Impacts of Climate Change on Pennsylvania Vectors

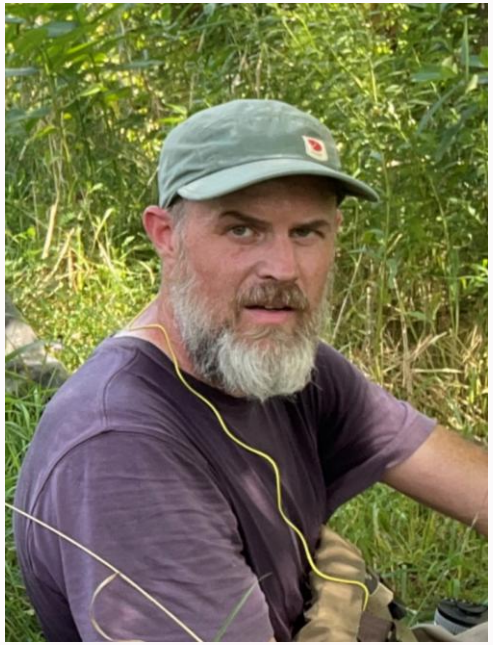
Vector Management

6/26/2025

Pennsylvania
Department of
Environmental Protection

Acknowledgements

Bryan Diehl
Mosquito-borne Disease Control Program



Dave Hurley
Mosquito-borne Disease Control Program

Jenna Noble
Tick Surveillance and Testing Program

John Lowin
Black Fly Suppression Program

Pennsylvania
Department of
Environmental Protection

Overview

- Which insects of public health importance are found in Pennsylvania are of concern?
- How is climate change affecting these?
- How does the changing climate affect Vector Management programs?

Pennsylvania
Department of
Environmental Protection

Pennsylvania's Vectors

Mosquito-borne Disease Program

Mosquitoes can spread diseases like West Nile Virus, Jamestown Canyon Virus, and Eastern Equine Encephalitis in Pennsylvania.

Tick Surveillance and Testing Program

Ticks can spread diseases like Lyme Disease, Anaplasmosis, and Babesiosis in Pennsylvania.

Black Fly Suppression Program

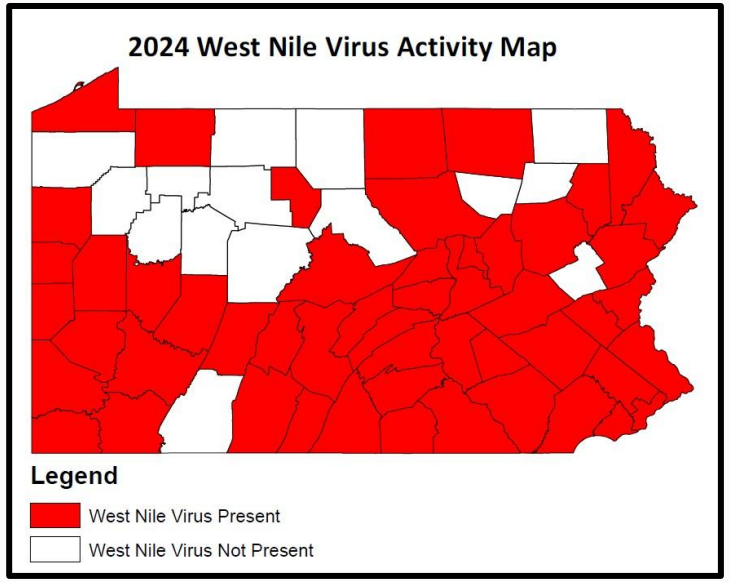
Black flies do not spread disease in Pennsylvania. However, they are a biting insect and can transmit disease elsewhere.

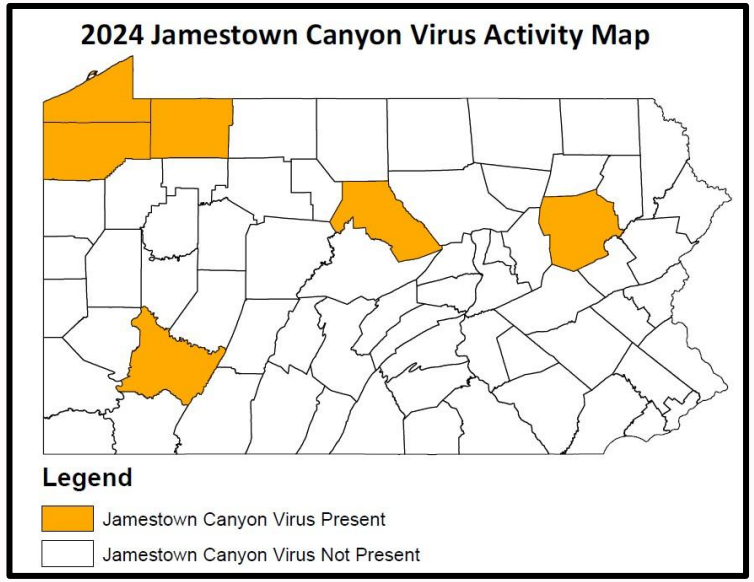
Climate Change in PA: Mosquitoes

Pennsylvania
Department of
Environmental Protection

Mosquito-borne Disease Program Background

- DEP offers financial, technical, and laboratory support for county partners to detect, test, and offer control services.
- These services are critically important to protect Pennsylvanians against existing and imported vector-borne diseases that are constantly evolving due to climate change and globalization.

