Pennsylvania Forest Health Highlights 2025

Forest Damage Surveys

Forest damages were mapped through aerial detections (Figures 1 and 2) and reported via ground observations. In 2025, 551,775 acres of wooded areas were reported with damages. Of all damage causal agents documented in 2025, anthracnose was the dominant defoliator, causing over 213,000 acres of damage (Figures 3 and 4). The second leading cause of defoliation was beech leaf disease in the eastern area of the state. Also notable were defoliation from spongy moth and fall cankerworm, and flagging from periodical cicada flagging.

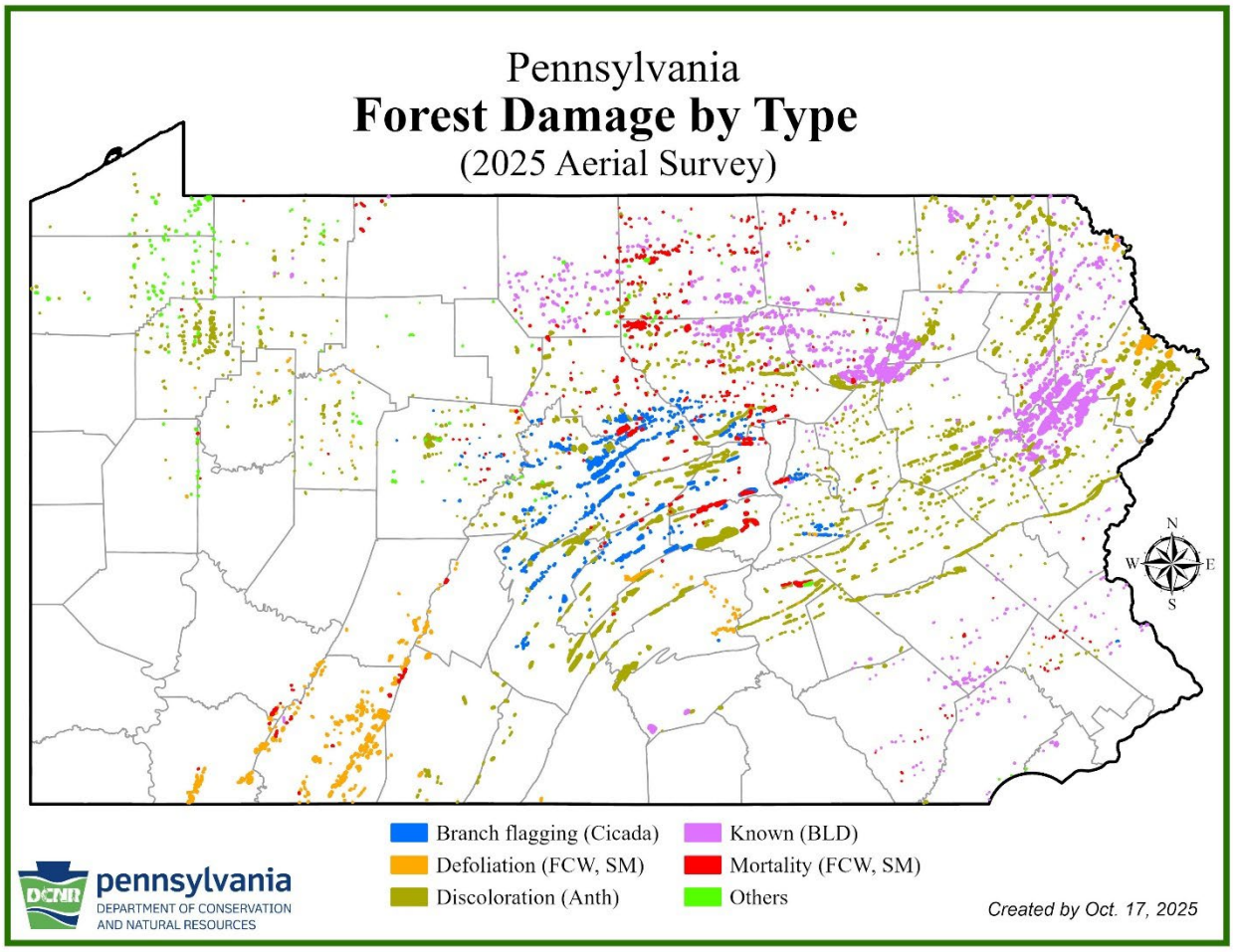


Figure 1. 2025 forest damages mapped through aerial survey.

