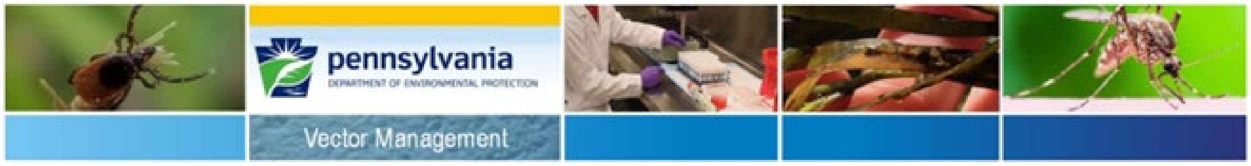

Image Credit and Copyright; The Earth Times - Asian tiger mosquito on a flower

A biological introduction to *Aedes albopictus* "The Asian Tiger Mosquito" and control recommendations for communities and homeowners

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Vector Management

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Introduction

In 2016 an outbreak of Zika virus in the continental U.S. caused by a local population of *Aedes albopictus* marked a turning point for the Country. As a result of the Zika virus outbreak, the Commonwealth began a historical review of *Aedes albopictus* records and initiated active monitoring of the population. Historic surveillance records in Pennsylvania indicate rapid population and vast geographic expansions of *Ae. albopictus* in the very short timeframe since its introduction posited to be the late 90s. The first known Pennsylvania collection of *Aedes albopictus* was Philadelphia County in July 2000. As of January 2023, *Ae. albopictus* is recorded as having established itself in all counties south of route 80, which bisects the State. Species persistence and geographic expansion is limited to the ability of their eggs to tolerate ground temperature where eggs overwinter in the soil. Surveillance observations since 2016 continue to track northern establishment as eggs adapt to temperatures and climate change moderates Pennsylvania winters. Given disease vectoring competence, prolific biting activity and urban evolutionary history of *Ae. albopictus*, it is expected that this mosquito will present a significant challenge for Pennsylvania in the decades to come.

In recent years, invasive species of insects have begun to contribute to the public health and economic nuisance burden in Pennsylvania. Addressed in this document is *Ae. albopictus* or the "Asian Tiger mosquito" (ATM). The ATM and its cousin, "The Yellow Fever" mosquito (*Aedes aegypti*), are uniquely competent at transmitting diseases by having the capacity to acquire and transmit most mosquito-borne viruses that exist in nature. Fortunately, most of the major diseases that plague other countries (Yellow Fever, Dengue, Malaria, Chikungunya and Zika virus) are not found Pennsylvania. Currently, West Nile virus is the only major mosquito-borne disease that occurs in the state. In addition to being able to competently transmit WNV, the ATM also has the potential to transmit other lesser-known native diseases such as: LaCrosse encephalitis and St. Louis encephalitis, which occur sporadically and are endemic in the continental United States. Clearly the most troublesome aspect of the presence of the Asian tiger mosquito in Pennsylvania is the capacity of this vector to transmit the aforementioned anthropogenic diseases that cause vast suffering and death in other countries. In this context, chikungunya, dengue fever, yellow fever and Zika are characterized as 'imported' diseases, where infected people travel from endemic regions infected with the virus and then return to Pennsylvania potentially leading to further transmission of the disease by local vector mosquitoes before appropriate infection control measures could be put in place. If we've learned anything from the recent Covid pandemic, the next outbreak is only a plane or cargo ship ride away.

This document is meant to give an overview of potential risks associated with *Ae. albopictus* and a management plan to assess and address those risks.

Biology

Using global trade as a primary means of distribution, *Aedes (Stegomyia) albopictus (Skuse)* has spread rapidly over the past few decades from its native range in SE Asia to many new regions across the globe (*Aedes albopictus* in Invasive Species Compendium, 2019). Specifically, it has been documented that the global trade of used automobile tires and tropical plants has allowed the eggs and larvae of *Ae. albopictus* to spread well beyond native habitats (Eritja & et.al, 2005). Since the first breeding populations were discovered near Houston, TX in 1985, invasive populations have now been established across North and South America (*Aedes albopictus* in Invasive Species Compendium, 2019)(Fig 1).