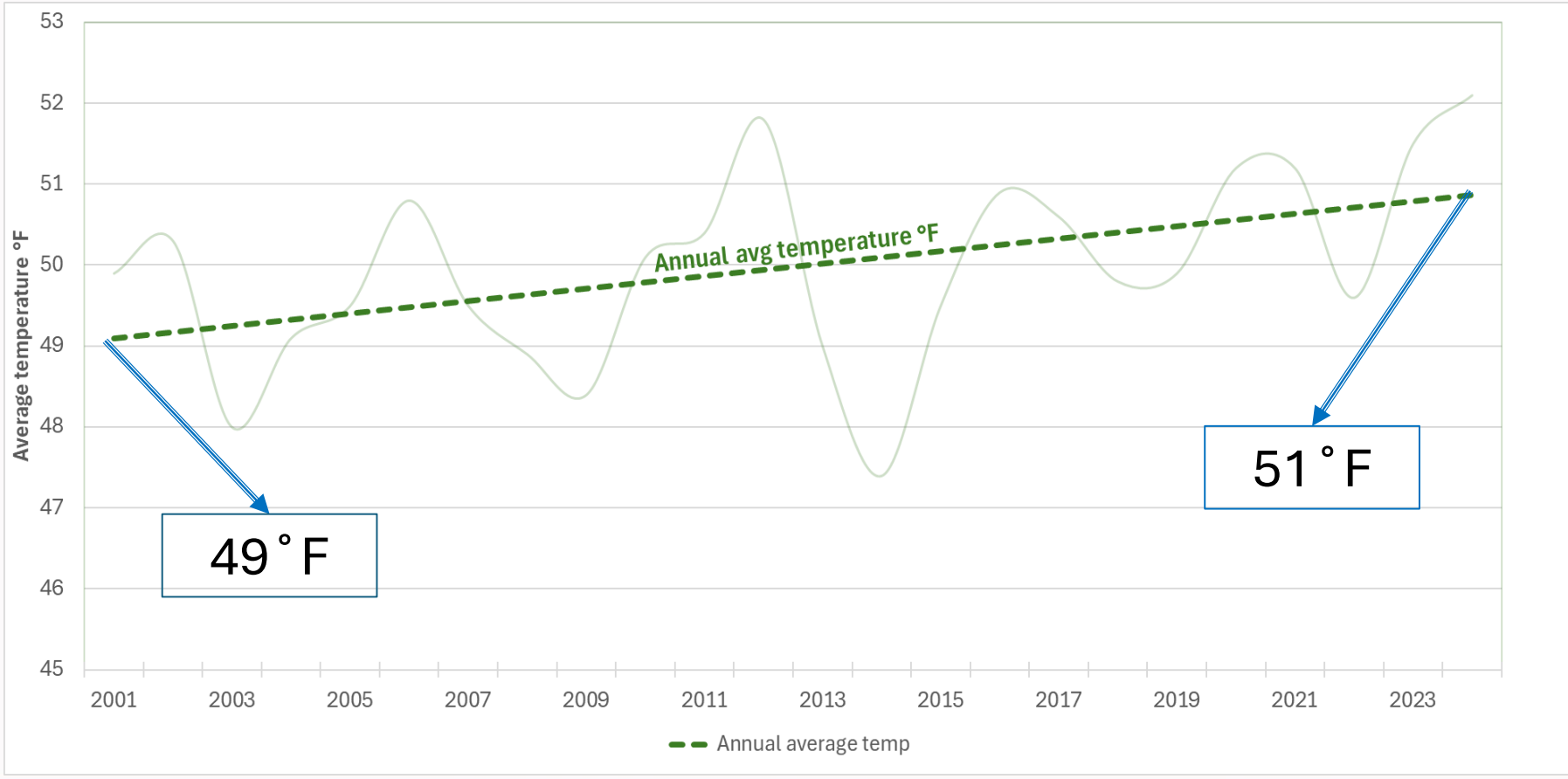




Pennsylvania Department of Environmental Protection

PA Statewide Avg Temp: 2001-2024

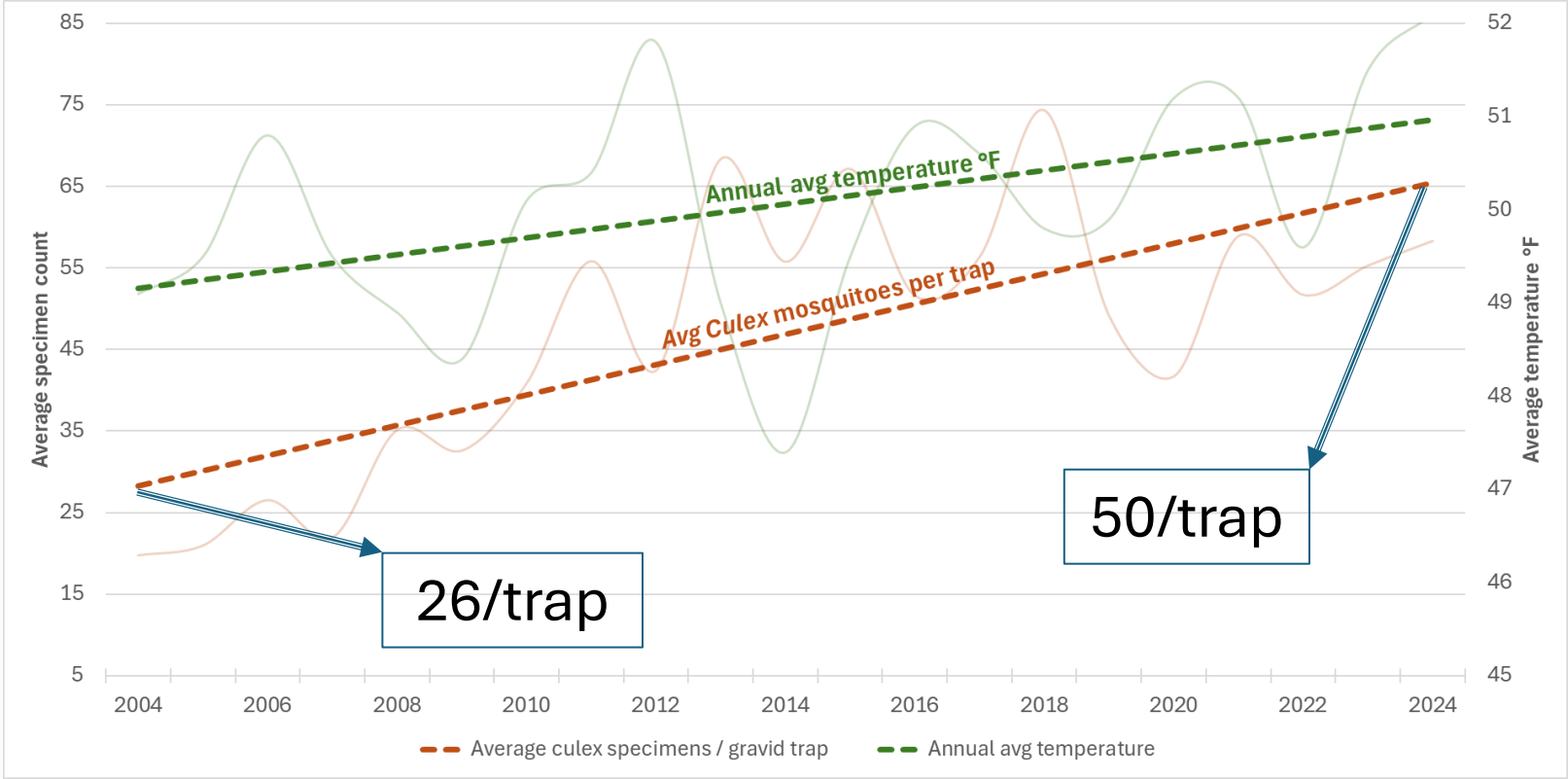
- Average, annual temperature has trended ~2˚F warmer since 2001
- Official NOAA data



Pennsylvania Department of Environmental Protection

Culex per trap with Avg Temp: 2004-2024

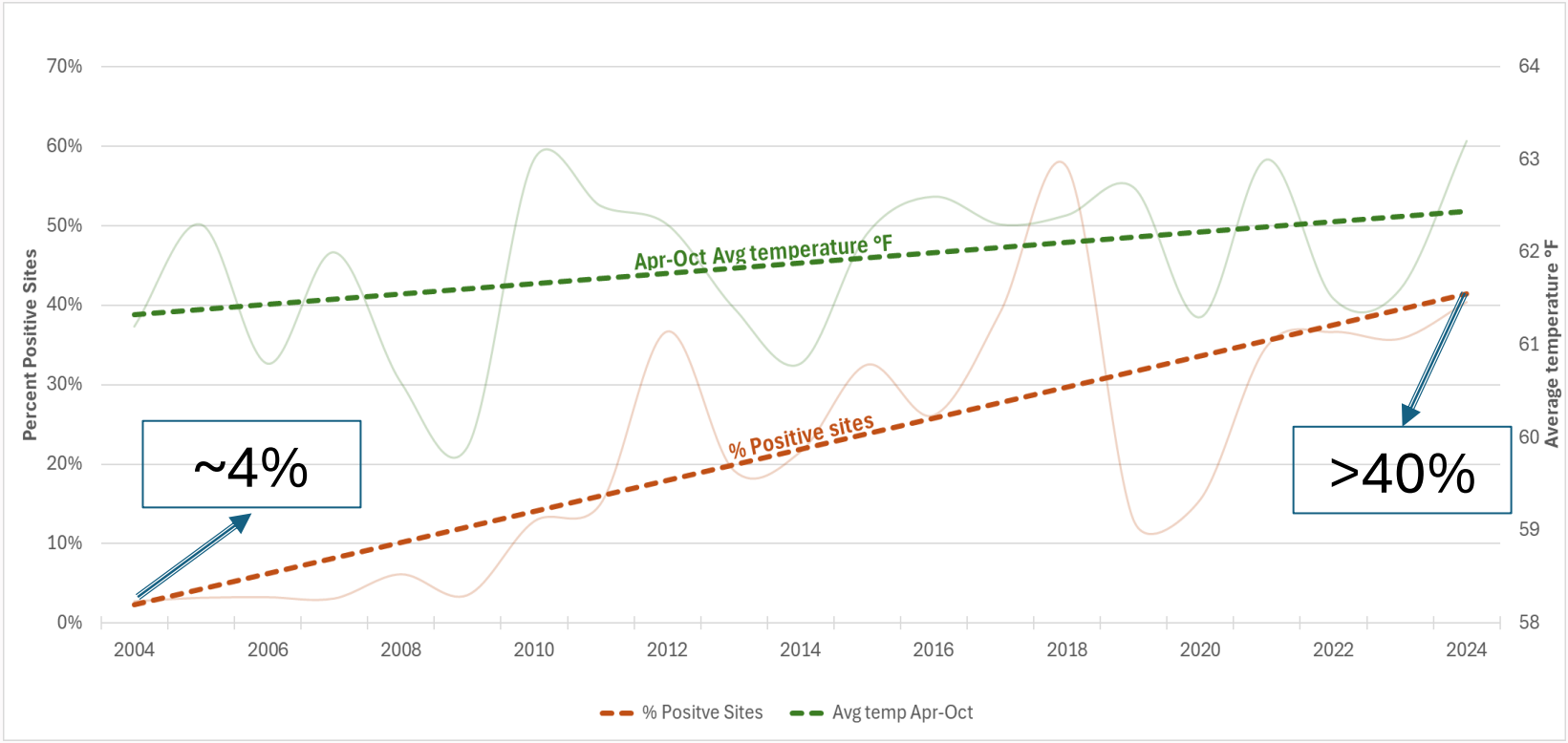
- Average *Culex* collected per trap has nearly doubled over the past 20 years



Pennsylvania Department of Environmental Protection

Viral Activity: WNV+ Sites & Average Temperature (Apr-Oct)