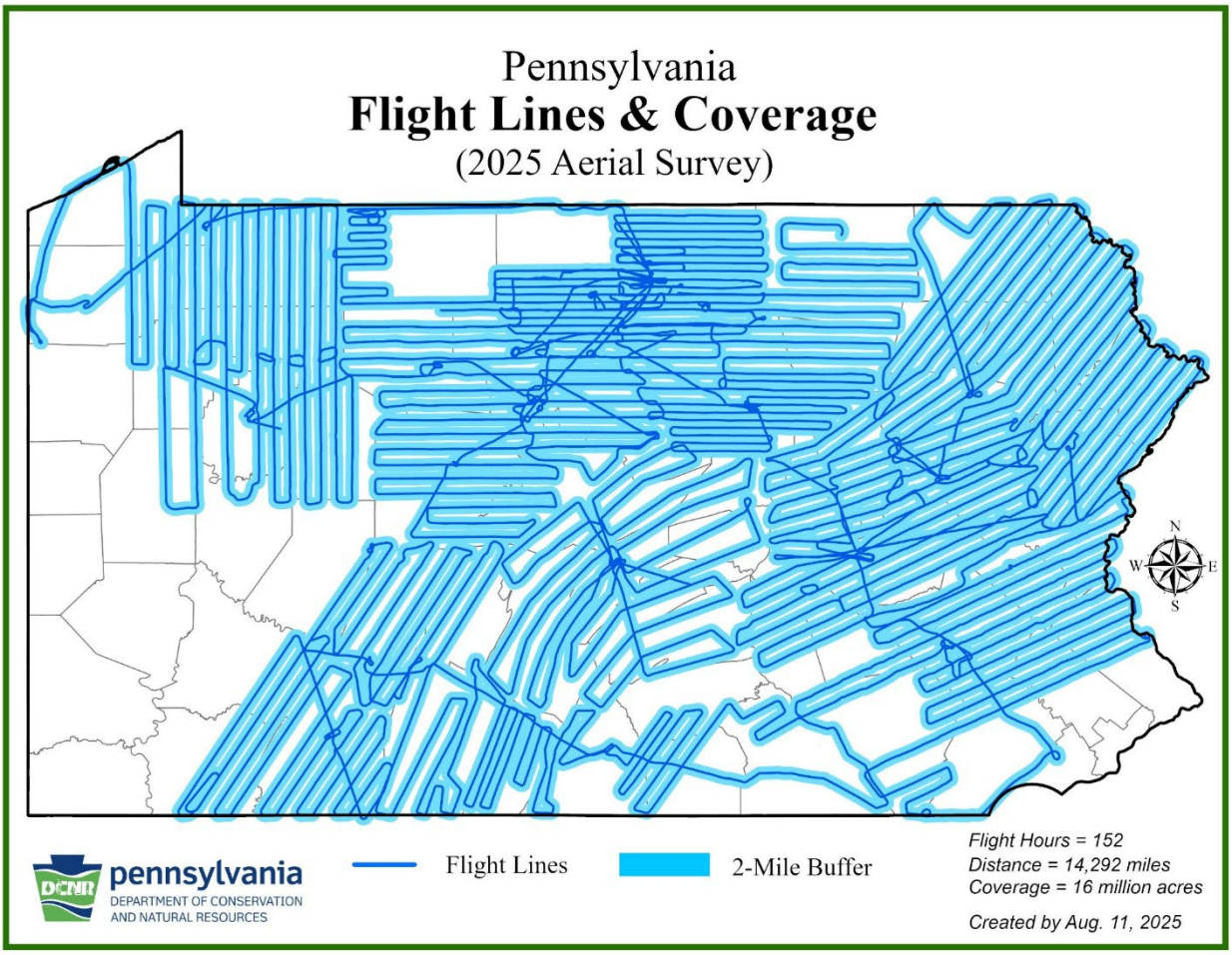


Figure 2. Aerial survey coverage in 2025.

Forest Pest	Acre
Anthracnose	*213,854*
Beech Leaf Disease	*136,062*
Fall Cankerworm	*44,338*
Periodical Cicada	*67,919*
Spongy Moth	*55,286*
Gall Wasps & Others	*34,316*
Total	***551,775***

Figure 3. List of major damage agents and the acreage impacted in 2025.

Gall Wasps & Others	Acre
Abiotic damage	*142*
Beech bark disease complex	*5,611*
Drought	*3,984*
Emerald ash borer	*2,820*
Fire	*2,252*
Flooding-high water	*24*
Frost	*10*
Hemlock woolly adelgid	*4,149*
Locust leafminer	*183*
Logging damage	*203*
Needlecast	*1,317*
Oak gall wasp	*9,404*
Oak shothole leafminer	*162*
Southern pine beetle	*103*
Tuliptree scale	*5*
Unknown	*177*
White pine blister rust	*29*
White pine needle damage	*3,282*
Wind-tornado/hurricane	*459*
Total	***34,316***

Figure 4. Greater detail on 'Other' DCA's from 2025.

Abiotic Conditions

Pennsylvania experienced considerable variation in precipitation during the 2025 growing season. Heavy rainfall in May likely contributed to a decline in spongy moth populations by enhancing the growth and spread of *Entomophaga maimaiga* fungus and the Nucleopolyhedrosis Virus (LdNPV), both major natural mortality agents of the species.

In contrast, the late season (August–September) was marked by a notable precipitation deficit, which placed additional stress on trees already impacted by early-season damages caused by spongy moths, anthracnose, periodical cicadas, and other stressors. (Figure 5).

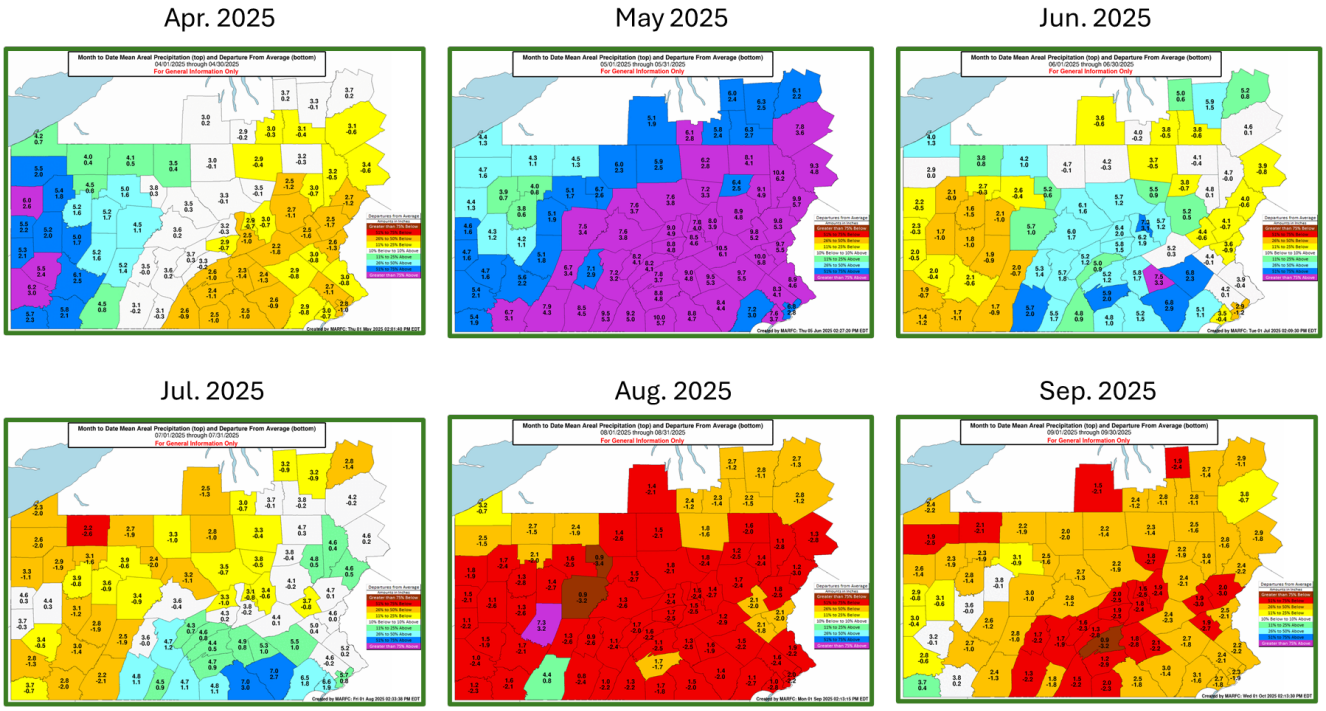


Figure 5. Month to date mean areal precipitation (top) and departure from sverage (bottom, and color symbology)

Hemlock

HWA has been identified in all 67 counties in PA, and annual surveys continue to estimate population levels (Figure 6).