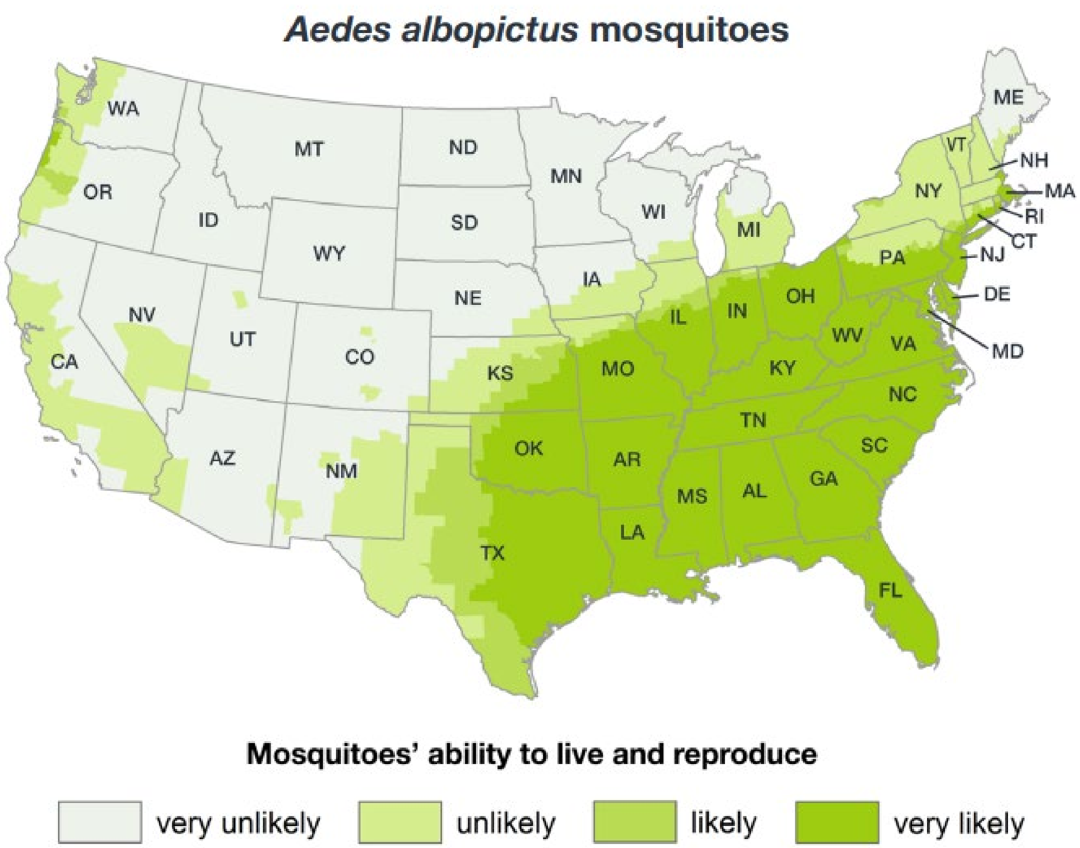

Figure 1: Estimated Range of Ae. Albopictus in the United States

In its native habitat, *Ae. albopictus* can be found breeding in tree holes and broken bamboo shoots. The small, cryptic nature of these habitats has led to the adoption of similar, artificial habitats in urban settings. Waste tires, empty cans, flowerpots, bird baths, clogged gutters, and other small, artificial containers have been adopted by *Ae. Albopictus* and proven to be prime breeding habitats.

The expansion of *Ae. albopictus* populations in Pennsylvania has been well-documented since the early years of the PA DEP West Nile Virus Surveillance and Control Program. In 2001, the program considered

Ae. albopictus to be established in the following counties - all located in SE PA: Lancaster, Delaware and Montgomery. Adult specimens were also collected in 2001 at a single tire retreading facility in Fayette County in SW PA. It is believed that the importation of tires from areas with established populations of *Ae. albopictus* provided a pathway for the species to travel to the site. Control efforts were undertaken to prevent the species from spreading to other nearby habitats. The population appeared to be confined to the tire retreading facility, and no other specimens were collected from outside of the site. Because it was believed that new specimens were being imported to the site on a regular basis, with subsequent tire deliveries, as opposed to the population being maintained at the site, the presence of the species at the site was not considered to be the result of an established population.

Prior to 2016, *Ae. albopictus* adult surveillance was conducted using a variety of traps at randomized sites in specific urban areas of Pennsylvania. In response to the Zika Virus Pandemic of 2016, Pennsylvania standardized the collection of *Ae. albopictus* with the widespread use of BG Sentinel 2 traps (baited with dry ice and BG-Lure) in every county in PA (Ryan & et.al, 2017). The statewide *Ae. albopictus* surveillance model adopted in 2016 has continued to the present day. As of 2/17/2023, *Ae. albopictus* specimens have been collected in 54 counties in PA. Established populations that demonstrate local reproduction and the ability to overwinter have been identified in 33 counties. Specimens have also been collected in an additional 21 counties, but these populations are intermittent as they have not demonstrated the ability to overwinter or reproduce locally (Fig. 2). In counties with established *Ae. albopictus* populations, local clusters are increasing in size and spreading within the adjacent urban habitats.

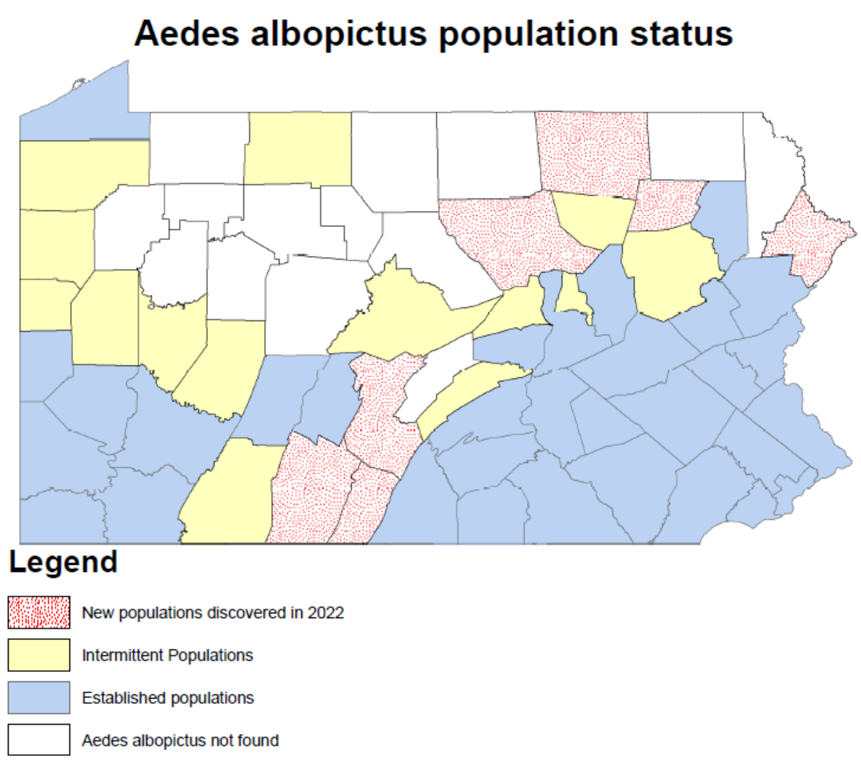

Figure 2: The status of Ae. albopictus populations by PA county as of 2/17/2023

Along with the closely related *Aedes aegypti* (commonly known as the Yellow Fever mosquito), *Ae. albopictus* is a member of the *Aedes* subgenus, *Stegomyia.* The taxonomy of *Ae. albopictus* is described by (Hawley, 1988):