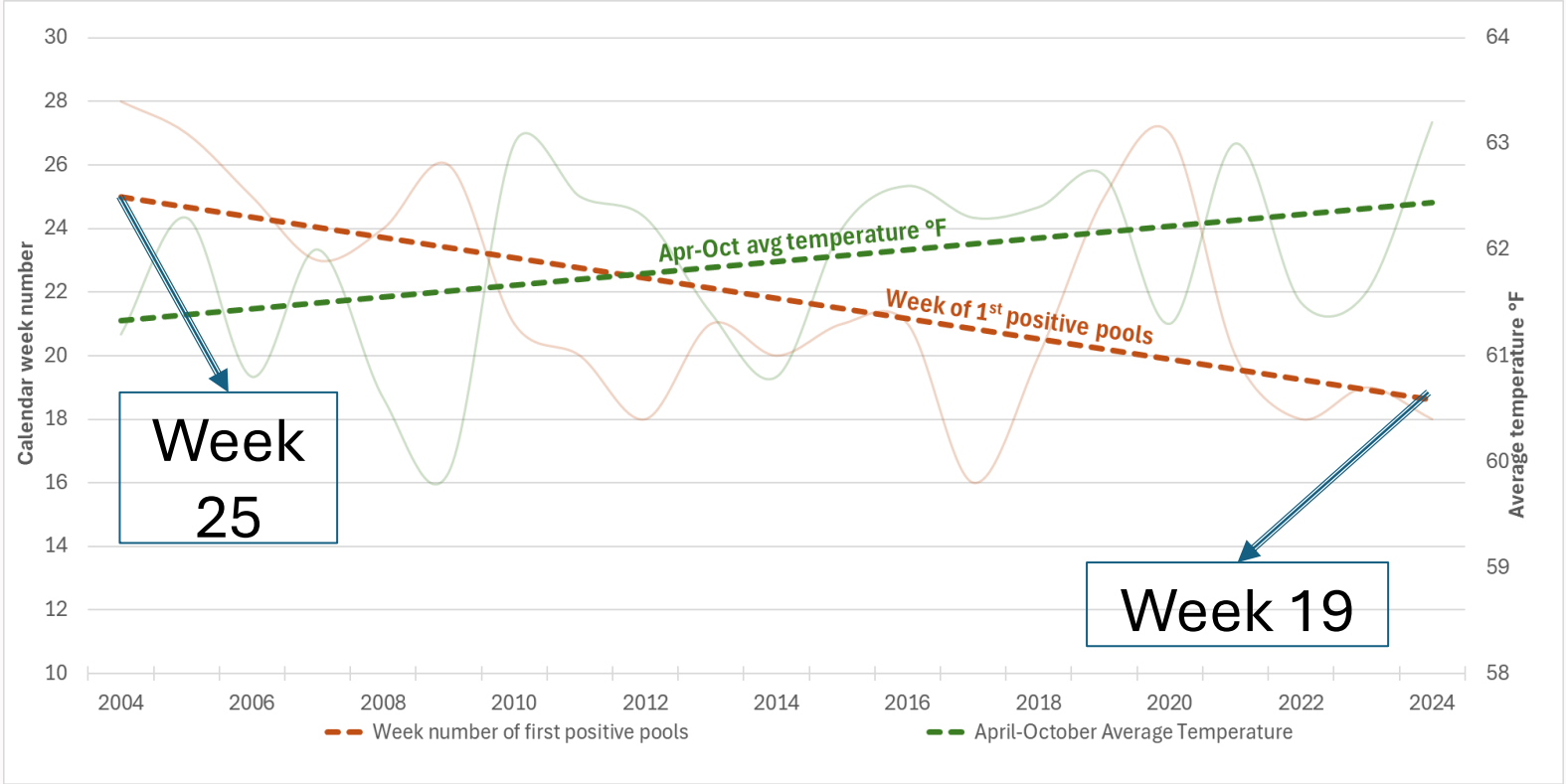
- % of sites testing positive for WNV has increased by ~2% per year since 2004
- WNV is spreading to more areas of PA



Pennsylvania
Department of
Environmental Protection

Week of First WNV Positive Collection

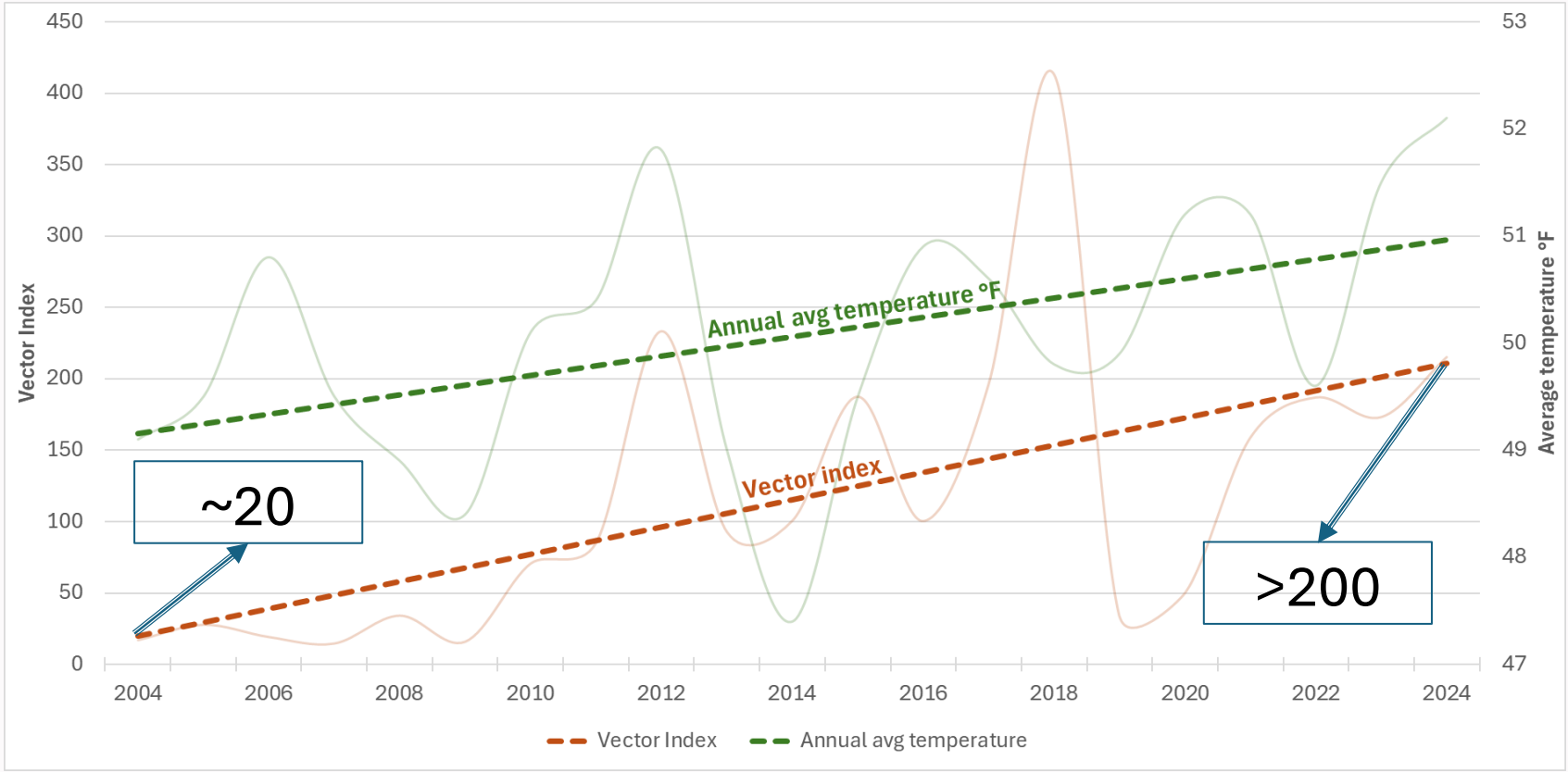
- Since 2004 - 1st annual WNV collection trending earlier by approx. 2 days/year
- Expanding season length and risk of human infection



Pennsylvania
Department of
Environmental Protection

WNV Risk: Vector Index & Temp (2004-2024)

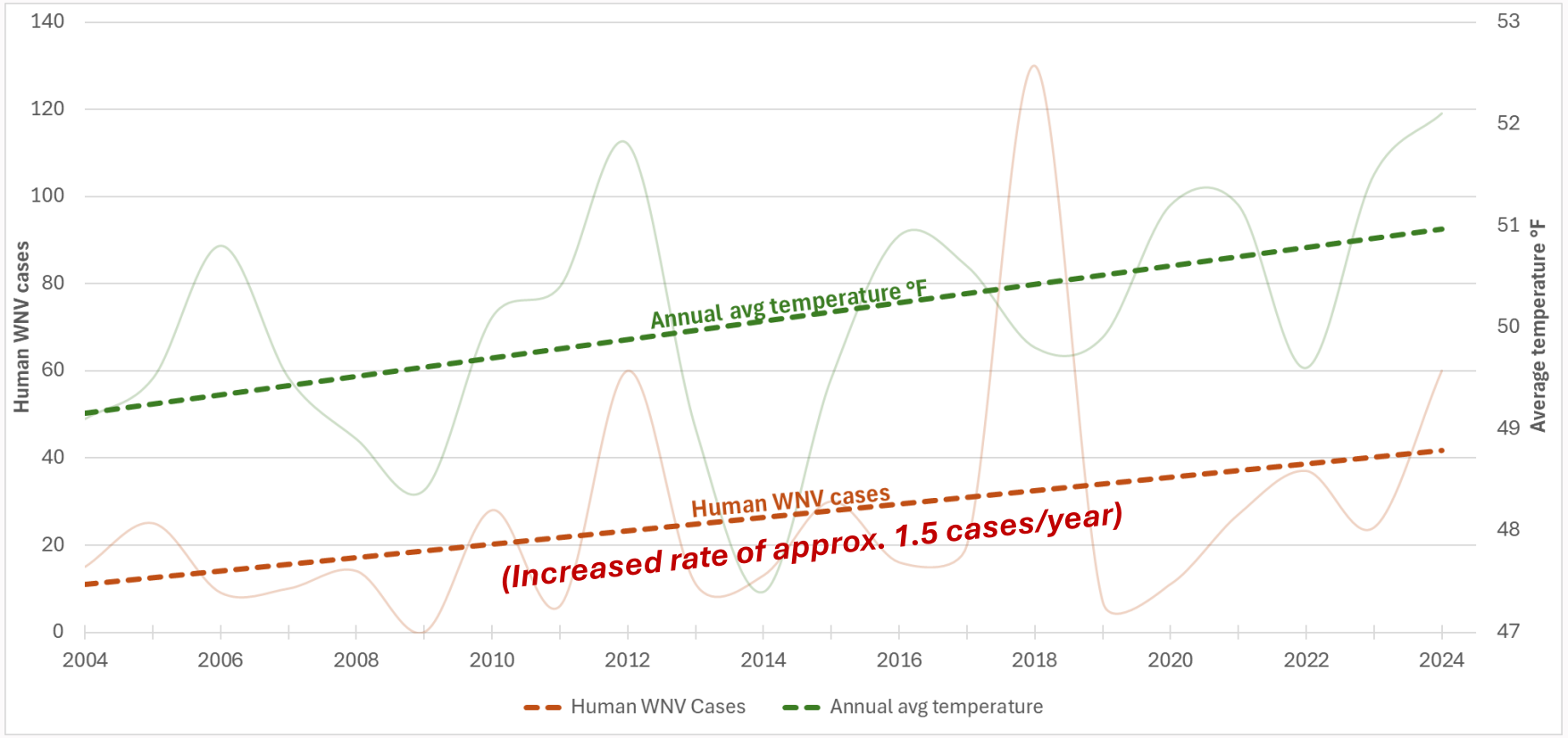
- Vector Index (VI) estimates disease risk
- WNV risk has increased by nearly <u>10 times</u>