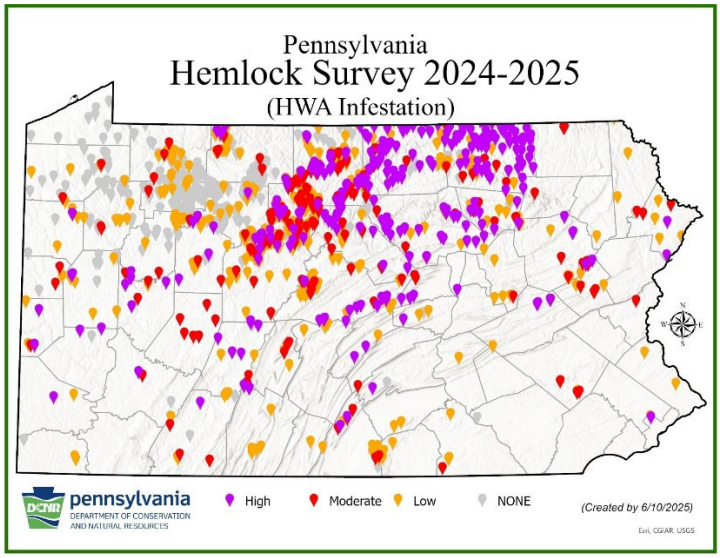


Figure 6. County map of Pennsylvania showing year counties recorded positive for HWA.

The winter of 2024-2025 did include significant killing temperatures. HWA mortality estimates hit 95% or more at many sites (Figure 7). Overall, PA continues to see increased impacts from HWA, especially on marginal sites.

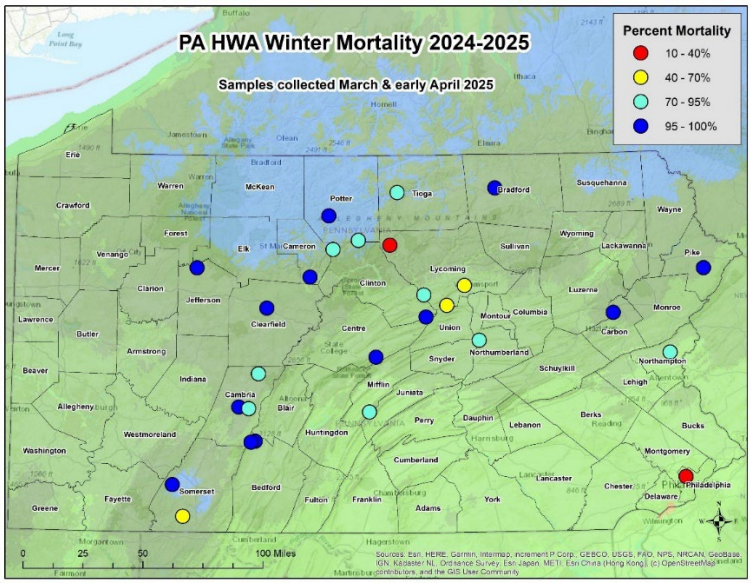


Figure 7. HWA Winter Mortality, 2024-2025.

HWA/elongate hemlock scale (EHS) suppression treatments are completed for 2025 (Figure 8). A total of 306,000" were treated statewide on DCNR lands. 32,767 inches were completed with soil injection of dinotefuran, and 7,500 inches were completed with basal spray of dinotefuran. 213,534 inches were completed with soil injection of imidacloprid, and 3,000 inches of CoreTect. About 100,000 inches of the total were completed through one contract at Cook Forest State Park, protecting one of Pennsylvania's most significant old growth stands on DCNR lands.

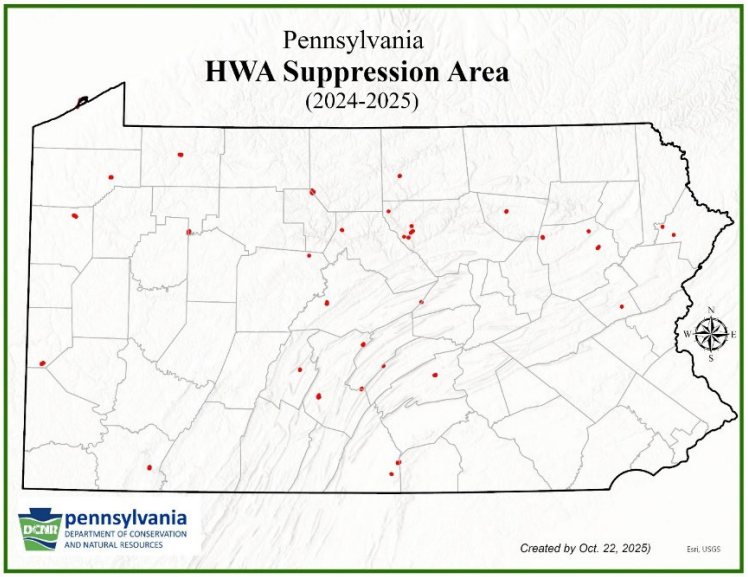


Figure 8. HWA suppression area 2024-2025.

In fall 2024/winter 2025, there were 2,865 Laricobius osakensis (Lo) and 3,239 Laricobius nigrinus (Ln) released at various sites to continue efforts at establishing a biological control program. During 2025, 51 field sites in PA yielded recoveries of 443 Laricobius adults (Figure 9).

