carrying, mosquitoes looking for a stagnant source of water to lay eggs on (Figure 2). The black tray on the bottom of the trap is filled with hay-infusion water made with lactalbumin and yeast that ferments in the sun for at least one week. This foul-smelling, stagnant source of water attracts female *Culex* mosquitoes and allows for them to lay their eggs on top of the water. When the female is ready to fly away, she is sucked into the battery-powered toolbox trap and up into a netted container. The battery-powered suction can remain stable throughout the evening and night until the netted container of mosquitoes can be collected the next morning. The nets are sinched off with a drawstring, and the netted container can be removed from the toolbox trap to prepare for processing.

Figure 2: Open gravid trap (left). Removable netted container with trapped mosquitoes (right). Curry, A. (2020). Gravid trap and trapped mosquitoes. [Photograph]. Allegheny County Health Department.

Culex mosquitoes thrive in urban and suburban brushy or wooded areas secluded from major winds and other disturbances. The sites chosen for trap placements are sites near residential areas bordering a wooded area. These containers of mosquitos were brought back to HCEP to be euthanized on dry ice. This humanely kills the mosquitoes while also preserving any viruses they may be carrying. The specimens are counted, placed in labeled tubes, and stored on dry ice until they are ready for shipment to the PADEP Vector Management Lab in Harrisburg for speciation and WNV testing.

In order to determine if control measures need to be taken, the vector index (VI) is calculated and must meet a threshold value to conduct adult mosquito control (Appendix A). Adult control can be conducted by loading an Ultra-Low Volume sprayer onto a truck to spray an adulticide such as Zenivex in at-risk neighborhoods. The active ingredient in Zenivex is

Etofenprox, a non-ester synthetic pyrethroid, which has a low toxicity to birds and is not harmful to honeybees. This product is also effective on Organophosphate-resistant mosquitoes, as resistance to products is constantly monitored for adulticides, pesticides used for adult control (Cornel et al., 2016). This is one method put in place to control for mosquito populations and keep Allegheny County residents safe from WNV.

1.1.3.2 Larval Surveillance

Not only are adult mosquitoes sought out for WNV surveillance, but larvae and pupae are as well. Although larvae and pupae are naïve, meaning they are not infected with nor can transmit WNV, surveillance for breeding sites and control of larvae are a major key to controlling mosquito populations in the area.

Stagnant water sources are a major focus for larval surveillance by the VCP. Gravid mosquitoes lay eggs on the surfaces of stagnant water sources and can hatch anywhere from within a few days to months depending on weather conditions (CDC, 2020). (Appendix A Figure 8). Stagnant water sources can result from any object capable of containing water. Scrap tires, clogged gutters, neglected pools, ornamental ponds, buckets, flowerpots, and catch basins can produce hundreds to thousands of mosquitoes in a season. Wetlands and naturally occurring water sources are also surveilled and treated by the VCP. Article VI of the county health code assists the county in controlling stagnant water sources on private properties. It is illegal to have sources of stagnant water on a private property, as it breeds mosquitoes and therefore violates the health code (ACHD, 2021).

Larvae and pupae were collected through a method called dipping. This method is very simple in that a cup on a long stick is dipped into a stagnant source of water to catch aquatic larvae and pupae. The larvae and pupae are then poured into a labeled tube and taken back to HCEP for processing. From there, they will be poured into boiling water to be euthanized, counted and placed in ethanol for shipment to the DEP. WNV testing is not conducted on larvae and pupae, they are counted and identified to species. This data provides the county information on mosquito activity in a specific area and is necessary to conduct prior to treatment with larvicides.

Larvae and pupae do not carry or transmit WNV, but it is still important to take control measures for mosquito larvae. A naturally occurring soil bacterium called *Bacillus thuringiensis israelensis* (Bti) is used as a larvicide in mosquito control efforts (Ben-Dov, 2014). Bti contains spores that produce toxins when ingested by larvae. These toxins cause the larvae to stop eating and eventually die. Because Bti is designed to control larvae through ingestion, this will not work against controlling for pupae, as the pupae stage of the life cycle does not actively feed. Bti is also not effective against controlling for adult mosquitoes, as adults do not feed on products applied to water sources (Ben-Dov, 2014). Bti can come in briquet, granule, pellet, tablet, and dunk forms that have varying lengths of residual in the environment. Any form can be added to stagnant water sources that cannot be drained or emptied. Bti can be bought at local gardening and hardware stores for residential use, and is also applied through control programs using planes, trucks, and sprayers. Because this larvicide is a naturally occurring soil bacteria, it is not harmful to humans, animals, crops, aquatic species, or the environment (Ben-Dov, 2014). The EPA registered this as mosquito, gnat, and black fly larvicide after studying its effectiveness and safety. With any bacteria, resistance is always a concern no matter what its use. However, a recent study showed a lack of resistance to Bti mosquito populations that have been treated with it for decades (Tetreau et al., 2013). Overall, Bti is a safe and effective larvicide crucial in reducing mosquito populations and the risk of people getting infected with WNV.

Bti is one larvicide option used every summer for the ACHD Catch Basin Program facilitated by the HCEP. Catch basins are one of the major breeding sites for mosquitoes in urban settings such as the Greater Pittsburgh Area. The Catch Basin Program is a week-long program where ACHD employees disperse Bti FourStar 180-day Briquets in catch basins and mark it with a fluorescent green paint. Almost 10,000 catch basins were treated in June 2020 within the City of Pittsburgh's East End, West End, North Side and South Side where WNV has been recorded in years past. The 2020 season was the 19th year ACHD conducted this program. This program helps to curb the number of adult mosquitoes that potentially carry WNV in the Greater Pittsburgh Area.

1.1.4 West Nile Virus Surveillance Findings in Allegheny County

Through the MBDCP, the VCP has been able to complete surveillance and control for WNV in Allegheny County, PA. In 2020, gravid traps were placed weekly at 28 fixed locations from May through September throughout the Greater Pittsburgh Area. In total, over 23,000 mosquitoes were collected from 579 gravid traps with a majority being *Culex pipiens* and *Culex restuans*. There were 560 trap samples sent to the Vector Management Lab, with 437 pools created for testing for the 2020 season. A pool consisted of 100 mosquitoes for each site each week. Of the 437 tested pools, 101 were positive for WNV, making this a 23% positivity rate for the 2020 season. Twenty-five of the 28 fixed sites were positive for WNV. In previous years, 2016 had a 29% positivity rate, 2017 at 18%, 2018 at 38%, and 2019 at 8%. Reasons for fluctuation in incidence of WNV in mosquitoes can include weather and climate patterns as well as bird populations. Seasons with more rain will produce more breeding sites, therefore more mosquitoes to contract and transmit WNV. Higher numbers of significant bird species populations also contribute to higher incidence rates within mosquitoes (Paz, 2015). Figure 3 shows the 28 fixed gravid trap sites for the 2020 season. The red markers indicate WNV positive sites, the green markers are WNV negative. This weekly monitoring of mosquito vector index drives decision making for adult control throughout the season. There was one Ultra-Low Volume truck spray for mosquitoes on both the North and South Sides on the evening of August 10, 2020. It is also important to note there were no human cases of WNV reported in Allegheny County for 2020 (ACHD, 2020).