Pennsylvania Department of Environmental Protection

Human Cases & Temperature: 2004-2024

- Trending increase of approximately 1.5 more human cases per year since 2004



Pennsylvania Department of Environmental Protection

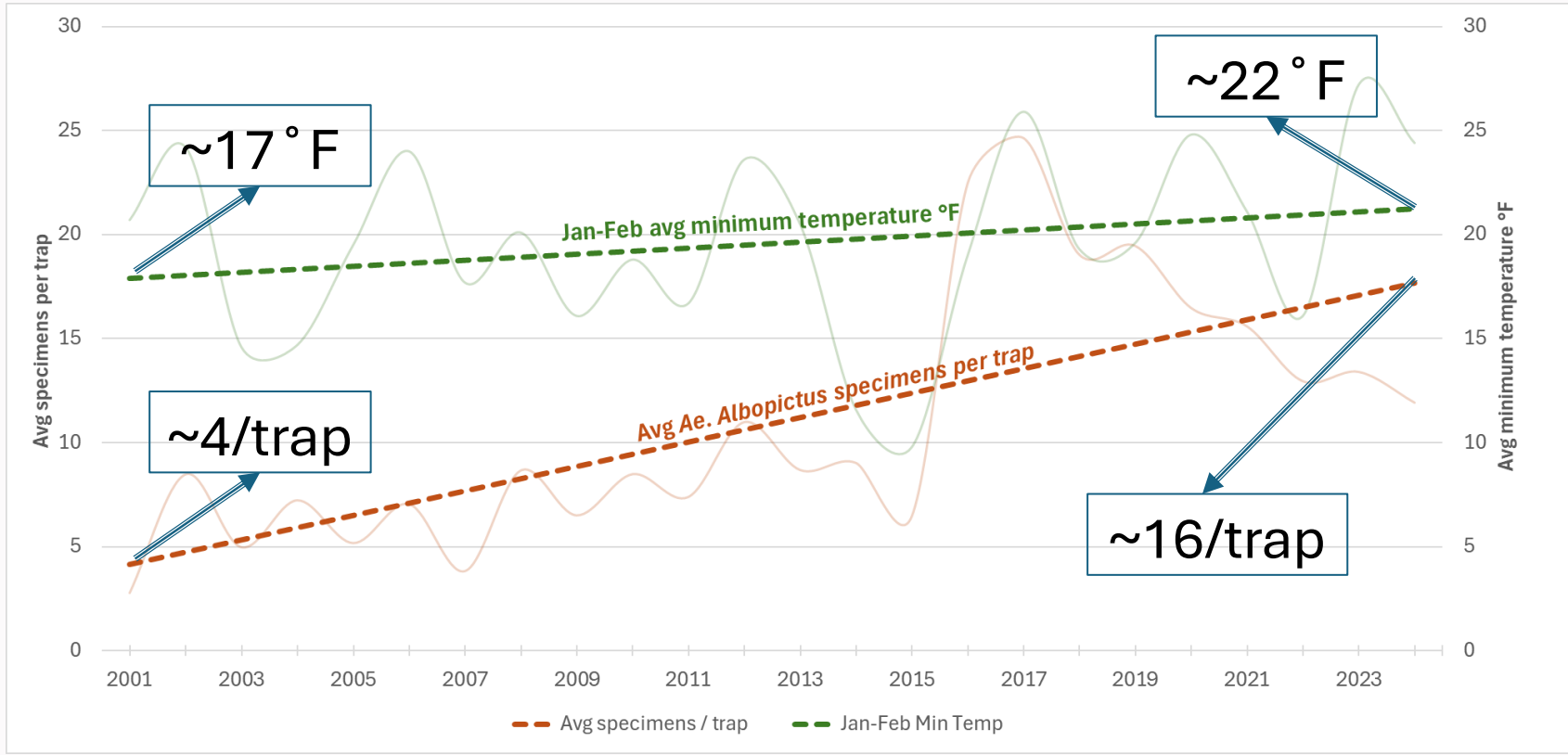
Concluding points – *Culex* & temperature:

- Since 2001, the average, annual temperature in PA has trended warmer by ~2˚F.
  - Warmer temperatures favor mosquito reproduction and activity.
  - *Culex* are bird feeders, and WNV is primarily a bird disease.
  - Culex mosquitoes are responsible for transmitting WNV in Pennsylvania
- *Culex* collected per trap has nearly doubled since 2004.
- 10x increase in WNV Risk (Vector Index) since 2004
- WNV is spreading to more areas of the state.
- WNV is being detected 6 weeks earlier than in 2004 – expanding the season.
- As the temperature increases, more people are becoming infected with WNV annually at an increase of 1.5 cases/yr

Pennsylvania Department of Environmental Protection

Aedes albopictus Collections & Winter Temps: 2001-2024

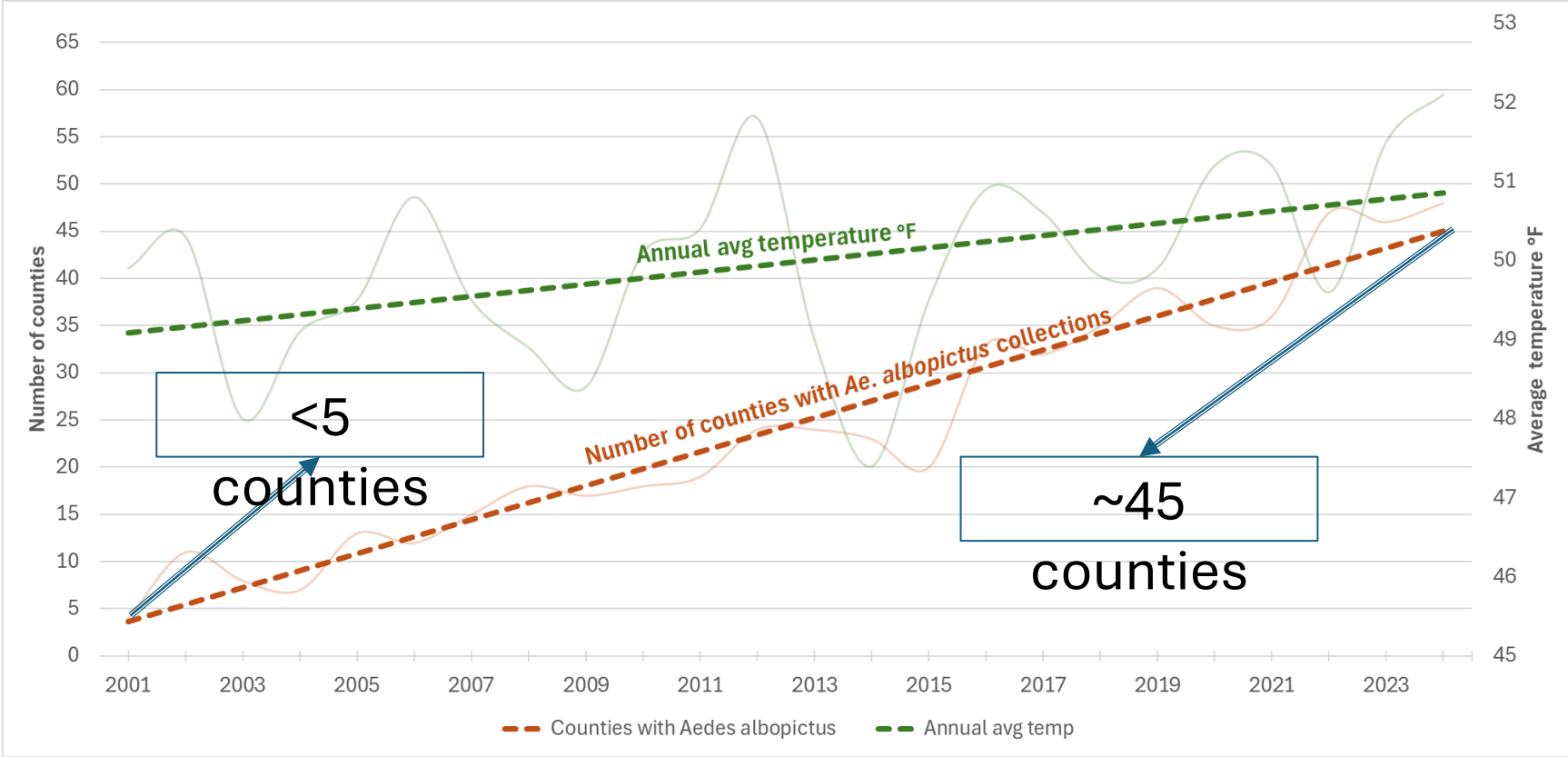
- *Ae. albopictus* (Tiger Mosquito)
- Primarily nuisance in PA, but major disease vector worldwide
- Minimum, average Jan-Feb temps increased by ~5˚F since 2001
- Average *Ae. albopictus* collections up ~4x since 2001