> "*Aedes albopictus* was originally described by Skuse (1894) from specimens from Calcutta, but a neotype was designated by Huang (1968) because of the loss of the original type specimens. *Aedes albopictus* is a member of the subgenus *Stegomyia*, the Scutellaris Group (Edwards' Group C of *Stegomyia*), and Albopictus Subgroup. The Albopictus Subgroup includes 12 species. In North America, *Ae. albopictus* may often be identified on the wing, since the only *Stegomyia* species also present there is the easily distinguished *Ae. aegypti (Linnaeus)*. Since larvae of most members of the Albopictus Subgroup occur in tree holes in southeast Asia, *Ae. albopictus* is believed to have originated in the forests of that region. How long ago *Ae. albopictus* developed the ability to colonize manmade containers is unknown, but that ability is the key to its present widespread and expanding distribution. The evolution of *Ae. albopictus* provides an interesting contrast with that of *Ae. aegypti*, which purportedly has its origins in Africa (Mattingly 1957). While both species have spread worldwide as a consequence of their ability to colonize man-made containers, only *Ae. albopictus* has developed a photoperiodic egg diapause, allowing colonization of temperate regions. *Aedes aegypti* has evolved a closer association with man, preferring to live inside his houses in parts of its range, while *Ae. albopictus* seems to have retained a greater ability to recolonize tree holes in forests after transport to a new region (Hawley, 1988) (Skuse, 1984) (Huang, 1968) (Soekiman & et.al, 1984) (Mattingly, 1957) (Davis & et.al, 2016)"

Aedes albopictus has proven to be successful in native, tropical regions where it does not undergo photoperiodic diapause and in temperate regions where it has adapted to colder climates by entering photoperiodic diapause, in the egg stage, to overwinter (Armbruster, 2016). In Pennsylvania, we have observed that the first hatches of overwintering *Ae. albopictus* eggs typically occur in mid-May with the last hatch usually occurring in early- to mid-October. Environmental factors play a major role in influencing the growth, survival, and reproduction of *Ae. albopictus* (Armbruster, 2016). Temperature, photoperiod, and the level of O_2 saturation in the water have an impact on everything from the timing of the first hatch of overwintering eggs in the spring to the development of larvae and pupae throughout the breeding season, the reproductive success of adults, and the initiation of photoperiodic diapause in the fall (Hawley, 1988) (Armbruster, 2016) (Kache & et.al, 2020)The photoperiodic diapause of *Ae. albopictus* as described by Armbruster (2016):

> "In its ancestral Asian range, Ae. albopictus has an unusually widespread latitudinal distribution, including tropical populations that do not undergo photoperiodic diapause and temperate populations that do undergo photoperiodic diapause. In the photoperiodic diapause response of temperate populations, the pupal and adult females are photosensitive; when exposed to short (autumnal) day lengths, females produce diapause eggs that undergo developmental arrest as a pharate larvae inside the chorion of the egg. Diapause is a hormonally controlled developmental arrest that is

> programmed by a token stimulus in advance of the onset of unfavorable environmental conditions and is not immediately terminated in response to favorable conditions. Thus, diapause is a phenotypically plastic response that provides an adaptive mechanism for the temporal coordination of growth, development, and dormancy in a seasonal environment (Hawley, 1988) (Armbruster, 2016) (Wang, 1966) (Mori & et.al, 1981) (Denlinger, Regulation of diapuase, 2002) (Denlinger & et.al, Mosquito Diapause, 2014)."

Being multivoltine in nature, a single, adult, female *Ae. albopictus* is capable of laying multiple clutches of eggs throughout the breeding season (Davis & et.al, 2016). Like all *Aedes* mosquitoes, for *Ae. albopictus* larvae to hatch, the eggs must first desiccate, or dry, before being immersed in water. The drought-resistant eggs are deposited above the waterline in natural containers (e.g., tree holes, rock pools) or in artificial containers (e.g., waste tires, buckets). As average daily temperatures approach 60°F in the spring, it's likely the first hatch of overwintering *Ae. albopictus* larvae will soon emerge. After hatching from the egg, mosquitoes progress through 4 larval stages before entering the pupal stage. Depending significantly on the average daily temperature, the combined larval and pupal stages may transpire over as few as 7 days (when average daily temperatures are near 96°F) to as many as 35 days (when average daily temperatures are near 59°F) (Kache & et.al, 2020). In the hottest months of the breeding season, it's not uncommon for *Ae. albopictus* in PA to develop from the egg stage to the adult stage within the span of one week (Fig 3).

After hatching from the egg, the tiny, first-instar larvae do not immediately begin to feed. Once feeding begins, small organic particles (e.g., bacteria, decaying organic matter) are ingested. From the 2nd instar through the middle of the 4th instar, larvae will continue to feed on organic matter in the water column to fuel their growth. The quality of the nutrition that is derived from the organic matter will determine the viability, survivability, and reproductive success of the mosquito throughout the rest of its life. Midway through the 4th instar development, larvae halt feeding in preparation to transform into the pupal stage. Mosquitoes in the pupal stages do not feed; however, all larval instars and the pupal stage require air to breath, respond to external stimuli, and are actively mobile.