1.1.5 Asian Tiger Mosquito Surveillance

Figure 3: WNV gravid trap sites 2020. (Red = WNV+, Green = WNV-). Lamonte, L. (2020). WNV Fixed Gravid Trap Sites. [Powerpoint slide]. Allegheny County Health Department.

Not only does the VCP survey for commonly found and native mosquito species in the county, but for the Asian tiger mosquito, *Aedes albopictus*, as well. These mosquitoes were introduced to the U.S. from Asia through the global tire trade through Houston, Texas in 1985 then quickly spread to 27 other states. The first infestations of the Asian tiger mosquito in Allegheny County were found in 2010 in residential West Mifflin and the industrial Strip District (ACHD, 2021). This mosquito is an invasive, aggressive, day-biting mosquito that actively seeks human blood meals. *Aedes albopictus* has the potential to carry multiple mosquito-borne diseases including Zika virus (ZIKV), Dengue virus (DENV), and Chikungunya virus (CHIKV) (Thompson et al., 2017). Pennsylvania increased surveillance for *A. albopictus* when the ZIKV outbreak occurred and hit the southern U.S. in 2016. The DEP invested in the BG sentinel trap, discussed in a later section, to help better track this species of invasive mosquito. Although there are currently no cases of ZIKV, CHIKV, or DENV in Pennsylvania, surveillance will continue as *A. albopictus* can carry and transmit these viruses and is extremely aggressive towards people causing complaint calls to increase. As this invasive species continues to spread through the U.S., the nuisance level becomes a concern. Figure 4 shows a map created by the CDC in 2017 on possible geographic ranges of this species and its likelihood to live and reproduce using county, historical, and climate records. The map does not represent risk for spread of disease (CDC, 2020).

Asian tiger mosquito habitat preferences tend to be near people, and their breeding sites are mostly artificial containers. Tires are a favorite breeding site and are an important part of surveillance in Allegheny County. Code enforcement through the ACHD Housing Article VI Health Code comes in to play in controlling *A. albopictus* populations. This prevents buildups of tires occurring on private or public properties and makes dumping tires on vacant properties illegal. Persistent code enforcement around tires and mosquito breeding sites through ACHD helps directly benefit public health measures.

1.1.5.1 Trapping and Collection

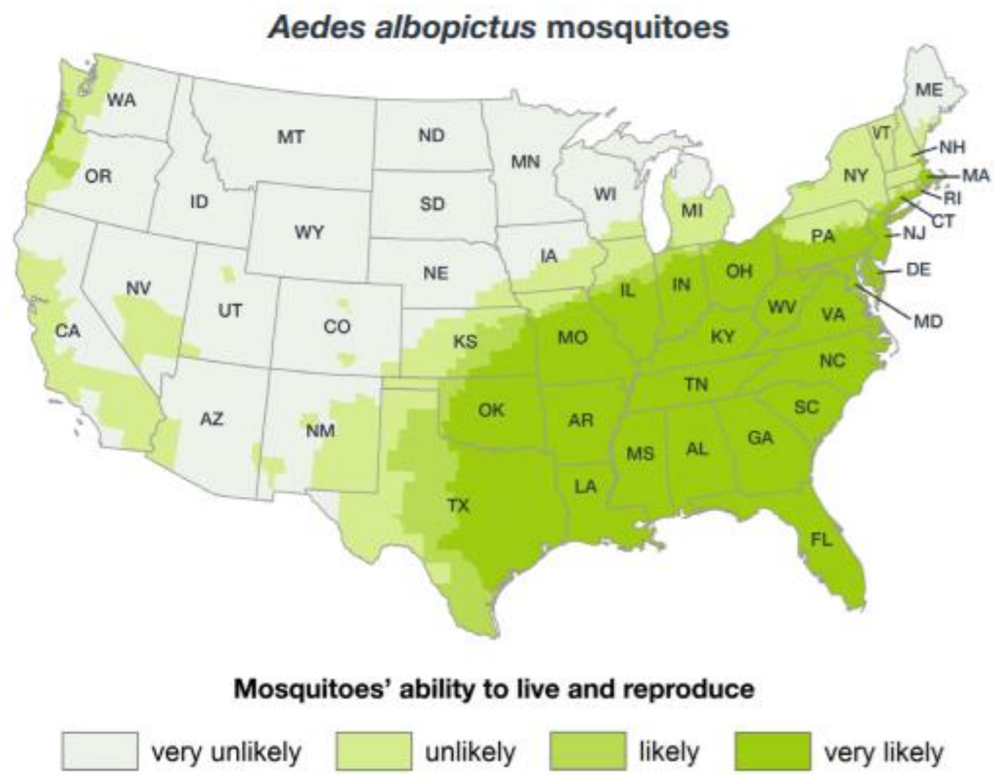


Figure 4: CDC projection of Aedes albopictus geographical range and likelihood of survival. (CDC", 2020).

Trapping the Asian tiger mosquito looks quite different than it does for *Culex* and other Pennsylvania species. A BG-Sentinel trap is used (Figure 5) rather than a gravid trap (Farajollahi et al., 2009). The BG-Sentinel trap is a host-seeking trap designed to attract *Aedes* species that may carry CHIKV, ZIKV, DENV, and yellow fever. The trap uses the BG-Lure which smells like human skin (combination of lactic acid, ammonia, and fatty acids) to attract the mosquitoes. A source of carbon dioxide, dry ice for example, is also used to mimic a mammal's breath. The trap itself is light and dark colored to mimic natural coloration patterns of wild mammals, another target for these mosquitoes. These traps are run for 24 hours to match the daytime biting tendencies of *A. albopictus*. The battery-powered fan keeps the mosquitoes from escaping the net, which can be closed by drawstring upon collection. These mosquitoes are euthanized with dry ice just like those from the gravid traps and prepared for shipping to the DEP. At the DEP lab, *Aedes* mosquitoes and larvae are identified to species and counted to monitor population numbers, sites, and breeding sites within Allegheny County.

Figure 5: BG Sentinel trap set up with dry ice container. Curry, A. (2020). Gravid Trap. [Photograph}. Allegheny County Health Department.