Pennsylvania Department of Environmental Protection

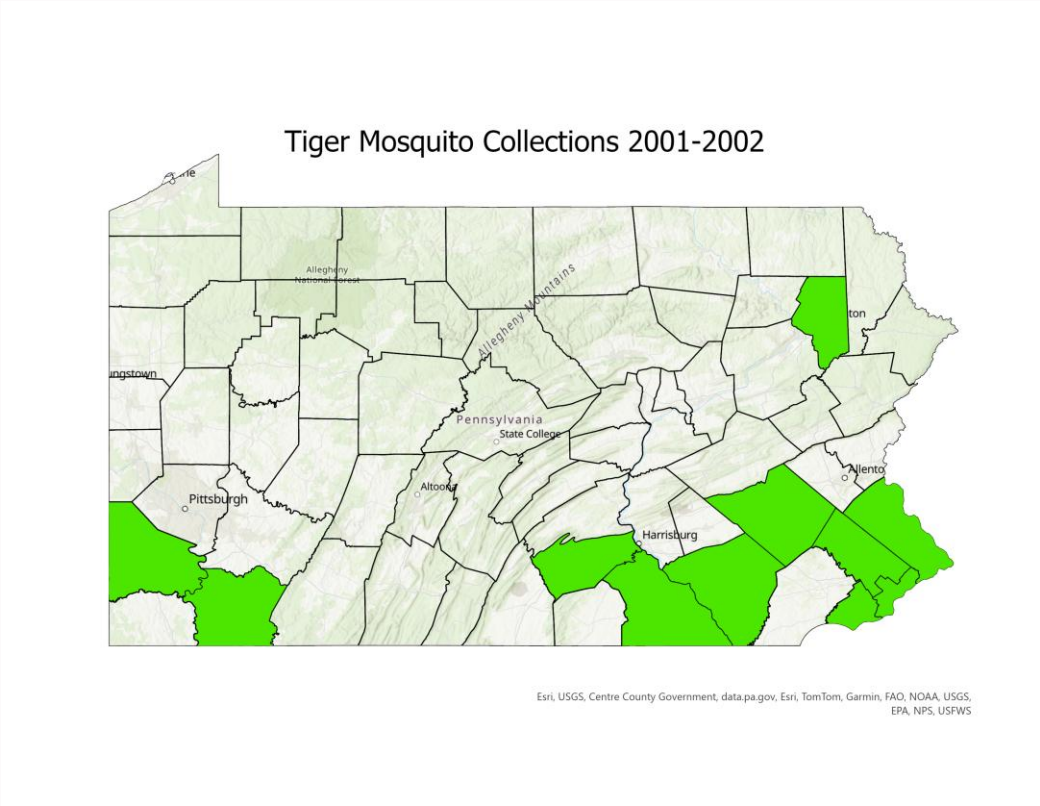
Counties with *Aedes albopictus* Collections - Annually

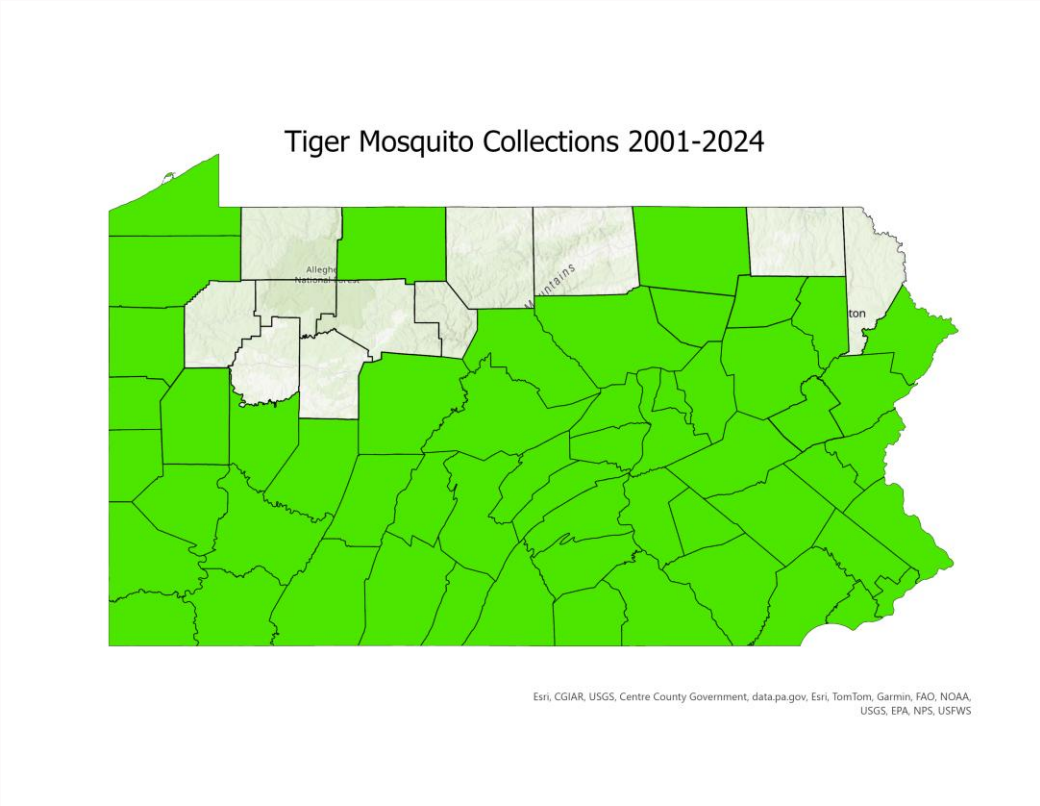
- Since 2001, the average number of counties, annually, with *Ae. albopictus* collections has increased from 5 to 45.



Pennsylvania
Department of
Environmental Protection

Counties with *Aedes albopictus* Collections





Pennsylvania
Department of
Environmental Protection

Concluding points – *Aedes albopictus* & temperature:

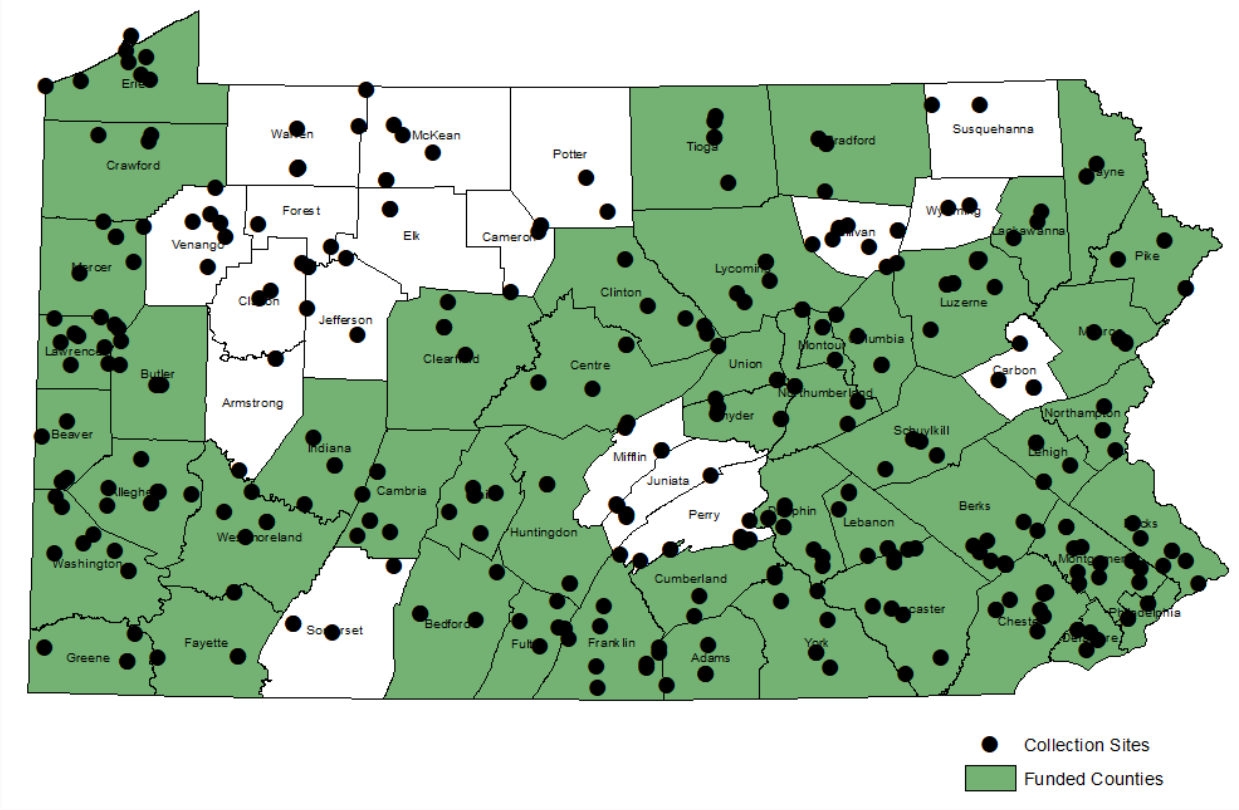
- *Ae. albopictus* eggs lay dormant in the winter/emerge in spring
  - Cold weather increases egg mortality.
  - January-February average temps are 5˚F warmer than 2001.
  - Warmer temperatures favor mosquito reproduction and activity.
- Trap collection averages are 4x higher than in 2001.
- Spreading range across the state: 45 counties now vs. 5 counties in 2001
- Primarily nuisance in PA, but major disease vector worldwide

Potential Impacts of Climate Change on Ticks and Tick-borne Diseases

Pennsylvania
Department of
Environmental Protection

Tick Program Background

- Our program conducts statewide surveillance in all 67 counties.
- Focus is primarily on the collection and testing of the Blacklegged tick and its primary associated pathogens because of its public health significance.