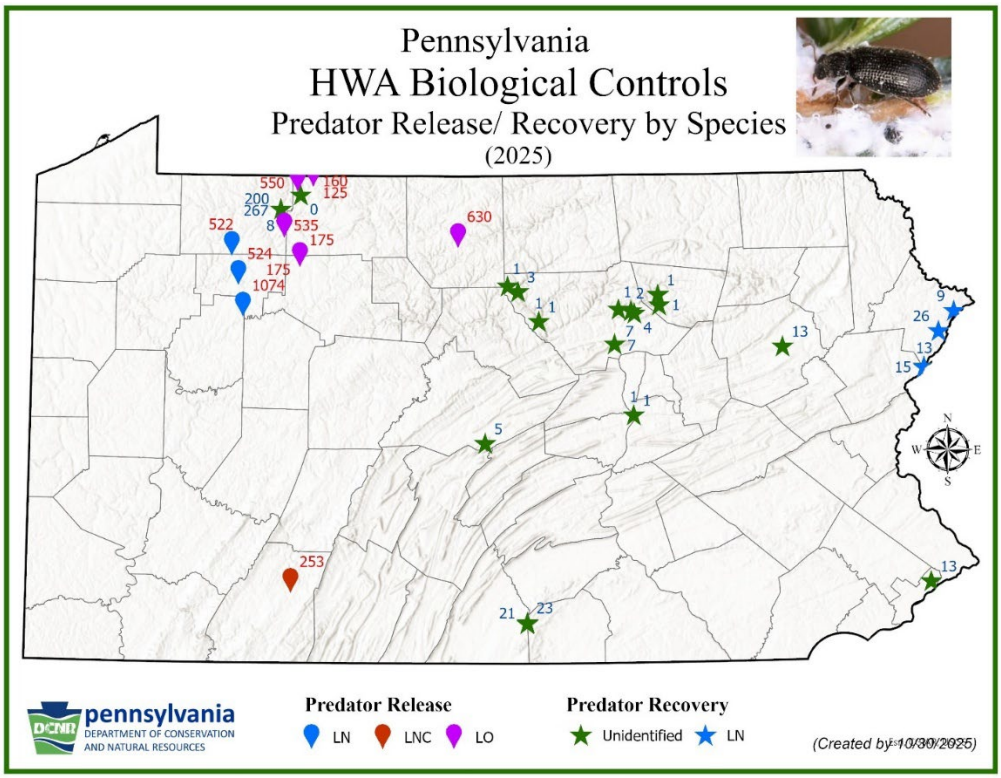


Figure 9. HWA Biological Control Release and Recoveries

Several districts are participating in hemlock habitat management/silvicultural trials, which started in winter 2024-2025 and will continue through 2026. Goals of these trials will be to maintain hemlock on that site as long as you can – which means focus on getting hemlock regen; increasing structural diversity and species diversity in the regen; maintain what other species are there in the overstory; increase the vigor of residual hemlocks in the overstory – whether this means because they have increased resources and/or HWA pressure reduces; creating more habitat/food for wildlife.

To support future resistance breeding efforts, Forest Health staff have begun targeted scouting to locate hemlocks that may be resistant to HWA impacts in areas with highest hemlock mortality (primarily in the Ridge and Valley ecoregion in central and south-central PA). We continue to collaborate with the USFS and Holden Arboretum on developing HWA-resistance bioassays and a breeding program. Towards this end, permanent hemlock surveys are being established statewide to monitor not only hemlock stressors but collect more quantitative data on crown health and mortality.

DFH staff continue to participate in regional and national working groups and research efforts focused on hemlock health, including HWA resistance, disease dynamics, treatment options, and biocontrol.

Staff conducted outreach to educate private landowners and NGO partners on monitoring hemlock health, identifying unique or resistant individuals or populations, and understanding how compounding stressors affect the health of hemlock forests. Presentations were delivered at the PA Forest Landowners Conference and to conservation groups such as WeConserve PA.

Staff have also initiated a systematic scouting effort on State Forests to search for hemlocks persisting within stands experiencing extensive mortality. While incidental observations and detailed hemlock surveys have occurred for many years, this targeted effort seeks to identify potential resistance and will include follow-up assays of hemlocks that survive beyond cohorts that succumbed to pest pressure.

Ash

All counties in Pennsylvania are now positive for emerald ash borer (Figure 10). In 2025 232 ash trees were treated with emamectin benzoate to help preserve ash genetics across the state.

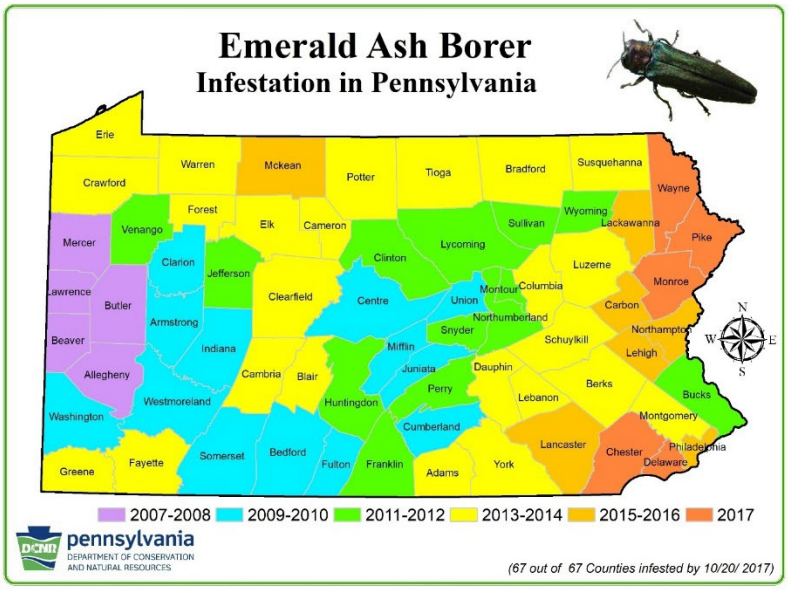


Figure 10. County map of Pennsylvania showing year counties recorded positive for EAB.

DFH staff continue to work with partners at the USFS Northern Research Station to identify 'lingering' ash in natural environments. Scionwood from these trees is collected in winter, grafted and grown to an appropriate size, assessed using an EAB-resistance bioassay and, if appropriate, incorporated into a broader breeding program. Incorporating many resistant genotypes from across the species' range will not only increase resistance to EAB but also help ensure future populations retain the genetic diversity needed to remain resilient to other stressors. These improved families will support reforestation efforts by restoring a genetically diverse, EAB-resistant ash component to future forests.

In early 2025, PA BOF DFH staff collected scion from 14 individuals across 10 Pennsylvania counties (see map). These were grafted and added to the breeding program by USFS collaborators in Delaware, Ohio DFH and nursery operations staff also attended a hands-on training workshop on hot-callus grafting techniques that improve success rates when working with ash.

DFH Staff are preparing to initiate independent winter grafting operations at Penn Nursery (Mira Lloyd Dock Resource Conservation Center, Spring Mills, PA) to supplement the work at the Delaware, Ohio research center. This expansion will increase grafting and assay capacity, allowing more genotypes to be processed annually. In addition to supporting regional ash-breeding efforts, DFH staff can prioritize conservation of Pennsylvania genotypes for a resistant ash conservation seed orchard at Greenwood Furnace Nursery. Penn Nursery and DFH staff have been planning and preparing for this orchard for several years. An additional 6–8 individuals will be sampled in winter 2025–26, with emphasis on underrepresented areas of the state (Figure 11).