1.2 Tick and Associated Disease Surveillance

The VCP not only conducts surveillance and control for mosquito species in Allegheny County, but for ticks and their associated pathogens as well. This collaboration is also with the PADEP and has received five years of funding from the state. This statewide surveillance of ticks to assess the risk of tickborne diseases in Pennsylvania started in July 2018 in coordination with 38 participating counties as a part of the recommendations given by the Pennsylvania Lyme

Disease Task Force (DEP, 2019). It will allow for Pennsylvania to better understand ticks in the environment and how they affect human health. This data will show how prevalent Lyme and other tickborne diseases are within participating counties and will guide information distribution and public health efforts to keep Pennsylvanians safe while outdoors.

1.2.1 Tick Species and Diseases

The ACHD VCP focuses on surveillance for three major tick species found across Pennsylvania. The blacklegged tick (*Ixodes scapularis*), the American dog tick (*Dermacentor variabilis*), and the Asian longhorned tick (*Haemaphysalis longicornis*) are the most prevalent of tick species and of most public health concern to humans within the state. *I. scapularis* is the most common tick species found in Allegheny County. This tick is of the most concern in this 5-year study because it carries and transmits the bacterium *Borrelia burgdorferi*, a pathogen responsible for Lyme disease (Springer et al, 2021). Lyme disease has been on the rise in Pennsylvania and has been one of the leading states in the nation for Lyme cases. According to a Pennsylvania Health Alert Network distribution in 2019, the 2017 data showed an incidence rate of 93.1 cases per 100,000 persons in Pennsylvania. This was seven times higher than the national rate of 13.1 cases per 100,000 persons (Levine, 2019). *Ixodes scapularis* is also responsible for spreading bacteria called *Anaplasma phagocytophilum* which causes anaplasmosis, and a parasite called *Babesia microti* responsible for babesiosis. *Dermacentor variabilis* does not carry Lyme, although it can spread *Rickettsia rickettsia*, the bacteria responsible for causing Rocky Mountain spotted fever to both humans and pets (Springer et al, 2021). This tick however has been collected less frequently throughout the years according to anecdotal evidence from the DEP. *Haemaphysalis longicornis* is an invasive species to the United States from Asia and was first found in New Jersey in 2017

(Egizi et al., 2020). These ticks do not favor human skin as much as *I. scapularis* (Rainey et al., 2018), however, remains a public health concern because a recent study published in 2021 discovered a field-collected *H. longicornis* tick to carry *B. burgdorferi* (Price et al., 2021). Research on *H. longicornis* is ongoing in the U.S., so in the meantime, public education around preventing tick bites is important information that should be made easily accessible.

1.2.1.1 Lyme Disease Background, Clinical Manifestations, and Treatment

Lyme disease is caused by a spirochetal bacterium *B. burgdorferi.* The infamous characterization of Lyme, erythema migrans, or better known as a "bullseye rash", was first described by Arvid Afzelius in 1909. He associated this rash to a tick and later suggested penicillin for treatment (Dammin, 1989). In 1975, multiple clinics saw an increase in cases of swollen joints, skin rashes, and fatigue in rural Lyme, Connecticut (NIH, n.d.). William Burgdorfer, a researcher at National Institute of Allergy and Infectious Diseases Rocky Mountain Laboratories, discovered the spirochete bacterium in the midguts of *I. scapularis* ticks in 1981 (Burgdorfer, et al., 1981). From there it was suggested that Lyme disease was spread by the bite of these ticks. This discovery has led to extensive research on Lyme with over 6,000 publications and has resulted in multiple treatment options.

Lyme disease is transmitted through the bite of an infected nymph or adult female *I. scapularis* tick. When a female lays her eggs, they hatch and become larvae in the summer months. The larvae take their first blood meal and molt into the nymphal stage next spring. After the first blood meal as a larva, it is possible for the tick to become infected with *B. burgdorferi* from their first host, the white-footed mouse (*Peromyscus leucopus*) for example. This mouse is the main reservoir for *B. burgdorferi* because the bacteria can cause a chronic, avirulent infection for transmissibility to the next tick vector (Voordouw et al., 2015). When the nymph searches for the next blood meal, it is possible to transmit *B. burgdorferi* to another host if it was infected during the first blood meal. The second host can be humans or other small mammals. After the second blood meal, the nymph will molt into an adult and primarily feed on white-tailed deer and sometimes humans. The female becomes engorged, finds a mate, lays eggs, and dies. Males typically do not seek blood meals and therefore are not associated with transmitting *B. burgdorferi* (Appendix A Figure 9).

After an infected tick bites and remains attached for 24 hours or longer, a person can become infected with *B. burgdorferi* (Lantos et al., 2020). Anywhere from 3 to 30 days after the infection, fever, chills, headache, fatigue, muscle and joint aches, and swollen lymph nodes may occur. In 70-80% of infected individuals, erythema migrans will occur. The rash may gradually expand up to 12 inches in diameter or more. It can be warm to the touch but is never itchy or painful. It is important to note that this rash does not always appear as the “classic” described rash and the skin may not appear to be red or have expanding or clearing central lesions. Signs and symptoms of a later infection weeks to months after a tick bite include severe headaches and neck stiffness, facial palsy, arthritis with severe joint pain and swelling, nerve pain, numbness and tingling in the hands and feet (Lantos et al., 2020).

As soon as it has been determined that a tick has bitten a human or the initial signs and symptoms of Lyme occur, it is important to seek treatment. Informing a healthcare provider of all symptoms is important, as Lyme can manifest differently in people. Laboratory testing of blood to detect presence of antibodies is the most current way to diagnose Lyme. If blood samples are positive, antibiotics, such as doxycycline, are used to treat Lyme disease. (Lantos et al., 2020). A Lyme disease vaccine called LYMERix once existed but was pulled from distribution and manufacturing in 2002 when adverse side effects were reported and the consumer demand for it decreased (Nigrovic and Thompson, 2007).

1.2.1.2 Anaplasmosis Background, Clinical Manifestations, and Treatment

Anaplasmosis is caused by *A. phagocytophilum*, another bacterium transmitted by *I. scapularis* (Woldehiwet, 2010). Anaplasmosis was originally described in Scotland in 1932 and referred to as Tick-borne fever. Another similar disease in horses causing granulocytic reactions was described in the United States in 1969. Two other similar granulocytic agents were described in dogs in the United States in 1971 and 1982. These organisms were thought to be different species of bacteria affecting specific species of domestic animals until 1994, when it was found that it was the same bacteria causing illness in humans and domestic animals (Woldehiwet, 2010). These bacteria were then classified as one and renamed *Anaplasma phagocytophilum* in 2001 due to a taxonomic change (Woldehiwet, 2010).