Pennsylvania Department of Environmental Protection

Increase, Expansion, and Efficiency

Population increase

- Tick development and reproduction times could be faster
- More surviving to adulthood and reproducing

Phenology expansion

- Emerge earlier and stay active longer in the year, with more overlap of life stages
  - Pathogens could increasingly be transmitted between ticks via cofeeding transmission

Life stages left to right: female, male, nymph, larva. Photo by Ben Paul, DEP (2024).

The Blacklegged tick (above) is responsible for causing most human illness in Pennsylvania.

Pennsylvania Department of Environmental Protection

Increase, Expansion, and Efficiency

Range expansion

- Range expansions both upwards (altitude) and outwards (latitude)

Pathogen efficiency

- Replication rates could increase
- Transmission times could decrease
- Possibly lead to disease incidence increase

Scanning electron microscope (SEM) image of *B. burgdorferi*, the Lyme Disease causing bacteria. Photo courtesy of the CDC, Jamice Haney Carr (2011).

Pennsylvania Department of Environmental Protection

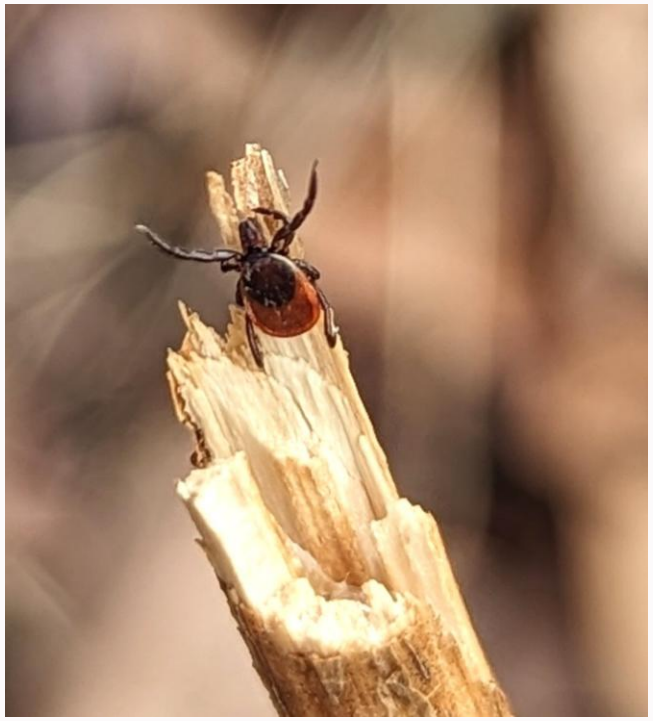
Increase, Expansion, and Efficiency

Questing efficiency

- Proportion of each day and year spent questing could increase
  - Increases chance of successful host acquisition
- Possibly lead to disease incidence increase

Human Behavior

- Outdoor recreation could increase due to warmer weather and coincide with increased tick activity
- Possibly lead to disease incidence increase



Questing female Blacklegged tick. Photo by Jenna Noble, DEP (2023)

Pennsylvania
Department of
Environmental Protection

Pennsylvania is home to more than the Blacklegged tick

- Many species of ticks are collected in Pennsylvania annually
- Each species presents with its own challenges
  - Habitat, life cycle, host preferences
  - Potential to spread different diseases

Pennsylvania
Department of
Environmental Protection

Lone Star Tick

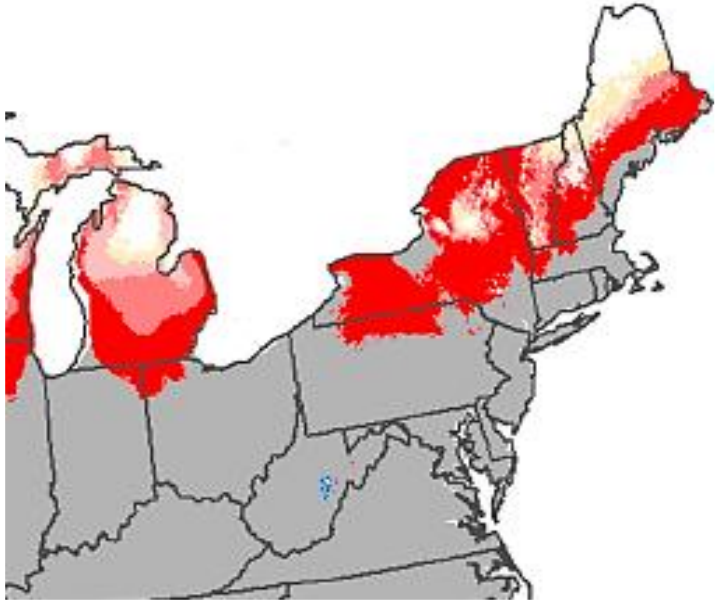
- *Amblyomma americanum*
- Possibility for expansion and establishment throughout the state
- Implicated as the primary cause of Alpha-gal syndrome. They are also competent vectors of a bacteria that causes ehrlichiosis in humans.
- Chance of increased incidence risk

Questing female Lone Star tick. Photo by Christian Boyer, DEP (2024)

Pennsylvania
Department of
Environmental Protection

Lone Star Tick

DEP Historical Collections



Model Projection

Range - Expansion •

Range - Current •

Pennsylvania
Department of
Environmental Protection

Gulf Coast Tick

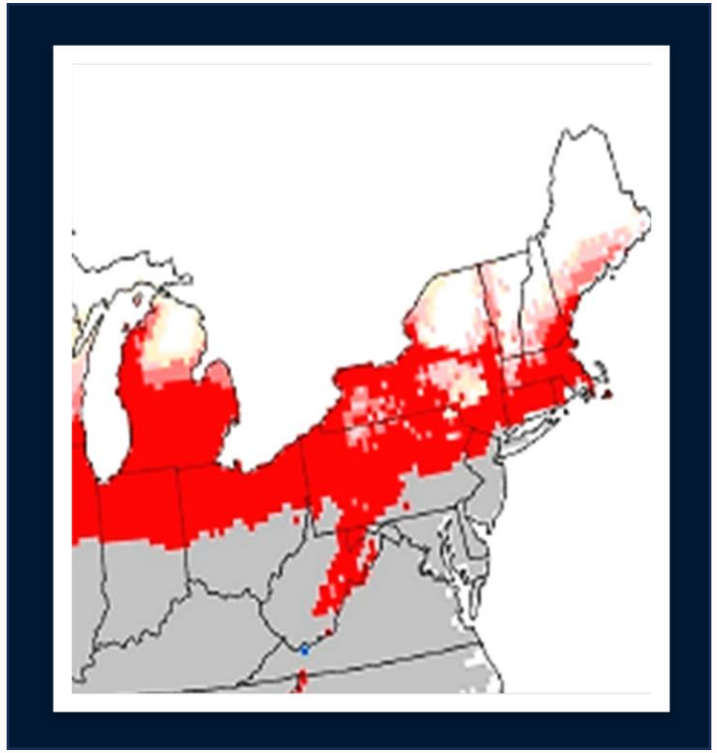
- *Amblyomma maculatum*
- Expansion and establishment throughout the state is possible
- Competent vector of a bacteria that causes spotted fever rickettsiosis in people
  - Gulf Coast ticks collected by DEP staff were sent to CDC for testing of *Rickettsia parkeri* in 2022
    - These results showed a 55% infection rate, which is the highest in the country
- Chance of increased incidence risk

Questing female Gulf Coast tick.
Photo by Christian Boyer, DEP (2024)

Pennsylvania
Department of
Environmental Protection

Gulf Coast Tick

DEP Historical Collections



Model Projection

Range - Expansion •

Range - Current •

Pennsylvania
Department of
Environmental Protection

Concluding Points

- As other tick species become increasingly prevalent and of concern, the program will need to invest more attention as a burden of disease to Pennsylvanians.
- The program enables the documentation of abundance and distribution changes in real time as we experience the effects of a shifting climate.
- We will experience novel challenges from the shifts in temperature and weather patterns that could alter program operations and protocols.