While in the pupal life stage, the mosquito transforms into an adult (imago). For the imago to successfully emerge, the pupae must rise to the surface of the water where the pupal case can safely split open. The imago emerges from the split pupal case and rests on the surface of the water while the body and wings harden and dry. It is important to note that the newly emerged imago is in an extremely vulnerable state. While resting on the surface and unable to fly, the mosquito is easily preyed upon by dragonflies and other predatory insects and animals. Since all mosquito life stages breath air, the imago is at risk of drowning if the water surface is not stable. Once sufficiently hardened and ready to fly, the imago must find a sugar source to replenish its energy reserves (Lucas & et.al, 2001). Female and male mosquitoes, alike, must feed on nectar to fuel their own metabolism. After ingesting nectar from flowers and plants, the imago will seek shelter to process the nectar and finish hardening its exoskeleton & wings. Once the initial nectar meal has been processed, males will begin searching for a mate. In need of the protein necessary for egg production, females will begin to seek out a host for an initial blood meal and may also attempt to mate. Most female *Ae. albopictus* mosquitoes will only need to mate once to produce a lifetime of eggs. After successfully mating, the average *Ae. albopictus* female will lay 42 – 88 eggs/blood meal cycle and may lay as many as 300 – 345 eggs in a lifetime depending on the number of subsequent bloodmeals taken (Hawley, 1988).

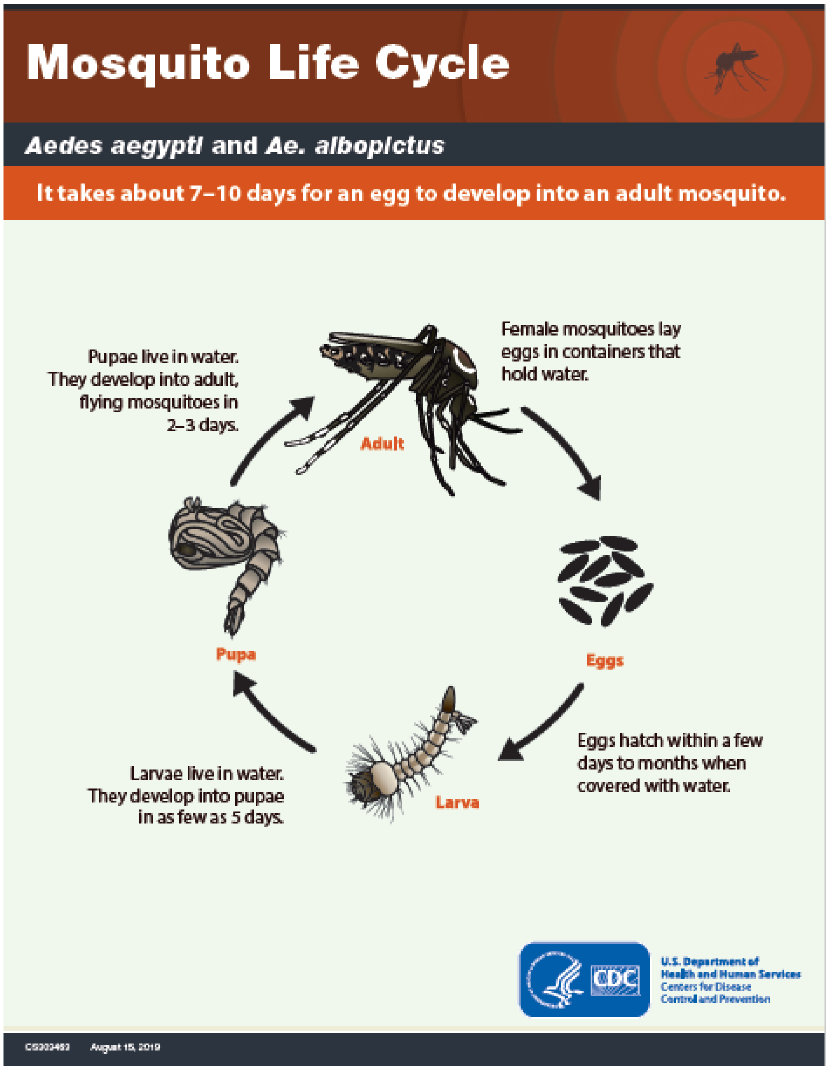

Figure 3: Ae. albopictus Life Cycle

Ae. albopictus is an opportunistic host-seeking species with a preference for obtaining blood meals from mammals; moreover, the species displays a particular affinity for feeding on large mammals – including humans (Hawley, 1988) (Richards & et.al, 2006). Feeding on birds is less desirable; therefore, mosquito-borne diseases that rely on avian amplification are typically not vectored efficiently by *Ae. albopictus* (Faraji & et.al, 2014). Host-seeking typically occurs at the ground-level in daytime hours (Hawley, 1988). Adult females can be found resting in shaded areas that are protected from direct sunlight and strong winds that somewhat mimic dense tropical forests. Because they are not strong fliers, *Ae. albopictus* will usually prefer to bite people below the knee (Hawley, 1988).

Ae. albopictus adults will typically stay within 100m – 300m of the general habitat and water source from which they emerged (Vavassori & et.al, 2019). When adults of the species are encountered in the field, this characteristic can be used to help locate the breeding source.

For female *Ae. albopictus*, and nearly all mosquitoes, the process of successfully obtaining a blood meal is complex and relies on the interpretation of multiple sensory cues. Before taking a blood meal, mosquitoes must detect and locate a host by using multiple adaptations to "smell", see, feel, taste, and possibly "hear" their prey (Vinauger & et.al, 2019) (Menda & et.al, 2019) (Raji & et.al, 2017). Animals expel carbon dioxide (CO_2) and other chemicals during respiration that mosquitoes can sense using olfactory receptors in their antennae, maxillary palps, and proboscis.[21] Mosquitoes' eyes are adept at seeing movement and color contrasts. Special cells in the antennae allow mosquitoes to sense or "feel" heat given off by animals. The feet and proboscis of mosquitoes contain taste receptors that may be used in conjunction with olfactory receptors to "fine tune" the place on the skin to bite. Studies conducted on the closely related species, *Aedes aegypti*, have suggested that mosquitoes may be able to "hear" the sounds of their hosts through the use of specialized cells attached to the base of hairs on their antennae (Raji & et.al, 2017) (Gopfert & et.al, 1999).