Anaplasmosis signs and symptoms normally arise within one to two weeks after the tick bite. Early clinical signs occur within one to five days and are typically mild to moderate (Springer et al, 2021). These include fever, chills, severe headaches, muscle aches, vomiting, and loss of appetite. Late illness rarely occurs but can cause severe illness if not treated early on. Late illness symptoms include respiratory failure, bleeding issues, organ failure, and in rare cases can be fatal. Delayed treatments, age, and compromised or weak immune systems are major risk factors for developing severe anaplasmosis. Anaplasmosis is detected through presence of antibodies and results can take several weeks to determine. Antibiotics, specifically Doxycycline, are normally given in the meantime if anaplasmosis is suspected. Currently, no vaccine is available for protection against Anaplasma (Springer et al, 2021).

1.2.1.3 Babesiosis Background, Clinical Manifestations, and Treatment

Babesiosis was first described by Babes in 1888 when he was investigating a mass cattle fatality event in Romania (Homer et al., 2000). In 1893, Smith and Kilbourne identified ticks as the vector for this disease in cattle, causing hemoglobinuria, fever, and anemia in the livestock. The first case to be found in humans was described in 1957 in a Yugoslavian farmer who presented to a local hospital with hemoglobinuria, jaundice, fever, and anemia. He was misdiagnosed with malaria and died 8 days later. Physicians reviewed slides of his blood after his death and later determined it was in fact a *Babesia* parasite. Concern in the United States began when five cases of babesiosis arose within three months in 1977 in Nantucket, Massachusetts (Homer et al., 2000). Babesiosis is now classified as an infection of the red blood cells by the *B. microti* parasite.

Most individuals infected with this parasite do not show or feel any symptoms. Those who do may experience fever, chills, sweats, body aches, nausea, and fatigue (Homer et al., 2000). Since the parasite infects and destroys red blood cells, hemolytic anemia can occur which can lead to jaundice and dark urine. Severe and life-threatening disease can occur in those without a spleen, those with weak immune systems, anyone with serious health conditions, or those who are elderly. Complications after infection may also occur and these include low or unstable blood pressure, thrombocytopenia, malfunction of vital organs, disseminated intravascular coagulation, and death. To diagnose babesiosis, blood smears are typically examined for intracellular parasites. Those who show no symptoms after infection should not seek treatment options, however, those more likely to develop severe illness are treated with antibiotics. Blood transfusions, vasopressors, and dialysis are extreme treatment options after severe illness has developed (Homer et al., 2000).

1.2.2 Collection and Testing

Ticks are normally found in and around leaf litter, grasses, fallen branches and logs, and the edges of animal-created and man-made pathways near shaded, wooded areas. Ticks will climb to the top of the grass or branch when they are ready to find a host. Blacklegged ticks will display a behavior called questing. They wave their front legs around in hopes that a host will pass to which it can attach, and the host is detected through the Haller's organ (Carr and Salgado, 2019). Collection methods for these ticks are based off this questing behavior. Two fixed sites were chosen for the 5-year study and were dragged bi-weekly for yearly comparisons from mid-April through August. During the other weeks, other parks and recreational areas within the county were selected for nymphal collection and species exploration. Once an ideal habitat was identified within a site, a white canvas or felt sheet called a drag cloth was dragged along the ground for ticks to latch on to (Figure 10). A site was dragged for a total of 100 meters. While conducting the drag, the fabric is turned over every five to ten meters to observe for crawling ticks. Larvae, nymphs, and adults are collected through the dragging method. These ticks were placed into a vial of alcohol with tweezers to preserve any potential pathogens during shipping. Ticks were tested by PCR at the Vector Management Lab for the three mentioned pathogens.

Figure 6: Dragging method for tick collection. Lamonte, L. (2020) A. Curry dragging ticks [Photograph]. Allegheny County Health Department.

1.2.3 Species and Pathogen Findings: 2019 and 2020 Data

Table 1 shows a comparison table for the 2019 and 2020 nymphal screenings for Schenley and Highland Parks. 33% of nymphs tested in Schenley were positive for Lyme in comparison to 39% in 2019. For Highland Park, 12.5% were positive for *B. burgdorferi* in 2020 and 29% were positive in 2019. Although county *B. burgdorferi* percentages were lower in 2020 compared to 2019, the overall statewide nymph data had an increase in Lyme. Schenley Park showed an increase in *A. phagocytophylum* from 5.5% in 2019 to 11% in 2020. As for babesia, no collections have been obtained to date in the 5-year study. When comparing state data from 2019 to 2020, all three pathogens had higher levels from the previous year. *Borrelia burgdorferi* has continued to remain high in Pennsylvania and is a current public health concern. It is important to note that there is a difference in the number of ticks collected from 2019 to 2020 amongst both fixed sites. Although ACHD cannot pinpoint the reason as to why this is, weather patterns and changing micro habitats within the parks themselves may have a role in the differences seen from year to year.

Table 1: Pathogen percentages for fixed sites in 2019 and 2020

	***Borrelia* (Lyme)**		***Anaplasma***		***Babesia***	
	2019	2020	2019	2020	2019	2020
Schenley Park	7/18 (39%)	3/9 (33%)	1/18 (5.5%)	1/9 (11%)	0/18 (0%)	0/9 (0%)
Highland Park	7/24 (29%)	1/8 (12.5%)	0/24(0%)	0/8 (0%)	0/24 (0%)	0/8 (0%)
Total	**14/42 (33%)**	**4/17 (23.5%)**	**1/42(2%)**	**1/17 (5.8%)**	**0/42 (0%)**	**0/17 (0%)**
PA Statewide	**23%**	**26.1%**	**4%**	**5.9%**	**1%**	**1.4%**

The slide borrowed from ACHD (Figure 7) shows all drag sites both positive and negative for *B. burgdorferi*. Out of the 28 sites which include Schenley and Highland Parks, 14 resulted in nymphs positive for *B. burgdorferi*. The list to the right of the map shows the positive sites.