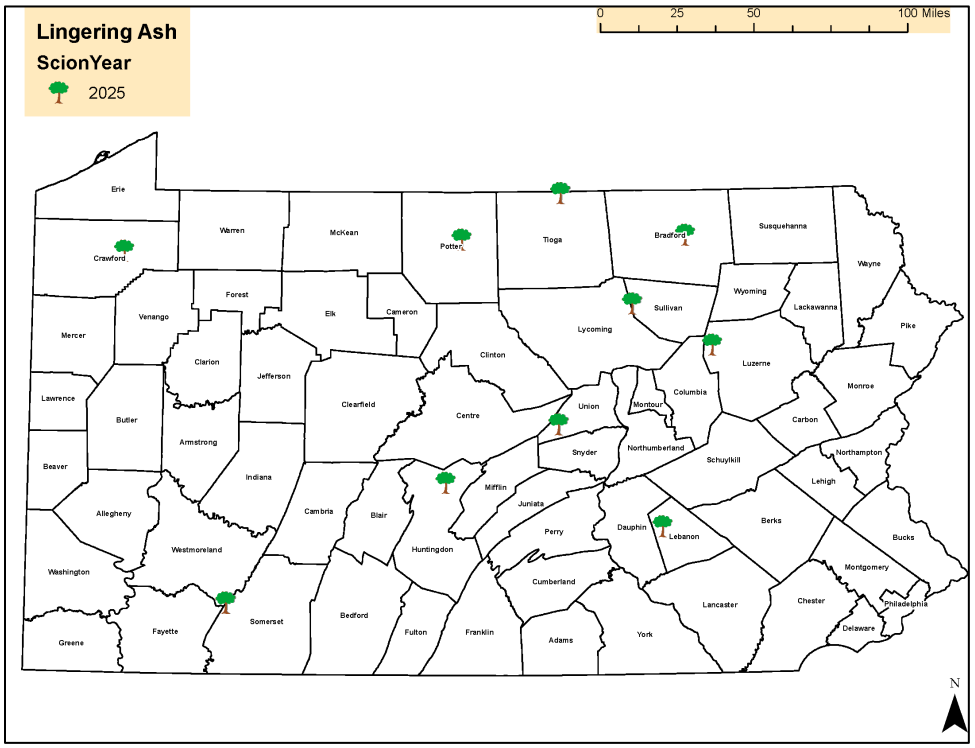


Figure 11. Lingering ash scion collections planned for winter 2025-2026.

Forest Tent Caterpillar

After several years of minimal trap catches, forest tent caterpillar moth was only monitored at 1 site in Sullivan County; few moths caught in 2025.

Southern Pine Beetle

Southern pine beetle (SPB) was monitored at 12 sites in 10 counties with traps (Figure 12). There was a new record in Perry County. Generally, however, SPB populations are still only significant in the very southeastern corner of the state.

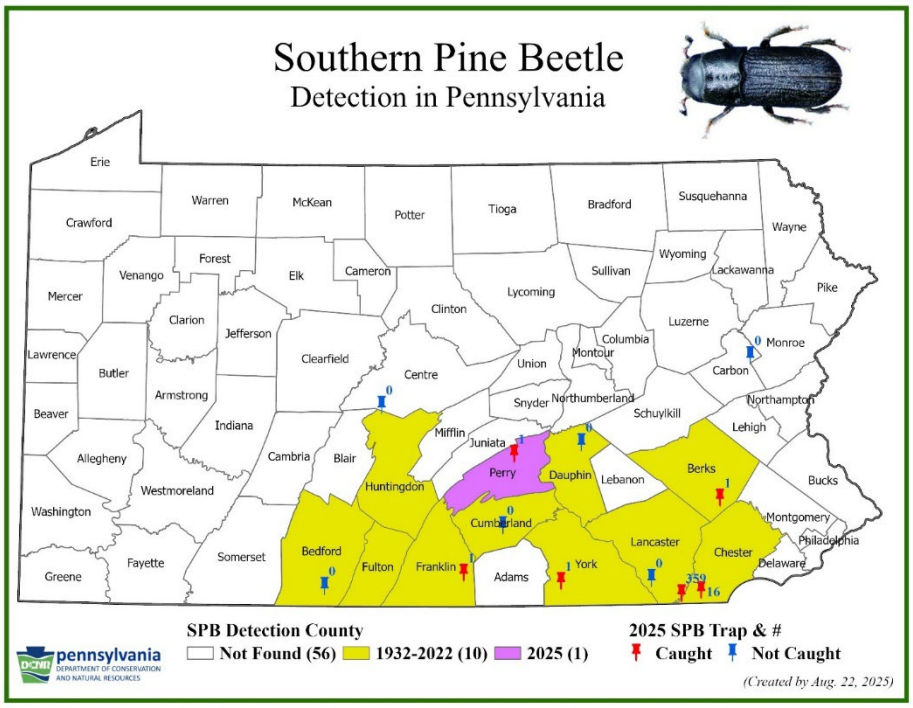


Figure 12. Southern pine beetle trap detection in Pennsylvania.

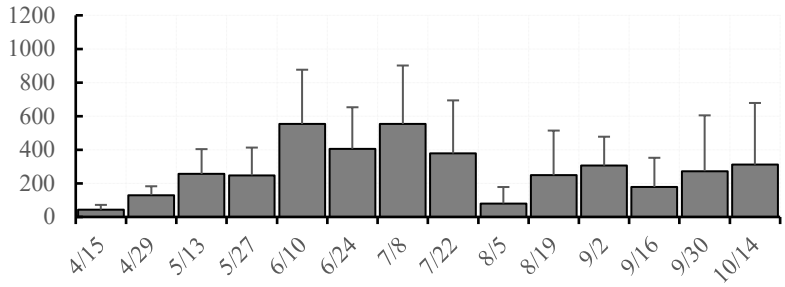
A more detailed study on the impacts of southern pine beetle has been ongoing at the higher population areas in southeastern PA. Beetle trapping was carried out in 15 plots at five sites (3 plots/site) in Goat Hill Preserve from April to October in 2024 and 2025 by using the 12-unit Lindgren funnel trap baited with frontalin, *endo*-brevicomin, and *Sirex* lure. Traps were checked every other week for a total of 28 weeks, with lures replaced every 6 weeks.