After landing on a host, female mosquitoes use their battery of sensory tools to locate capillaries near the surface of the skin. The proboscis is used to probe just beneath the surface to find and pierce a capillary for blood. The proboscis itself is a complex instrument which is comprised of seven total parts: four cutting tools, one canal to inject saliva from the mosquito to the host, one canal to withdraw blood from the host to the mosquito, and a protective sheath that covers all of the parts. After piercing the capillary, the mosquito injects saliva into the host's blood that contains both numbing and anticoagulant agents. The numbing agent reduces the likelihood that the mosquito will be detected by the host, and the anticoagulant prevents the blood from clotting. During the injection of saliva, pathogens may be passed from the mosquito to the host. In female mosquitoes, there are two pumps in the head that work in tandem to efficiently ensure a steady flow of blood from the host to the mosquito's gut (Kim & et.al, 2011). The mosquito feeds until a signal to stop is sent from the gut along the ventral nerve cord (Dwadz, 1969). Once enough blood has been taken, the mosquito will fly to a protected area to rest and digest the blood meal over the course of several days. Protein from the blood is used to create eggs for the next generation of mosquitoes.

Health risks and nuisance burden of *Aedes albopictus* in Pennsylvania

Health risks

As non-native species of mosquitoes, such as *Ae. albopictus*, encroach into new habitats we must be prepared to evaluate public health risks and act to mitigate those risks.

Based on research from lab settings and in the wild, *Ae. albopictus is* considered to be a competent vector of at least 23 arboviruses including: Zika, Chikungunya, Yellow Fever virus, Rift Valley Fever virus, Japanese encephalitis virus, West Nile virus and Sindbis virus, Potosi virus, Cache Valley virus, La Crosse virus, Eastern Equine Encephalitis virus, Mayaro virus, Ross River virus, Western Equine Encephalitis virus, Venezuelan Equine Encephalitis virus, Oropouche virus, Jamestown Canyon virus, San Angelo virus and Trivittatus virus. Additionally, there have been recent global outbreaks of Chikungunya and Zika attributed specifically to *Aedes* species including the 2016-17 Zika outbreak in the Americas.

Ae. albopictus feeds on a wide range of hosts and is known to be a significant biting nuisance, with the potential to become a serious health threat as a bridge vector of zoonotic pathogens.

Additionally, the movement of viremic hosts can result in disease outbreaks in non-endemic areas. Climate change could increase the distribution of *Ae. albopictus* beyond its current boundaries which could enhance the transmission potential of Chikungunya virus, dengue virus and other vector borne diseases in temperate regions. It should be noted that while the potential for non-endemic vector borne diseases merits observation, these diseases are, at this time, found in rare occurrences in Pennsylvania.

Potential health risks include but are not limited to the below diseases:

Chikungunya

Chikungunya virus is spread to people by the bite of an infected mosquito. The most common symptoms of infection are fever and joint pain. Other symptoms may include headache, muscle pain, joint swelling, or rash. Outbreaks have occurred in countries in Africa, Asia, Europe, and the Indian and Pacific Oceans. In late 2013, Chikungunya virus was found for the first time in the Americas on islands in the Caribbean. There is a risk that the virus will be imported to new areas by infected travelers. There is no vaccine to prevent or medicine to treat chikungunya virus infection. Travelers can protect themselves by preventing mosquito bites. When traveling to countries with Chikungunya virus (CDC, 2022).

Dengue

Dengue virus is spread to people through the bite of an infected *Aedes* species (*Ae. aegypti* or *Ae. albopictus*) mosquito. Dengue is common in more than 100 countries around the world.
Forty percent of the world's population, about 3 billion people, live in areas with a risk of dengue. Dengue is often a leading cause of illness in areas with risk. Forty percent of the world's population, about 3 billion people, live in areas with a risk of dengue. Each year, up to 400 million people get infected with dengue. Approximately 100 million people get sick from infection, and 22,000 die from severe dengue. Dengue is caused by one of any of four related viruses: Dengue virus 1, 2, 3, and 4. For

this reason, a person can be infected with a dengue virus as many as four times in his or her lifetime (CDC, 2022).

Zika

Ae. albopictus is considered a potential vector of Zika virus. Zika is spread mostly by the bite of an infected *Aedes* species mosquito (*Ae. aegypti* and *Ae. albopictus*). Zika virus disease is generally mild, and severe disease requiring hospitalization and deaths are uncommon. Zika infection during pregnancy can cause serious birth defects and is associated with other pregnancy problems. Rarely, Zika may cause Guillain-Barré syndrome, an uncommon sickness of the nervous system in which a person's own immune system damages the nerve cells, causing muscle weakness, and sometimes, paralysis. Very rarely, Zika may cause severe disease affecting the brain, causing swelling of the brain or spinal cord or a blood disorder which can result in bleeding, bruising or slow blood clotting (CDC, 2022).

West Nile Virus

West Nile virus (WNV) is the leading cause of mosquito-borne disease in the continental United States. It is most commonly spread to people by the bite of an infected *Culex* species mosquito, however *Ae. albopictus* has been shown to be a competent vector in laboratory settings. Cases of WNV occur during mosquito season, which starts in the summer and continues through fall. There are no vaccines to prevent or medications to treat WNV in people. Fortunately, most people infected with WNV do not feel sick. About 1 in 5 people who are infected develop a fever and other symptoms. About 1 in 150 people who are infected develop a severe illness affecting the central nervous system such as encephalitis (inflammation of the brain) or meningitis (inflammation of the membranes that surround the brain and spinal cord). Symptoms of severe illness include high fever, headache, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness, vision loss, numbness and paralysis. Severe illness can occur in people of any age; however, people over 60 years of age are at greater risk. People with certain medical conditions, such as cancer, diabetes, hypertension, kidney disease, and people who have received organ transplants, are also at greater risk. Recovery from severe illness might take several weeks or months. Some effects to the central nervous system might be permanent. About 1 out of 10 people who develop severe illness affecting the central nervous system die (CDC, 2022).