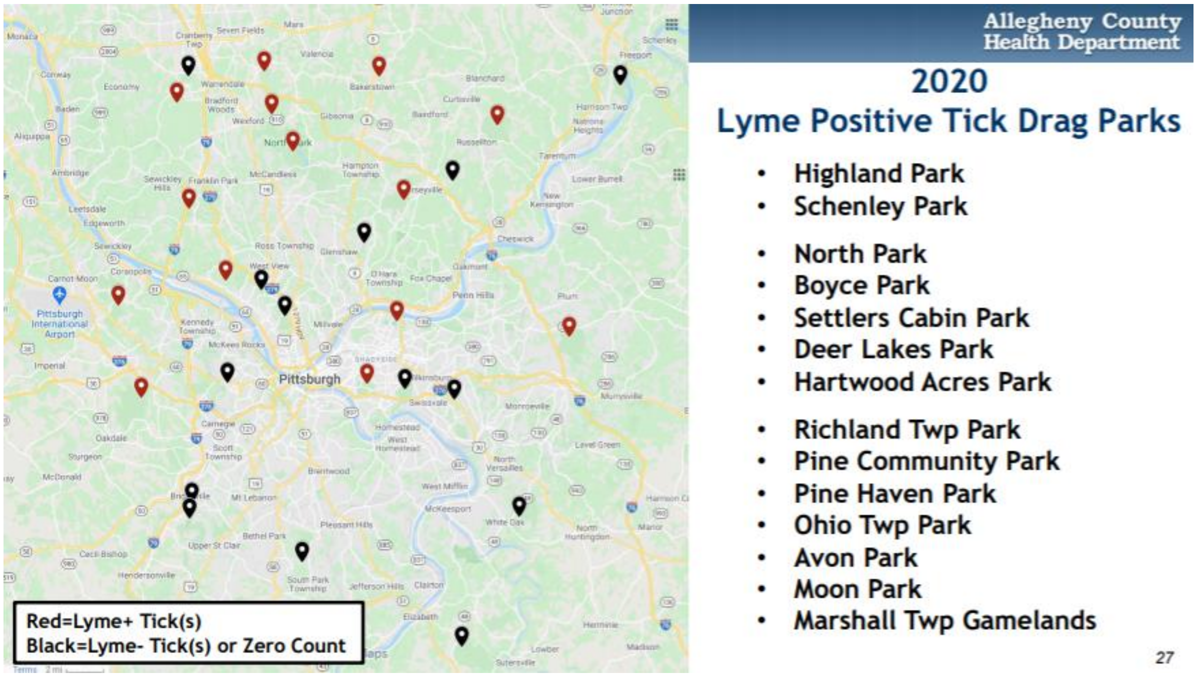


Figure 7: Tick dragging sites and positive location names (Red = Lyme +, Black = Lyme -). Lamonte, L. (2020). 2020 Lymee Positive Tick Drag Parks [Powerpoint Slide]. Allegheny County Health Department.

Another important finding in August 2020 is the first Asian longhorned tick environmental collection in Allegheny County's Schenley Park. Before this finding, this species had only been found in the eastern half of Pennsylvania. This tick often feeds on livestock and can be responsible for exsanguination (Wormser et al., 2019). Females can also reproduce without a mate, a process called parthenogenesis (Beard et al., 2018). Although not considered a major threat to human health with the current research available, this invasive species finding is important for assessing acarological risk for the county regarding human health.

1.3 Prevention Measures

Mosquito and tick prevention is also very important when it comes to vector surveillance. Preventing bites from these vectors is the most effective way to prevent illness from occurring when enjoying activities outdoors. The most effective way to control for mosquito bites is using larval dunks and dumping sources of stagnant water in nearby areas. If mosquitoes cannot breed and lay eggs on stagnant water, there will be no mosquitoes to bite and transmit WNV. Properly installed door and window screens within homes are also important in order to keep biting mosquitoes from coming indoors. When outside, it is important to wear long-sleeved shirts and long pants. Repellents can also be used such as DEET or the oil of lemon eucalyptus to further prevent mosquito bites. As for ticks, it is best to avoid a tick bite by avoiding prime tick habitat. Do not walk through leaves and tall grasses, or along unkept pathways and trails. Wearing long pants tucked into socks will also help prevent ticks from getting to your skin to attach for a meal. Repellents such as DEET can be used on skin to prevent tick bites, and Permethrin for clothing and shoes. After any outdoor activities, especially during the spring, summer, and fall months, it is important to self-check for ticks on your skin. The quicker an attached tick is removed, the less likely the chances are of becoming infected with pathogens it could potentially carry. Showering is also encouraged, as washing skin will help to remove any ticks that may not have attached yet. Prevention is key when it comes to public health education around vectors and their associated pathogens and safety.

2.0 Community Outreach and Education Plan Overview

In reviewing the materials provided for schools on the Allegheny County Vector Control website, it was determined that an outreach and educational program for children and parents may be beneficial in attempt to educate more of the general public about vector-borne diseases. The materials posted on the Allegheny County Health Department website are available for schools to use for educational purposes. In order to educate children about vector-borne diseases, a summer camp-like plan has been developed to keep children engaged with interaction and outdoor stimulation. This plan can only be put into place after the COVID-19 pandemic when quarantine orders are lifted, and the risks are lower as this would involve close interaction among ACHD vector control staff, parents, and children from around Allegheny County. In theory, this specific program would only be a small part to the envisioned ACHD-wide week-long summer camp that would be hosted. Different departments could hold different interactive activities for any age group to get the public more informed about their county health department and what it does for the community.

2.1 Target Audience and Stakeholders

This program would be targeted to middle school-aged children with parental supervision if desired. The information and materials presented would be appropriate for the 11-13 year-old age group, and easy for parents to follow along with if they decide to accompany their child throughout the weekly activities. The VCP staff would host this event in a park with easily accessible mosquito and tick habitat, along with any administration or volunteers currently employed at the ACHD Housing and Community Environment Program.

Important stakeholders in this program must be considered and included for this program to take place. The materials need to be age-appropriate for the targeted age group. Parents who may accompany their child must also be considered when it comes to transportation to and from the program, as well as the time of day. Children may not be able to attend if parents or guardians are working in the evening and are unable to provide transportation. Babysitters may have to be responsible for transportation to and from the activities. Funding for this program is also a major component that must be considered. Perhaps the PA DEP could provide funding, the PA DOH, or obtain funding through outside grant applications or fundraisers throughout the year. If ACHD has any funds that could be contributed to the program that would be sought out as well. Not much funding would be required, as the money that would be spent would be on snacks for participants and an extra surveillance tools that may be necessary for all individuals to participate. Funding will also cover any background checks employees and volunteers may need in order to work with and educate minors. The program would be made available on the county website for participants to apply to sign up with the VCP.