Preliminary Results (Figure 13)

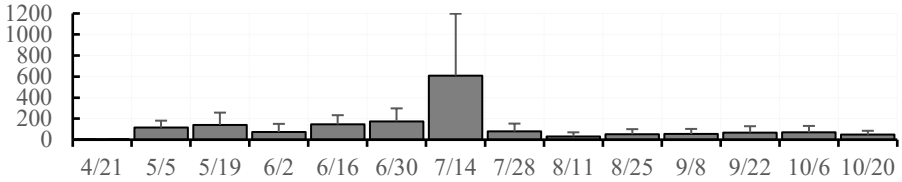
1. SPB population decreased from 2024 to 2025 in general
2. Single population peak observed in 2025 compared to multiple peaks in 2024.
3. Clerid population seems to stay at similar levels between 2024 and 2025.
4. Population spike observed in May 2025 for clerid beetle.
5. Further analysis needed for more information.

a. SPB

2024

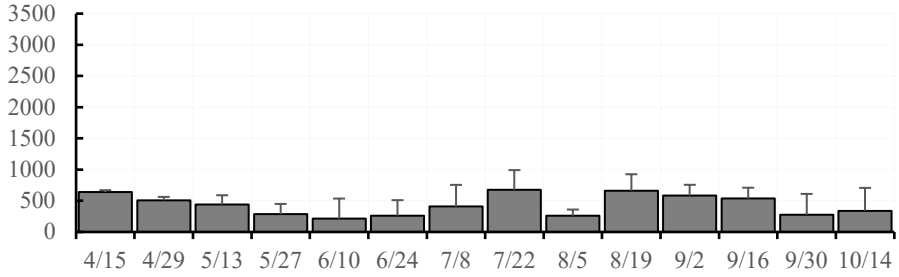


2025



b. Clerid beetle

2024



2025

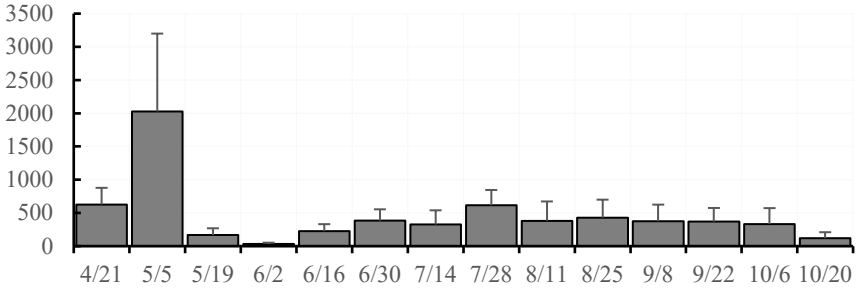


Figure 13. SPB study preliminary results.

Spongy Moth

Pennsylvania has continued monitoring spongy moth population through evaluating its egg mass density. In the 2024-2025 season plots were sampled state-wide and the sites with 800 egg masses per acre or above located primarily in east-central and northeastern areas, forecasting a moderate to heavy defoliation in those areas (Figure 14).

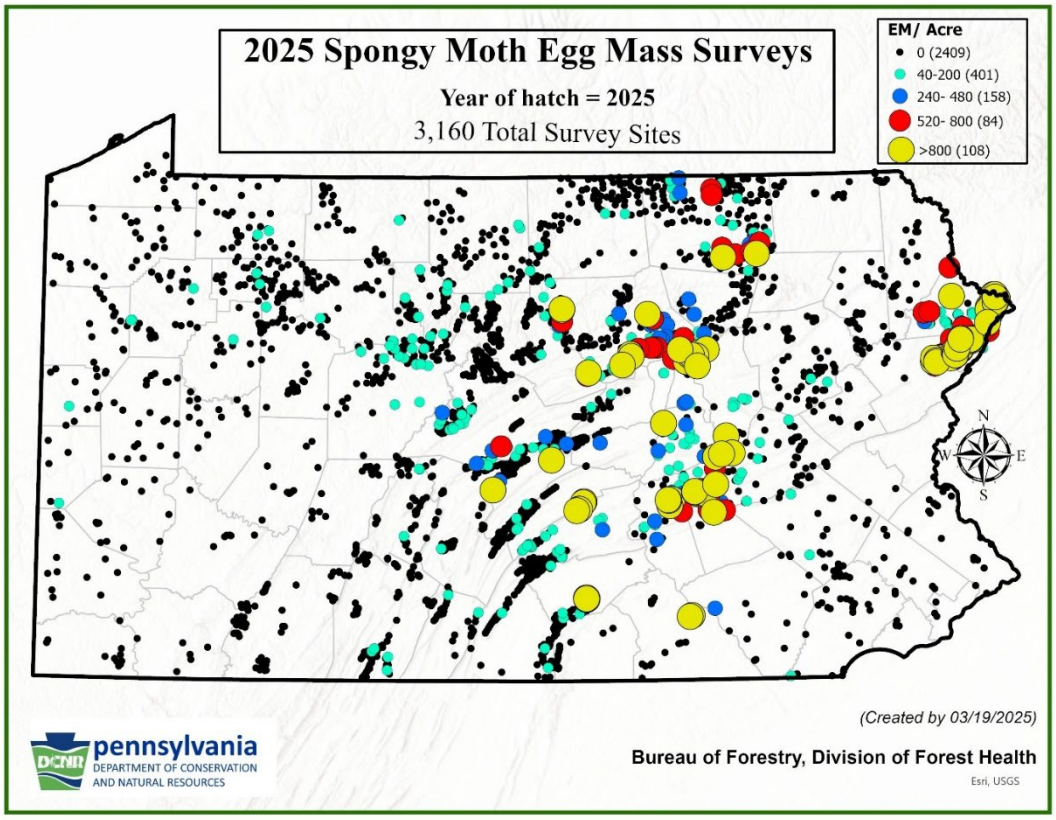


Figure 14. Map of 2025 spongy moth egg mass survey.

Pennsylvania Department of Conservation & Natural Resources (DCNR) implemented an aerial spongy moth suppression program in 2025. The operational period for the suppression program was April 30 through May 24 and included aerial applications within 13 counties. A total of 52 spray blocks totaling 64,699 acres (plus 10,080 acres of double applications) were treated with either *Bacillus thuringiensis* subspecies kurstaki (Btk) or tebufenozide (Mimic 2LV). Participants included State Forest lands and State Parks (Figure 15 and 16).