Dog Heartworm

Ae. albopictus has a role in the transmission of Dirofilaria in Asia, North America and Europe. Dirofilaria (filarial nematodes *D. immitis* and *D. repens*) is a parasite transmitted primarily between dogs (or other canids which act as reservoir hosts) and mosquitoes, but which can also affect humans. Recent evidence has shown transmission of the parasite by Italian *Ae. albopictus* populations, coupled with an increase in prevalence of human dirofilariasis in Italy.

Human infections are increasing in Europe. Although it is unusual for the parasite to develop into the adult stage in humans, at least three cases of microfilaraemic zoonotic infections have been reported in Europe (European Centre for Disease Prevention and Control, 2022).

Nuisance burden

While *Ae. albopictus* is a competent vector of some arboviruses, the primary impact in Pennsylvania is as a nuisance. These impacts range from various social and economic impacts that reduce quality of life. *Ae. albopictus* is a day biting mosquito that completes its life cycle in and around people and uses our living space as its environmental niche. This close proximity creates frequent interaction and results in numerous public complaints of biting insects. The abundance of complaints generated by *Ae. albopictus* can strain resources of government vector control programs and as a result should be considered in any management plan where *Ae. albopictus* has established populations.

In addition, the peak species density for Ae. albopictus occurs mid-summer into the fall making Ae. albopictus a burden to outdoor activity and tourism in Pennsylvania. (Fig. 4)

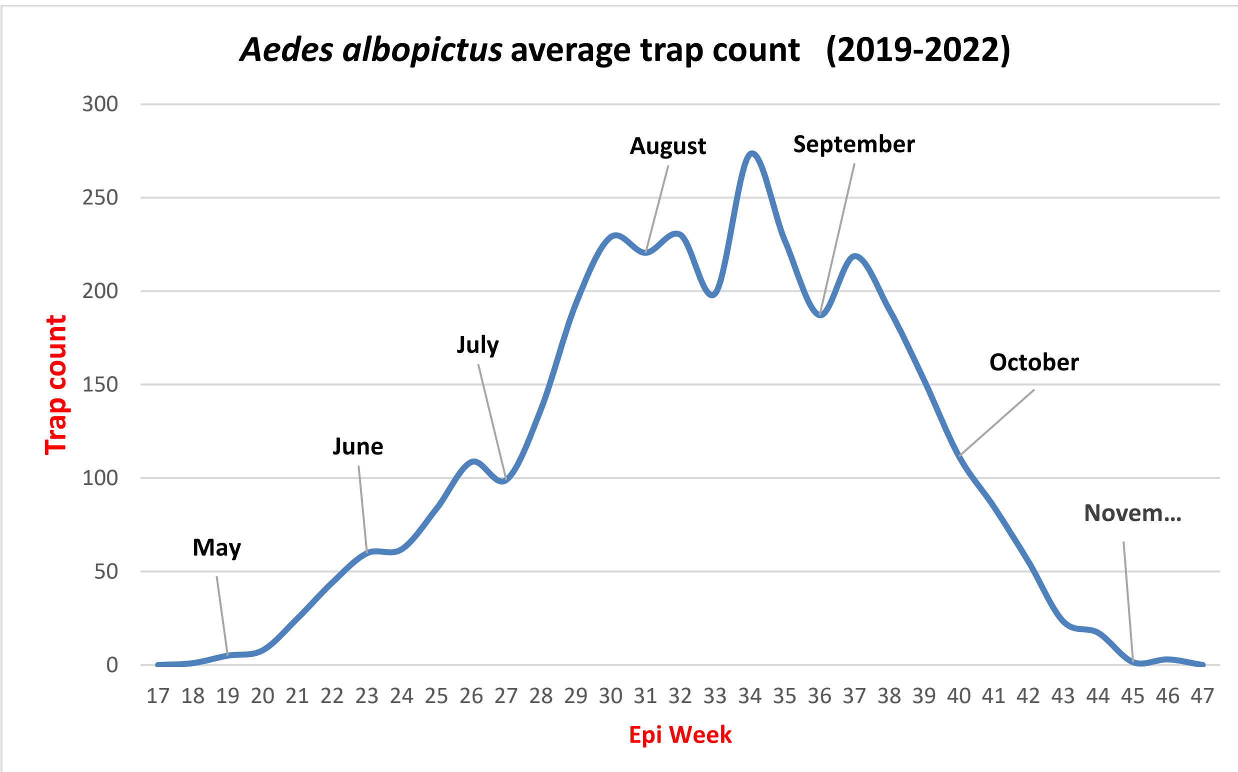

Figure 4: Ae. albopictus Temporal patterns

Response and Prevention

The PA DEP Vector Management response and prevention strategies are based on Integrated Mosquito Management (IMM). IMM uses a combination of methods to prevent and control both nuisance mosquitoes and mosquitoes that spread viruses like dengue, West Nile, Zika, and others. These methods include surveillance, habitat reduction, public outreach and control using a wide range of control products.

PA DEP Vector Management has an existing surveillance program to monitor activity and presence of *Ae. albopictus*. We are aware of *Ae. albopictus* activity in 54 counties in Pennsylvania. Close surveillance and laboratory testing of *Ae. albopictus* is an integral part of any response planning and actions. During the 2016-17 Zika outbreak in the Americas (Florida and Texas in US), the PA DEP conducted several Zika response operations where it was determined there was a cluster of imported human Zika cases (2 or more within 2 miles). Response operations included habitat identification, larval surveillance and control and community outreach. After action reviews from the Zika cluster responses resulted in further discussions about the way Pennsylvania vector programs approach response planning for potential future outbreaks and the nuisance burden of *Ae. albopictus* which are outlined below.