2.2 'Backyard Bugs Summer Activity Week'

The name of this specific program would be 'Backyard Bugs Summer Activity Week'. The goals of this program conducted at North Park would be to inform the target audience of common vectors within Pennsylvania and the current diseases that can be spread to humans through their bites alongside helping them understand prevention measures to stay safe while outdoors. The children will be able to identify both *Culex* and *Aedes* mosquitoes and *Ixodes* ticks as well as understand their general lifecycles, how to trap and collect vectors, breeding sites, prevention and control measures, and know the diseases associated with each species. The program will be 5 days long during the overlap of mosquito and tick surveillance seasons in summer. Due to the necessary specimen collecting and materials, 20 children will be permitted to sign up for the week-long program. Ideally, four children will be assigned to one volunteer or employee group leader and will remain with that group. Sites will be wheelchair accessible to accommodate for children with mobile disabilities. Activities for each day will typically last 2 hours

Day one will be about tick and mosquito education in a pavilion, lecture style with an introduction to the vectors by showing them live mosquitoes and ticks. The children will be shown a quick slideshow on what mosquitoes and ticks are, what they do, how they interact with the environment and the food chain, how to prevent them from biting, etc. Again, this material will be age-appropriate to comprehend.

Day two will consist of dragging for ticks. Each group will get a drag cloth and go to a different area within North Park to drag for ticks. The Tick App ("The Tick App", n.d.) can also be downloaded if the children have smartphones to help them identify ticks. This app shows pictures and has information on how to understand and prevent human exposures to ticks. The children will decide where to drag based on prime habitats learned on day one. The children will look over the drag cloths for ticks and assist in collecting them with tweezers. Before leaving the park, the groups will convene to share findings and discuss how to prevent ticks from biting and how to conduct self-checks before returning home.

Day three will consist of setting one gravid trap per group and collecting one larval sample per group. The children will work together to set up the traps and find a larval sample as well. The group leader will explain dunks when larvae are found. The groups will reconvene and discuss the importance of controlling for larvae and what day four will bring for picking up the traps.

Day four will consist of setting a BG sentinel trap for the Asian tiger mosquito and picking up the gravid trap to take back for processing. The children will assist in setting up the BG trap, one per group, and obtain the net from the gravid trap as well. A quick education session on the Asian tiger mosquito will be given at the end of the session, and the gravid nets will be placed on dry ice at the park to demonstrate knocking down.

Day five, the BG sentinel trap will be picked up, and the mosquitoes can be viewed while in the net. A quick overview of why it is important to know about ticks and mosquitoes will be given, as well as the importance of prevention measures while outside. The parents are asked to be present for day five to be included in this talk as well. If funding allows for it, a take-home kit for parents consisting of a bottle of lemon eucalyptus oil, bottle of permethrin, a pack of dunks, and brochures on local tick and mosquito information will be given out. The children would receive vector-themed school supplies such as notebooks and pencils, stickers for water bottles and notepads, or any other fun, age-appropriate related treats. An online form will be sent to parents through email asking for feedback and suggestions for the different activities to work out any kinks during the first year of this program.

Backyard Bugs could potentially create another practicum opportunity for a Pittsburgh Summer Institute applicant. The 200 required hours could be obtained through assisting with the program, creating education materials, maintaining communication with participants, be a group leader, and research other vector control outreach programs to better this initial plan. Other options for the program could include condensing the week into a weekend and have two full days of activities. There are also summer programs that already exist at South Park and Settlers Cabin Park that this program could be implemented in to, as the infrastructure for these programs already exist.