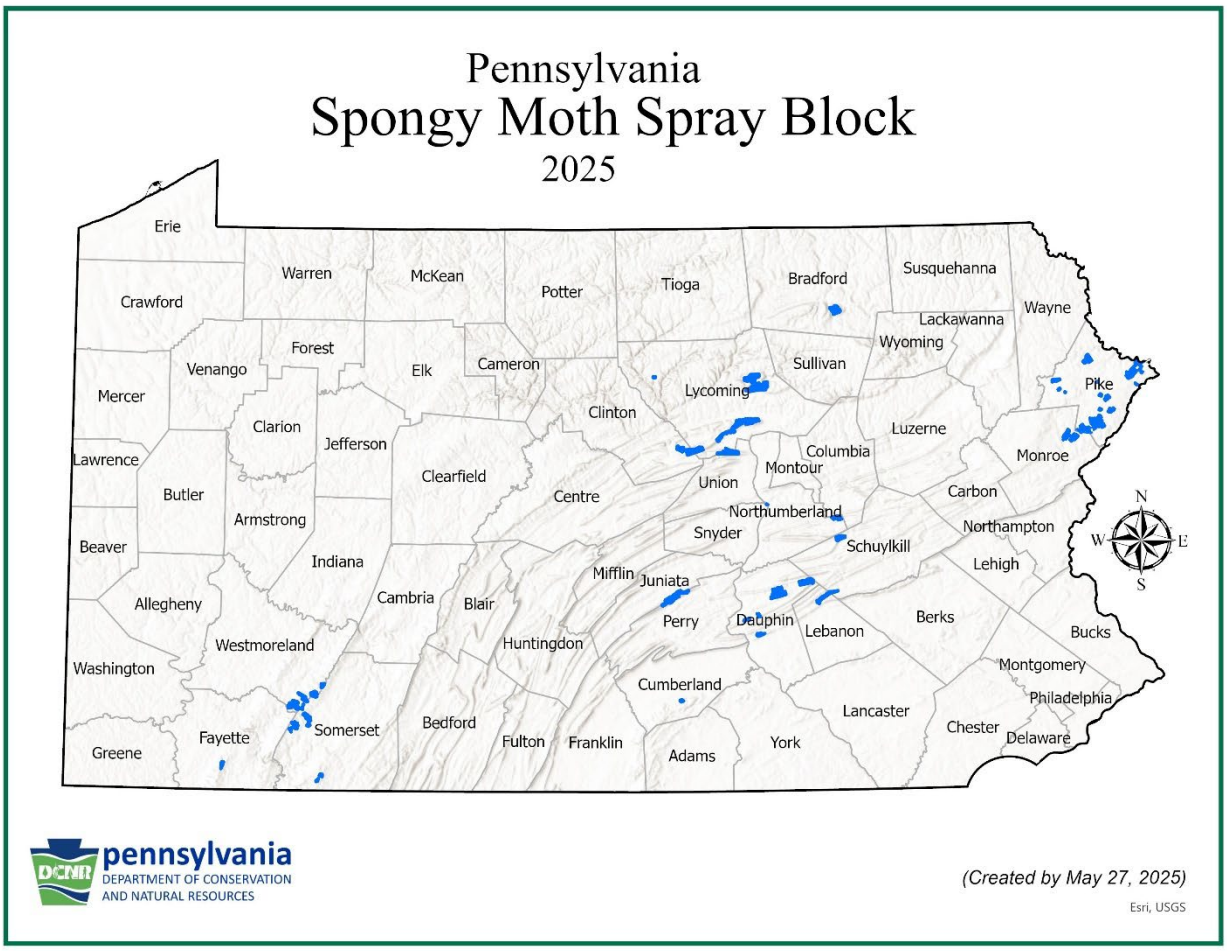


Figure 15. 2025 Spongy moth spray blocks by DCNR (note that blocks in Westmoreland, Somerset and Fayette are associated with fall cankerworm, not spongy moth).

2025 *Lymantria dispar dispar* spray acreage			
Treatment	Helicopter Bt	Fixed Wing Mimic	Total Acres
First Application	25,064	39,635	64,699
Second Application	10,080		10,080
Total Acres	35,144	39,635	74,779

Figure 16. 2025 DCNR spongy moth spray acreage by ownership, aerial craft, and insecticide.

A separate suppression program on spongy moth was also conducted in the same period by Pennsylvania Game Commission (PGC) in 2025. A total of 26 spray blocks totaling 37,416 acres were treated on PGC lands (Figure 17).

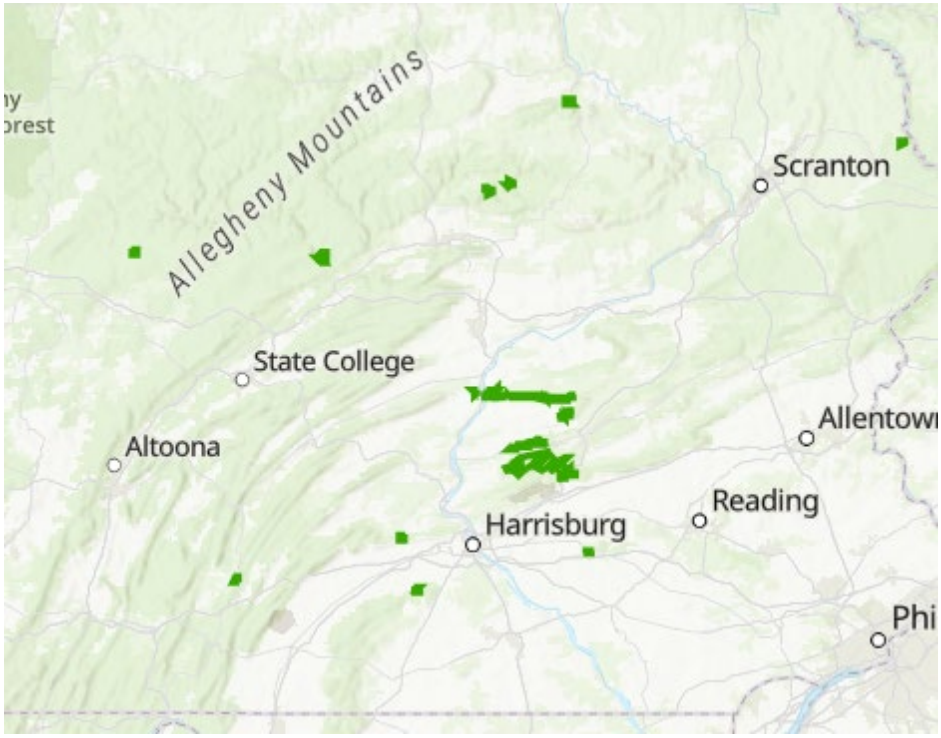


Figure 17. 2025 Spongy moth spray blocks by PGC.

Beech

Beech leaf disease (BLD) has been confirmed in all 67 counties in the state. Three of the 6 monitoring plots established in 2020 were remeasured again in 2024; the other three were remeasured in spring of 2025 (Figure 18).