As is often the case in risk management, education is an important mitigation tool. Citizens should be educated on mosquito habitat and the ways to eliminate this habitat when possible. Public outreach combined with vigorous surveillance, specimen testing and larval and adult control programs are key components of the prevention of mosquito borne diseases.

Mosquito Management

As of the writing of this document, *Ae. albopictus* is primarily considered to be a nuisance species in urban/suburban neighborhoods that acts as a potential bridge vector for WNV. Management of this species is challenging due to the prolific cryptic urban reproduction cycle and daytime activity period that *Ae. albopictus* uses as a survival strategy. Once established in a community, it is often challenging, albeit not impossible, to successfully manage and reduce *Ae. albopictus* populations. *Aedes albopictus* deposits eggs in residential containers, which can be numerous and hard to detect and treat, as well as larger containers located at businesses and within cities like tires, junkyards and catch basins (Unlu & et.al, 2013). The cryptic nature and the species' affinity for breeding in small, artificial containers allows it to proliferate in densely populated neighborhoods. Individual homeowners within the community, along with the municipality, must work to maintain properties and reduce standing water. In neighborhoods with established populations of *Ae. albopictus*, active code enforcement is often necessary to assist with the compliance of standing water codes. The PA DEP can assist by providing technical support and guidance to public & local governments, but ultimate success is dependent on effective, local mitigation efforts.

Integrated Mosquito Management

When developing a plan to reduce established populations of *Ae. albopictus*, the PA DEP recommends that communities and municipalities consider adopting the principles of Integrated Mosquito Management (IMM). IMM is a science-based approach that utilizes a combination of various methods and tools to manage mosquito populations and reduce the risk of mosquito-borne disease transmission. At its foundation, IMM relies on larval, pupal, and adult mosquito surveillance to monitor mosquito populations and guide habitat reduction and control efforts. Comprehensive mosquito surveillance provides data that is used to assess the effectiveness of mitigation efforts. Larval and adult mosquito surveillance can also assist with locating mosquito breeding sources based on the number of specimens collected. Due to typical habitat dispersal patterns, collection counts relay the proximity to the primary breeding source. Once a breeding source is identified, the ability to remove or eliminate the stagnant, standing water should be considered first. If the breeding source cannot be eliminated, attempts should be made to drain or remove the water. If unable to remove the water, use of mosquito larvicides and pupicides should be considered depending on the life and feeding stage of the mosquito larvae. If aquatic treatment is not viable, terrestrial mosquito control should be implemented according to established disease and nuisance reducing thresholds. Oftentimes, it may be necessary for all steps to be used, concurrently, to achieve complete mosquito management.

In addition to mosquito surveillance and control, a robust IMM program relies on education and outreach to the public and municipal officials. Efforts should be made to provide the public with recommendations for reducing standing water around homes and the community. Education related to reducing bites should also be disseminated such as, the use of mosquito repellents, wearing long sleeves and pants, and avoiding being outside during optimum mosquito feeding times. Outreach to municipalities and municipal code enforcement officials should prioritize the need for active code enforcement with regards to mosquito breeding habitats (e.g. abandoned swimming pools, waste tires, artificial containers, etc.). Ideally, well-maintained properties and neighborhoods should require less use of mosquito larvicides and adulticides. By solely eliminating stagnant, standing water sources, it's possible to significantly reduce or eliminate mosquito populations and infestations in a community.

The final component of IMM is accurate record-keeping. Many changes occur over time that impact mosquito populations, such as: changing weather patterns, community land use, prior mosquito control efforts, source reduction, and community engagement. Having consistent data that can be reviewed and analyzed over days, weeks, months, and years is necessary to accurately assess the effectiveness of an IMM plan, and it provides the information needed to make meaningful improvements to the plan. Record keeping can help communities predict patterns of disease and nuisance burdens.

Governmental (County, Municipal, State) Cooperation

IMM of *Aedes albopictus* mosquito can be difficult due to the cryptic and often overlooked habitats it utilizes during its reproductive cycle. The PA DEP surveillance data has shown that ATM populations surge and peak in mid to late summer and can make it difficult for people to enjoy being outside for any length of time due to their vicious biting. However, we have observed a significant reduction in their populations is possible when multiple community levels, such as legislators, government officials and homeowners, work together to increase awareness about mosquito biology, establish local standing water ordinances and provide adequate resources for local vector control offices.

There are many ways that municipalities can help with the *Ae. albopictus* problem. A great first step is enacting standing water ordinances. These ordinances give the municipalities the authority to enforce cleanup when mosquito habitat is located. To better protect the health of their citizens, municipalities can help minimize the potential for mosquitoes to breed on municipal-owned property. Identifying potential problem areas and working to solve drainage issues are a few examples to help reduce the ATM at the municipal level. Lastly, municipalities can help promote education regarding mosquito breeding source reduction and best-management practices to avoid contracting a mosquito-borne illness.

Ideally, the best way to reduce populations of *Ae. albopictus* is through the removal of their breeding habitat, also known as source reduction. Source reduction has the advantage to eliminate not only the current generation, but also future generations, from using the same habitat for the reproductive cycle. Aside from source reduction, efficient control in cryptic habitats has been demonstrated by using truck-mounted Buffalo Turbine sprayers dispensing liquid larvicides. This type of operation requires dedicated staff and increased pesticide expenditures. Currently only Philadelphia uses truck-mounted liquid larvicide applications as a strategy to combat *Ae. albopictus*. Given complaints from the public, possible disease importation, population projects and anticipating the impacts of climate change, it is expected that the use of liquid larviciding may become necessary in additional PA counties.