Impacts of Climate Change on Black Flies

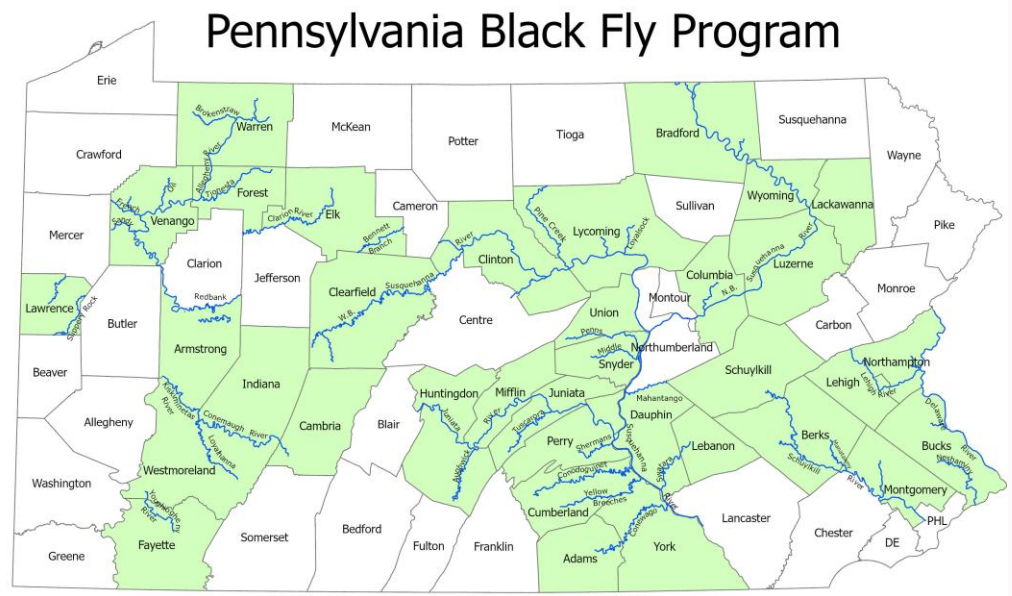
Pennsylvania
Department of
Environmental Protection

Background Info on Black Flies

- Commonly referred to as “Gnats”
- Larvae require fast flowing water where they filter feed until they develop into adults.
- Adult Females require a blood meal to reproduce and will seek out a host to feed on dependent on species.
- Adults can fly up to 20 miles from where they hatch to find a host and can become a major pest to livestock and people.

Pennsylvania
Department of
Environmental Protection

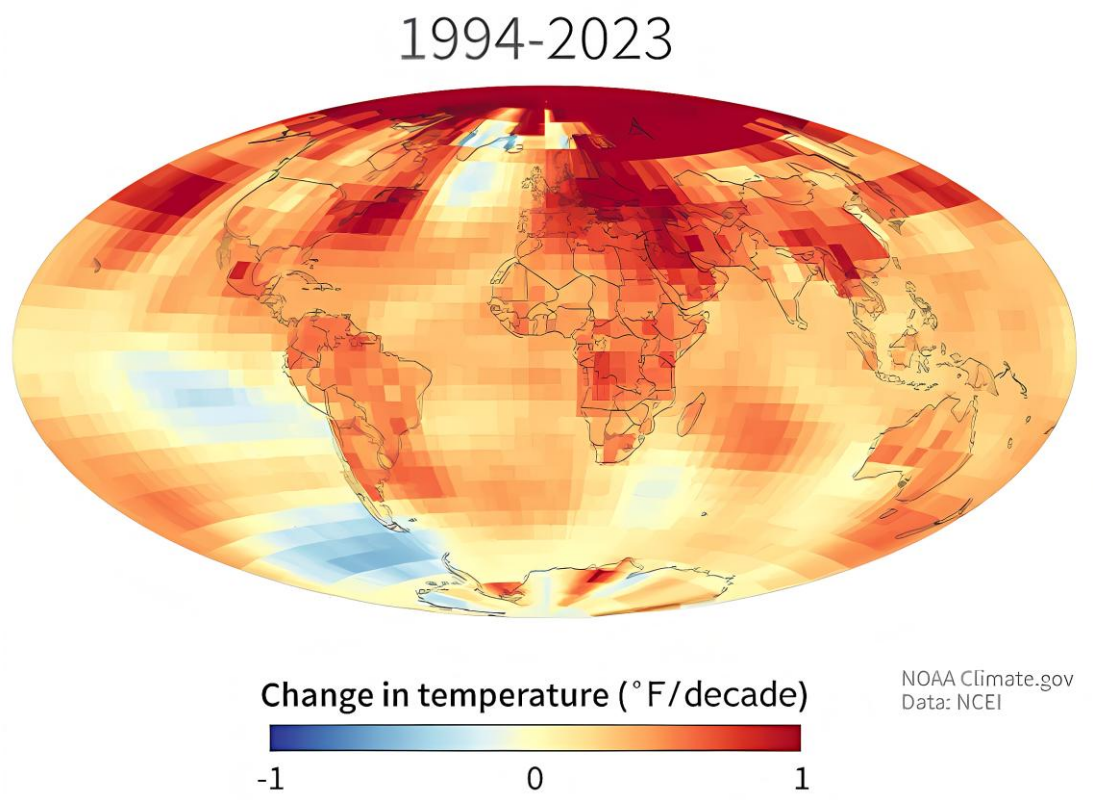
Black Fly Suppression Program



- **Goal:** To reduce nuisance black fly populations to tolerable levels during the spring & summer recreational season using environmentally compatible methods.
- Valuable program for outdoor recreation in PA
- Operating in 35 counties across 1800 miles of waterways in the state.
- Been in operation 40+ years using a biological larvicide sprayed via helicopter in flowing waterways, *Bacillus thuringiensis israelensis* (BTI). Nontoxic to other organisms
- Program targets human pest species in PA, *Simulium jenningsi*.
- Nuisance in biting behavior and allergic reaction in some people.

Pennsylvania
Department of
Environmental Protection

Temperature's Effect on Distribution



The projected rise in annual air temperature by 7°F by mid-century is strongly linked to an increase in annual stream water temperatures.

- Maximum water temperature during the warmest month is one of the most important physical factors determining which black fly species live in streams (Kazanci 2006; Cunze et al. 2024).

Lowland species such as *S. jenningsi* have been found to exhibit a higher tolerance for rising temperatures and are expected to adapt well to these changes (Cunze et al. 2024).

Pennsylvania
Department of
Environmental Protection

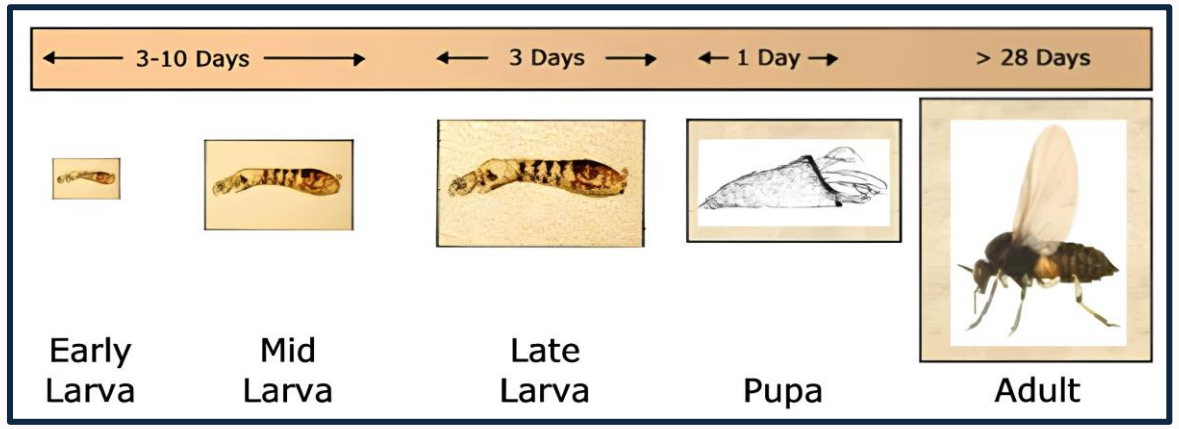
Range Expansion

- *S. jenningsi* populations may increase in streams typically suitable to a variety of black fly species.
- Non-pest black fly species may not be able to tolerate the increasing water temperatures.
- Streams producing larger *S. jenningsi* populations could require increased operations from the black fly program to prevent a significant nuisance to people in the vicinity.

Pennsylvania
Department of
Environmental Protection

Extended Season for Black Fly Control Measures

Black Fly Life Cycle



Black fly species producing multiple generations per year, such as *S. jenningsi*, rely on warm water temperature to stop reproducing in the fall and to start reproducing again in the spring.

- Rising temperatures may extend the season in which adult blackflies reproduce.
- Longer season that pest control operations are required.