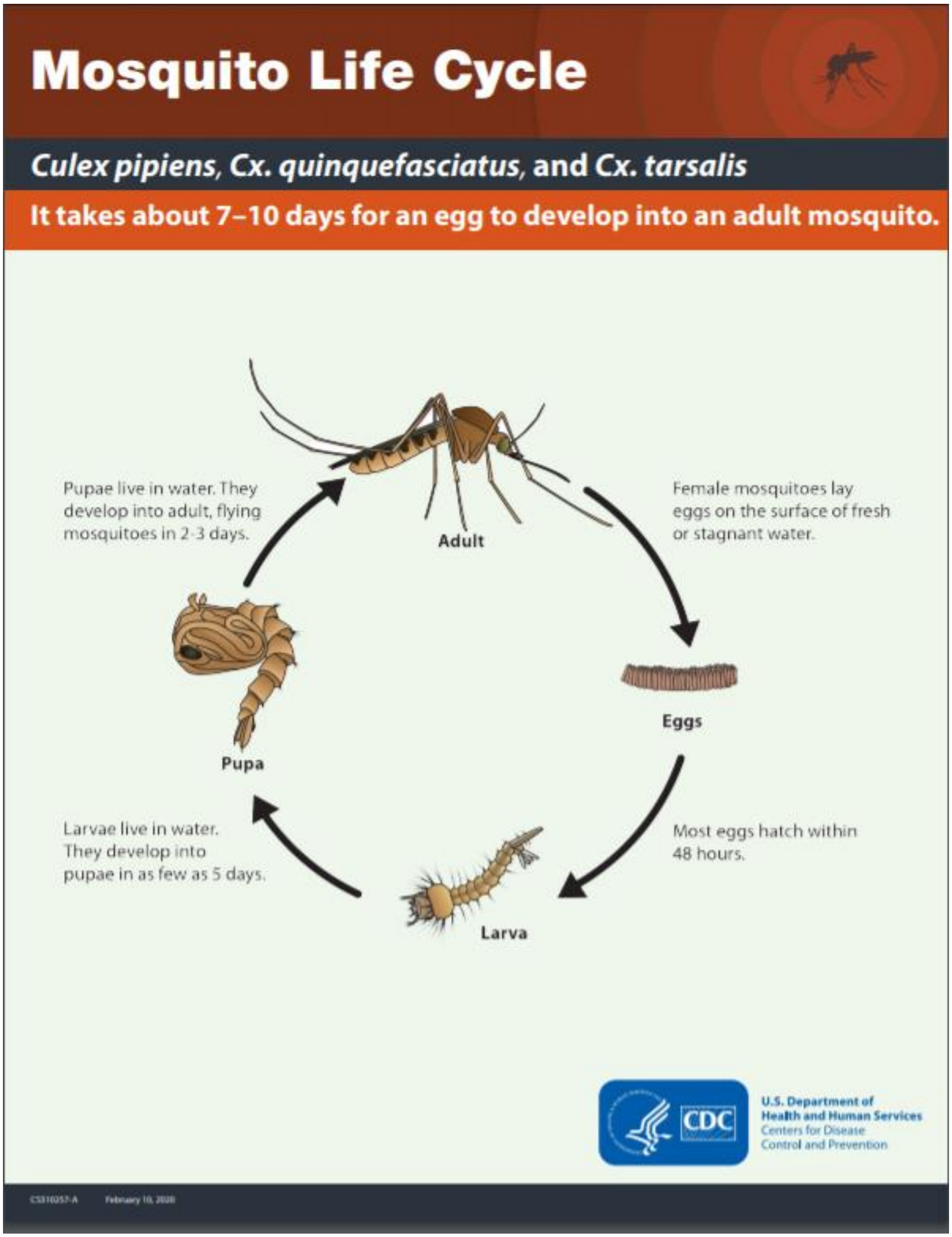
2.3 Program Limitations

This program does have limitations as to who would be able to participate in the week-long program. Because the signups are on the County Parks website, those without internet access, email access, computer or smartphone access will most likely not have access to sign up on their own. The program requires children to be present for all five days, requiring parents, guardians, or babysitters to have reliable transportation to and from North Park. Children would need play or older clothing to participate, as fieldwork can and will get messy. ACHD would also have limited personnel to assist with this program and must consider if overtime pay can be given as compensation or not. Trainings on collection methods and education materials for the employees would also be necessary in order to be a group leader in this program. The Vector Control Program would also have to adjust their fieldwork schedule for the week this program is run in order to help facilitate the program. The risk for bites and disease exposure also increases if parents sign their children up for Backyard Bugs, so protection measures would also need to be planned and implemented for the safety of participants. If this program were to be implemented, and depending upon success, the plan would be revisited and revised as needed.

3.0 Conclusion

West Nile virus and Lyme disease continue to remain public health concerns in Allegheny County. The Vector Control Program at ACHD will continue mosquito and tick surveillance efforts in order to keep these pathogens at bay and keep track of species distribution and population sizes. This data is beneficial to understanding pathogen transmission and human exposures. Not only does the yearly WNV and Lyme surveillance gather data for the county, but species exploration is also important for assessing acarological risks to human health. Education and outreach materials and measures are key in informing the public of the risk of these vectors and pathogens as well as getting them on board to lowering their risk of infection when engaging in outdoor activities. The Backyard Bugs outreach and education program is one way to get children involved and knowledgeable on these vectors and pathogens to keep themselves safe.

Appendix A


Mosquito Life Cycle
Culex pipiens, Cx. quinquefasciatus, and Cx. tarsalis
It takes about 7–10 days for an egg to develop into an adult mosquito.
Adult
Female mosquitoes lay eggs on the surface of fresh or stagnant water.
Eggs
Most eggs hatch within 48 hours.
Larva
Larvae live in water. They develop into pupae in as few as 5 days.
Pupa
Pupae live in water. They develop into adult, flying mosquitoes in 2-3 days.
CDC
U.S. Department of Health and Human Services
Centers for Disease Control and Prevention
CS310257-A
February 10, 2020

Life stages of *Culex* species mosquitoes

Eggs

- Adult, female mosquitoes lay eggs on the surface of fresh or stagnant water. Water sources can include barrels, horse troughs, ornamental ponds, unmaintained swimming pools, puddles, creeks, ditches, and marshy areas.
- A female *Culex* mosquito lays eggs one at a time. Eggs stick together to form a raft of 100 to 300 eggs. The raft floats on the water.

Larva

- Larvae hatch from mosquito eggs and live in water.
- Larvae can be seen in the water. They are very active and are often called "wigglers."
- They feed on materials found in the water.
- Larvae shed their skin (molt) several times during this stage.

Pupa

- Pupae live in water. Pupae do not have external mouthparts and do not feed during this stage.
- An adult mosquito emerges from a pupa and flies away.

Adult

- Adult female mosquitoes bite people and animals. Mosquitoes need blood to produce eggs.
- After blood feeding, female mosquitoes look for water sources to lay eggs. Several days pass between feeding and looking for a place to lay eggs.
- *Culex* mosquitoes don't fly long distances, but have been known to fly up to 2 miles (3.2 km).
- Some *Culex* mosquitoes prefer to live near and bite birds. They bite people when other animals are not nearby.
- Because *Culex* bite animals and people, they live outdoors or near homes.

For more information on diseases spread by mosquitoes:

- www.cdc.gov/westnile
- www.cdc.gov/easternequineencephalitis
- www.cdc.gov/sle

For more information on mosquitoes:

- www.cdc.gov/mosquitoes

Eggs stick together to form a raft.

Larvae in the water.

Pupae in the water.

Female mosquito **before** a blood meal.

Female mosquito **after** a blood meal.

Figure 8: Culex species life cycle and description. ("Mosquito Life Cycle", n.d.).

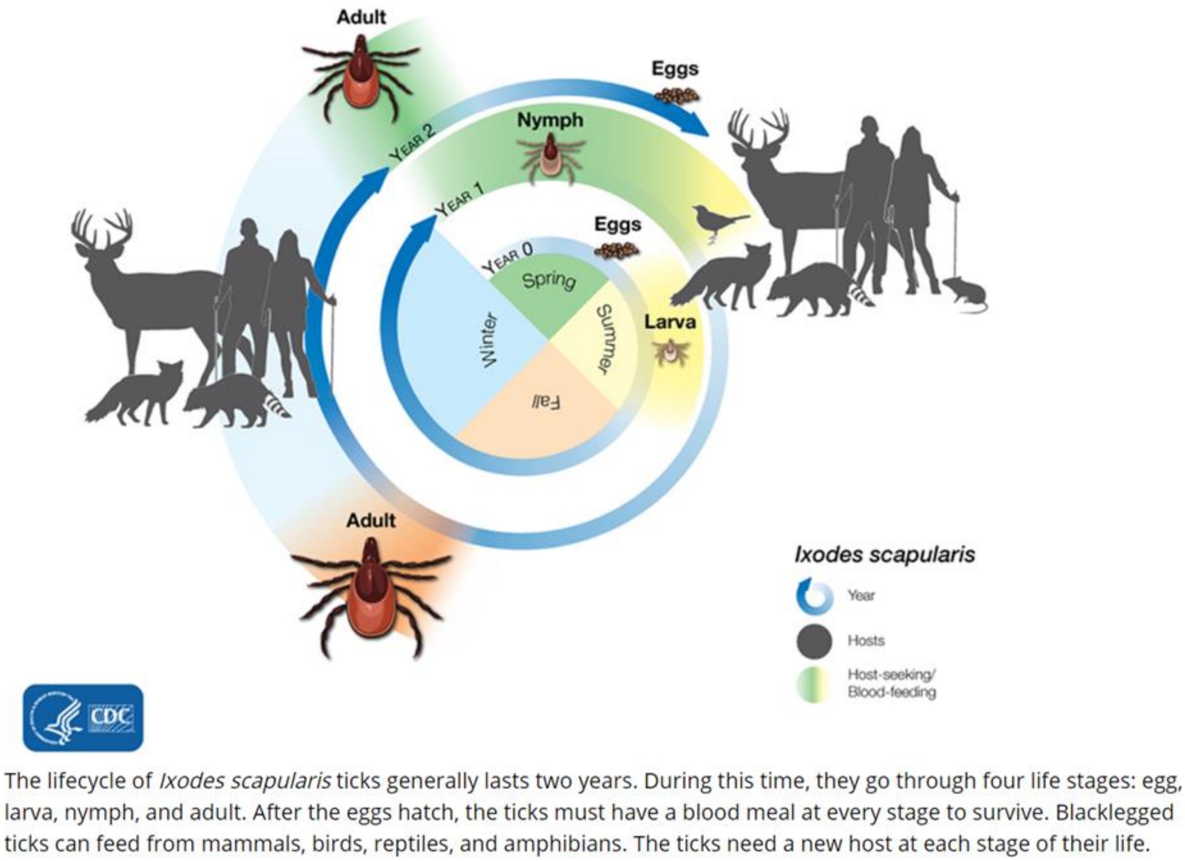


Figure 9: Tick lifecycle. ("How ticks spread disease | CDC", 2020).