Homeowners

Source reduction, the removal of habitat used by mosquito larvae, can greatly affect the distribution of mosquito larvae in a neighborhood by limiting the amount of habitats for ovipositing mosquitoes leading to significantly lower numbers of adult mosquitoes (Richards & et.al, 2008) (Fonseca & et.al, 2013). *Aedes albopictus* can complete their life cycle in a bottle cap amount of water. Eliminating mosquito breeding sites is the most efficient way to get rid of mosquitoes, but it cannot be done without community involvement.

Because this mosquito does not travel far from where they hatch, property owners and residents can have a dramatic impact on local mosquito populations by following some simple prevention measures. Most homeowners don't realize they have *Ae. albopictus* habitat in their yards, or they don't realize how much relief eliminating these habitats around the home can provide from biting activity. Residential habitats include but are not limited to the following:

- Birdbaths
- Kids toys
- Kids pools
- Pools
- Small and cryptic containers such as:
    - Bottle caps
    - Cutoff fence posts
    - Underground pipe/corrugated pipe
    - Recycling containers
    - Cat/dog bowls and food containers
    - Gutters
    - Ornamental ponds
    - Flowerpot rims
    - Tarps
    - Pool filter boxes

Homeowners can use pesticide products, like Mosquito Dunks, to treat standing water that can't be eliminated. Dunks contain a safe and effective bacterial product that once suspended in the water column, is ingested by the mosquito larvae, killing them within 24 hours. Products for lawns and landscapes that kill the adult ATM contain the active ingredient pyrethrins that homeowners can apply on their property. These products can be purchased at home improvement and hardware stores.

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Glossary:

- Antennae: one of a pair of slender, movable, segmented sensory organs on the head of insects, myriapods, and crustaceans.
- Anthropogenic: of, relating to, or resulting from the influence of human beings on nature.
- Arboviruses: any of various RNA viruses (as an arenavirus, bunyavirus, or flavivirus) that are transmitted chiefly by arthropods and include the causative agents of dengue, encephalitis, sandfly fever, and yellow fever.
- Arthropods: any of a phylum (arthropoda) of invertebrate animals (such as insects, arachnids, and crustaceans) that have a segmented body and jointed appendages, a usually chitinous exoskeleton molted at intervals, and a dorsal anterior brain connected to a ventral chain of ganglia.
- Canid: any of a family (canidae) of carnivorous animals that includes the wolves, jackals, foxes, coyote, and the domestic dog.
- Capillaries: a minute thin-walled vessel of the body.
- Cryptic habitat: concealed mosquito habitat.
- Dirofilariasis: infestation with filarial worms of the genus dirofilaria and especially with the heartworm (d. Immitis).
- Encephalitis: inflammation of the brain that is caused especially by infection with a virus (such as herpes simplex or West Nile virus) or less commonly by bacterial or fungal infection or autoimmune reaction.
- Established population(s): refers to specimens collected that demonstrate evidence of local reproduction and overwintering.
- Exoskeleton: an external supportive covering of an animal (such as an arthropod).
- Filarial: any of numerous slender filamentous nematodes (wuchereria, onchocerca, and related genera) that as adults are parasites in the blood or tissues of mammals and as larvae usually develop in biting insects.
- Guillain-Barré syndrome: an uncommon autoimmune disorder of sudden onset that is an inflammatory neuropathy affecting the peripheral nervous system, that is initially marked by tingling, numbness, weakness, or loss of sensation in the feet and legs usually spreading to the arms, upper body, and face, that often causes severe nerve pain and breathing difficulties and sometimes progresses to paralysis and in rare instances death.
- Imago: an insect in its final, adult, sexually mature, and typically winged state.
- Integrated mosquito management: management of mosquitoes that minimizes the use of chemicals and emphasizes natural and low-toxicity methods.
- Intermittent population(s): refers to specimens collected that lack evidence of local reproduction and overwintering.
- Larvicide: an agent for killing larval pests.
- Maxillary palps: a small several-segmented process on the outer aspect of each maxilla of an insect that is believed to have a sensory function.

- Meningitis: a disease marked by inflammation of the meninges that is either a relatively mild illness caused by a virus (such as various coxsackieviruses) or a more severe usually life-threatening illness caused by a bacterium (especially the meningococcus, neisseria meningitides, or the serotype designated b of haemophilus influenzae).
- Microfilaraemic: the presence of microfilariae in the blood of one affected with some forms of filariasis.
- Mitigation: the act of mitigating something or the state of being mitigated: the process or result of making something less severe, dangerous, painful, harsh, or damaging.
- Multivoltine: having several broods in a season.
- Nematodes: any of a phylum (nematoda or nemata) of elongated cylindrical worms parasitic in animals or plants or free-living in soil or water.
- Nuisance species: one that is annoying, unpleasant, or obnoxious (pest).
- Overwintering: occurring during the period spanning the winter.
- Ovipositing: to lay eggs.
- Pathogens: a specific causative agent (such as a bacterium or virus) of disease.
- Photoperiod: a recurring cycle of light and dark periods of constant length.
- Photoperiodic diapause: a key determinant of abundance in both space and time, and the timing of entry into and exit out of diapause strongly affects seasonal population dynamics and thus the potential for arbovirus transmission. A period of physiologically enforced dormancy between periods of activity.
- Proboscis: any of various elongated or extensible tubular processes (such as the sucking organ of a butterfly) of the oral region of an invertebrate.
- Pyrethrins: either of two oily liquid esters c21h28o3 and c22h28o5 having insecticidal properties and occurring especially in the flowers of pyrethrum.
- Reservoir hosts: a living organism on or in which a parasite lives.
- Temperate regions: having a moderate climate which especially lacks extremes in temperature.
- Viremic: the presence of viruses in the blood.
- Zoonotic: an infection or disease that is transmissible from animals to humans under natural conditions.