Pennsylvania
Department of
Environmental Protection

More Generations per Year

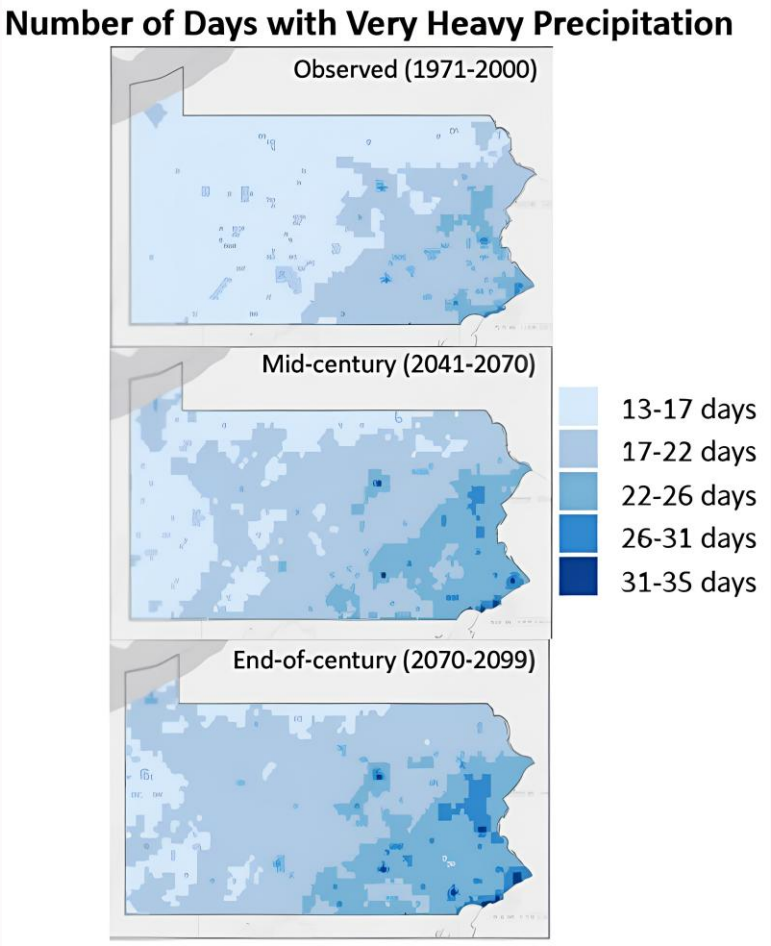
Higher annual temperatures allow insects to produce more generations per year (Bale et al. 2002; Skendzic et al. 2021; Cunze et al. 2024).

The time it takes for a black fly to complete its life cycle is less at higher temperatures and more at lower temperatures (Bernotienė and Bartkevičienė 2013)

- Pennsylvania's nuisance black fly species may complete their life cycles more quickly.
- Less time between life cycles may require a shorter frequency between larvicide applications.
- Increased cost to the Pennsylvania citizens

Pennsylvania
Department of
Environmental Protection

Heavy Rainfall Events Complicating Treatments



Application of material is a flow-based calculation. Concentration is based on flow.

- Increased flows will result in more application of material at a higher cost.
- Muddy water limits effectiveness of BTI (Iburg et al. 2011).

More days of heavy rain are predicted with climate change. This will limit feasibility of conducting spray operations.

- Increased number of adult black flies from missed treatments.
- Exponential increase in black flies if several control operations are postponed from heavy rains.

Pennsylvania
Department of
Environmental Protection

Concluding Points

- **Warming temperatures and more rainfall will lead to:**
  - Range Expansion – non-native species
  - Longer active season (start earlier and stay later)
  - Faster completion of life cycles resulting in more generations/year
  - Increased chance of encountering biting insects while enjoying the outdoors increasing disease burden
  - Increased financial burden of Pennsylvanians to combat these bugs

Pennsylvania
Department of
Environmental Protection

Get In Touch

Doug Orr

Office of Program Integration/Vector Management

2575 Interstate Drive

Harrisburg, PA 17110

…

(717)497-4606 / doorr@pa.gov

The Department of Environmental Protection's mission is to protect Pennsylvania's air, land and water resources and to provide for the health and safety of its residents and visitors, consistent with the rights and duties established under the Environmental Rights Amendment (Article 1, Section 27 of the Pennsylvania Constitution).

Pennsylvania
Department of
Environmental Protection

References

Alkishe A., Raghavan R.K., and Peterson A.T. Likely Geographic Distributional Shifts among Medically Important Tick Species and Tick-Associated Diseases under Climate Change in North America: A Review. *Insects* (**2021**) 12, 225.

Daniel M., Danielova V., KrizB., and Kott I. An attempt to elucidate the increased incidence of tick-borne encephalitis and its spread to higher altitudes in the Czech Republic. *Int. J. Med. Microbiol. Suppl*. (**2003**) 293:37, 55-62.

Dantas-Torres F. Climate change, biodiversity, ticks and tick-borne diseases: The butterfly effect. *Int. J. Parasitol.* (**2015**) 452-461.

Estrada-Pena A., Gray J.S., Kahl O., Lane R.S., and Nijhof A.M. Research on the ecology of ticks and tick-borne pathogens-methodological principles and caveats. *Front.Cell.Infect.Microbiol.* (**2013**) 3:29.

Gilbert L. The Impacts of Climate Change on Ticks and Tick-Borne Disease Risk. *Annu. Rev. Entomol.* (**2021**) 66:373-388.

Gilbert L. Altitudinal patterns of tick and host abundance: a potential role for climate change in regulating tick-borne diseases? *Oecologia* (**2010**) 162(1):217-225.

Levi T.F., Keesing F., Oggenfuss F., and Ostfeld R.S. Accelerated phenology of blacklegged ticks under climate warming. *Phil. Trans.Royal. Soc. B.* (**2015**) 370:20130556.

Lindgren E., Telleklint L., and Polfeldt T. Impact of climate change on the northern latitude limit and population density of the disease-transmitting European tick *Ixodes ricinus*. *Environ. Health Perspect*. (**2000**) 108(2):119-123.

MacDonald A.J., McComb S., O'Neill C., Padgett K.A., and Larsen A.E. Projected climate and land use change alter western blacklegged tick phenology, seasonal host-seeking suitability and human encounter risk in California. *Global Change Biol*. (**2020**) 26:5459-5474.

Pennsylvania
Department of
Environmental Protection

References

Monaghan A.J., Moore S.M., Sampson K.M., Beard C.B., and Eisen R.J. Climate change influences on the annual onset of Lyme disease in the United States. *Ticks Tick. Borne. Dis.* (2015) 6:615-622.

Ochanda H., Young A., and Mutugi J. The effect of temperature on the rate of transmission of *Theileria parva* infection to cattle by its tick vector, *Rhipicephalus appendiculatus*. *Parasitology* (1988) 97:239–245.

Ogden N.H., Bigras-Poulin M., O'Callaghan C.J., Barker I.K., Lindsay L.R., Maarouf A., Smoer-Tomic K.E., Waltner-Toews D., Charron D. *Int. J. Parasitol*. (2005) 1:35(4):375-389.

Ogden N.H. and Lindsay L.R. Effects of climate and climate change on vectors and vector-borne diseases: ticks are different. *Trends Parasitol*. (2016) 32:646-656.

Ogden N.H., Beard C.B., Ginsberg H.S., and Tsao J.I. Posible Effects of Climate Change on Ixodid Ticks and the Pathogens They Transmit: Predictions and Observations. *J. Med. Entomol*. (2021) 58(4) 1536-1545.

Ostfeld R.S. and Brunner J.L. Climate change and Ixodes tick-borne diseases of humans. *Philos. Trans.R. Soc. Lond. B Biol. Sci*. (2015) 370, 20140051.

Nuttall P.A. Climate change impacts on ticks and tick-borne infections. *Biologia* (2022) 77:1503-1512.

Raghavan R.K., Peterson A.T., Cobos M.E., Ganta R., Foley D. Current and Future Distribuion of the Lone Star Tick, Amblyomma americanum (L.) (Acari: Ixodidae) in North America. *PLoS ONE* (2019) 14(1):e0209082.

Wu X.T., Duvvuri V.R., Lou Y.J., Ogden N.H., Pelcat Y., and Wu J.H.Developing a temperature-driven map of the basic reproductive number of the emerging tick vector of Lyme disease Ixodes scapularis in Canada. *J Theor. Biol*. (2013) 319, 50-61.

Pennsylvania Department of Environmental Protection

References

Bale, J. S., Masters, G. J., Hodkinson, I. D., Awmack, C., Bezemer, T. M., Brown, V. K., ... & Whittaker, J. B. (2002). Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. *Global change biology*, *8*(1), 1-16.

Bernotiene, R., & Bartkeviciene, G. (2013). The relationship between water temperature and the development cycle beginning and duration in three black fly species. *Journal of Insect Science*, *13*(1), 1–15. https://doi.org/10.1673/031.013.0101

Cunze, S., Jourdan, J., & Klimpel, S. (2024). Ecologically and medically important black flies of the genus *Simulium*: Identification of biogeographical groups according to similar larval niches. *Science of The Total Environment*, *917*, 170454. https://doi.org/10.1016/j.scitotenv.2024.170454

Iburg, J. P., Gray, E. W., Wyatt, R. D., Cox, J. E., Fusco, R. A., & Noblet, R. (2011). The effect of seston on mortality of *Simulium vittatum* (Diptera: Simuliidae) from insecticidal proteins produced by *Bacillus thuringiensis* subsp*. israelensis*. *Environmental entomology*, *40*(6), 1417-1426.

Kazanci, NİLGÜN. (2006). Ordination of Simuliidae and climate change impact. *Acta entomologica serbica Suplement*, 69-76.

Skendžić, S., Zovko, M., Živković, I. P., Lešić, V., & Lemić, D. (2021). The impact of climate change on agricultural insect pests. *Insects*, *12*(5), 440. https://doi.org/10.3390/insects12050440

Climate Change in Pennsylvania - Impacts and Solutions for the Keystone State. *UCS drought image*

Climate Change: Global Temperature | NOAA Climate.gov *Temp change image*

Pennsylvania Climate Impact assessment 2021 for Rainfall events figure