Integrated Pest Management: IPM is a program and approach to pest management that relies on environmentally effective practices throughout the Unites States. It can be adopted by agencies and programs alike to better pest management approaches and practices. These programs use updated and comprehensive information on all vector lifecycles and their interactions with and within the environment. It is used to manage and control pest and vector damage by the most economically inclined means with the least amount of hazard to the environment and people. The IPM approach can be used in agricultural settings such as gardens or crop production, or non-agricultural settings such as the home, public space, or workplace. IPM includes information on appropriate usage of pesticides among other control measures.

IPM programs operate by setting action thresholds which determine when control measures need to be taken when certain pest populations are reached. Monitoring and identifying pests is also important for appropriate control measure decisions. Pest prevention works to keep pests and potential pathogens and other harms from becoming a threat to health or crops. Control is used once thresholds and prevention methods are deemed no longer effective or reasonable. ("Integrated Pest Management (IPM) Principles", n.d.). Figure 10 is a visual of an IPM pyramid from Penn State in collaboration with the Pennsylvania Department of Agriculture.

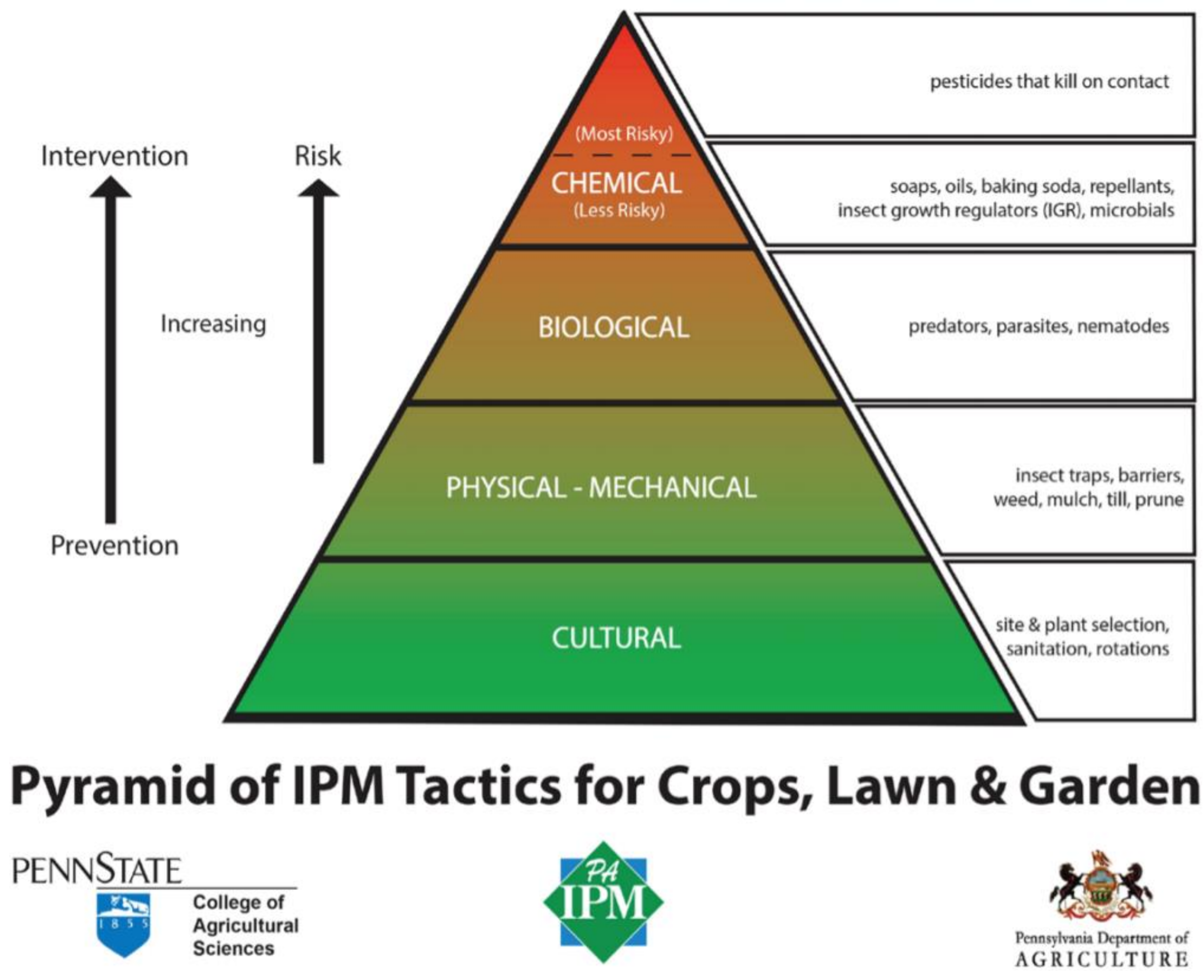


Figure 10: IPM pyramid generated by Penn State. Adapted from CHAPTER 3 BEST PRACTICES FOR PESTICIDE USE. Adapted with permission.

Vector Index (VI): The Vector Index is an estimate of the abundance of infected mosquitoes in an area and incorporates information describing the vector species, relative abundance of those species, and the WNV infection rate in each species into a single index for an area. The VI is calculated by multiplying the average number of mosquitoes collected per trap night by the proportion infected with WNV. This number is the average number of infected mosquitoes collected per trap night in the area during the sampling season. In areas where more than one species of mosquito is present, a VI is calculated for each species of importance and the VIs are summed to represent the estimate of the infected vector abundance. Higher VIs represent increases in risk for human disease. Once a target VI is reached, this will determine which sites or areas need to have adult mosquito control measures taken. ("West Nile Virus in the United States: Guidelines for Surveillance, Prevention, and Control", 2013)

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