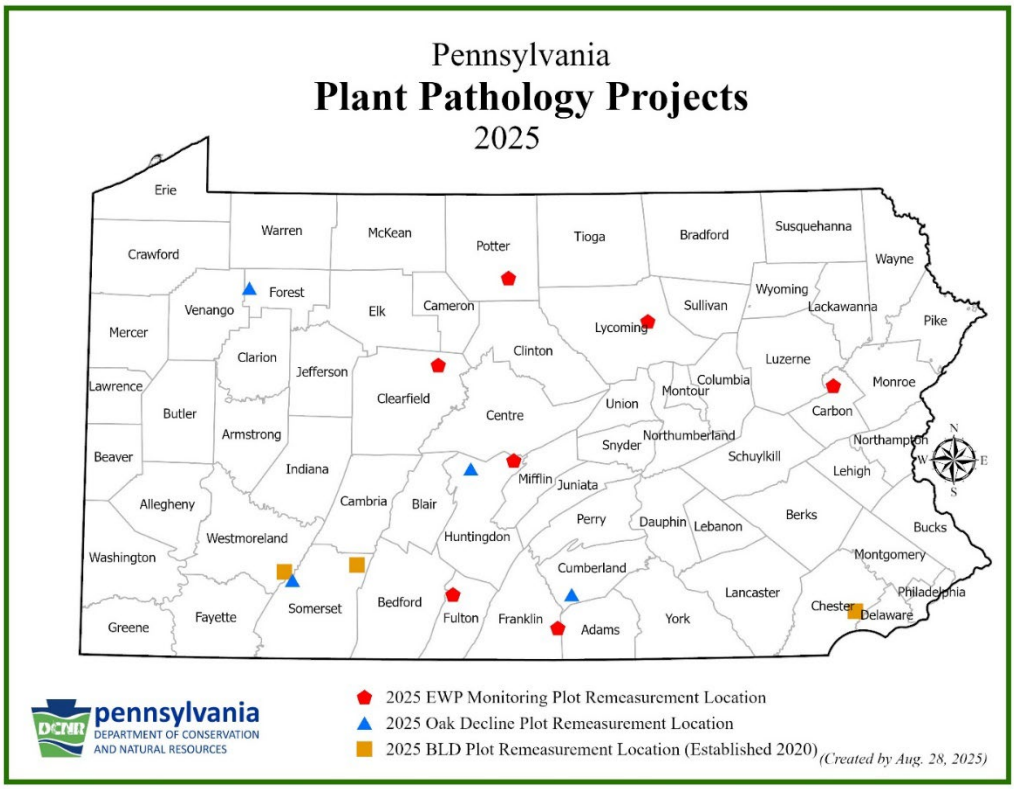


Figure 18. Beech leaf disease monitoring plot locations (orange).

Polyphosphite 30 fertilizer treatments were conducted at Nolde Environmental Education Center (EEC) in July and again in September (Figure 19). This is the third year of treatments. The same protocols were followed that are being done in Cleveland Metro Parks and Davey Tree Company for experimental consistency. Each treated beech tree was paired with an untreated tree (control) of same DBH and severity of symptoms. The fertilizer was applied using a soil drenching method around the base of each selected treatment tree. The rate used was 2 oz of product + 14 oz water / inch DBH.

Efficacy of Polyphosphite 30 can't be determined at this time since the trees are large, mature trees and it is thought that it will take several years to see any improvement in the tree health (if at all). Beech scale is established in Nolde after first detected last year. In time, we expect to observe a buildup of the scale population on the beech resulting in feeding injury in the bark and *Neonectria* fungi colonization shortly after and eventual tree death.

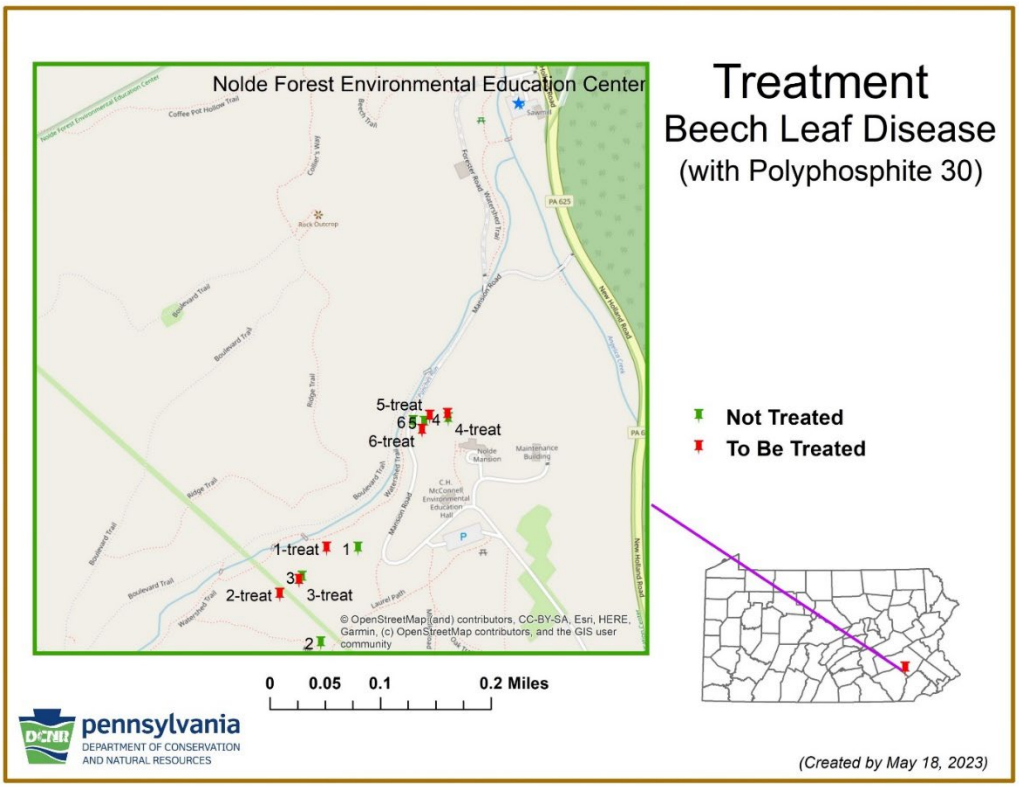


Figure 19. Polyphosphite 30 treatment locations.

Initial Arbotect 20S fungicide trials were conducted in June by Rainbow Science and DCNR at three locations in June: Johnson Natural Area (NA), Buck Hollow, and Nolde EEC (Figure 21). These trials used two different reduced chemical ratios (Figure 20).

Location	**Chemical Ratio (DBH in inches)**	**Example (10-inch DBH Tree)**
Johnson NA	*Low Ratio:* **Product Volume (oz)** = DBH (inches) x 0.4 oz. **Water Volume (oz)** = Product Volume (oz) x 40 oz H2O	4 oz product: 160 oz H2O
Buck Hollow & Nolde EEC	*Higher Ratio:* **Product Volume (oz)** = DBH (inches) x 1.6 oz. **Water Volume (oz)** = Product Volume (oz) x 32 oz H2O	16 oz product: 512 oz H2O

Figure 20. Arbotect 20S treatment levels.

Based on expected infestation levels, retreatment with Arbotect 20S is anticipated once every 2 to 4 years. Treated beech trees should be monitored annually starting after the 2- to 4-year mark, similar to established protocol used for ash trees.

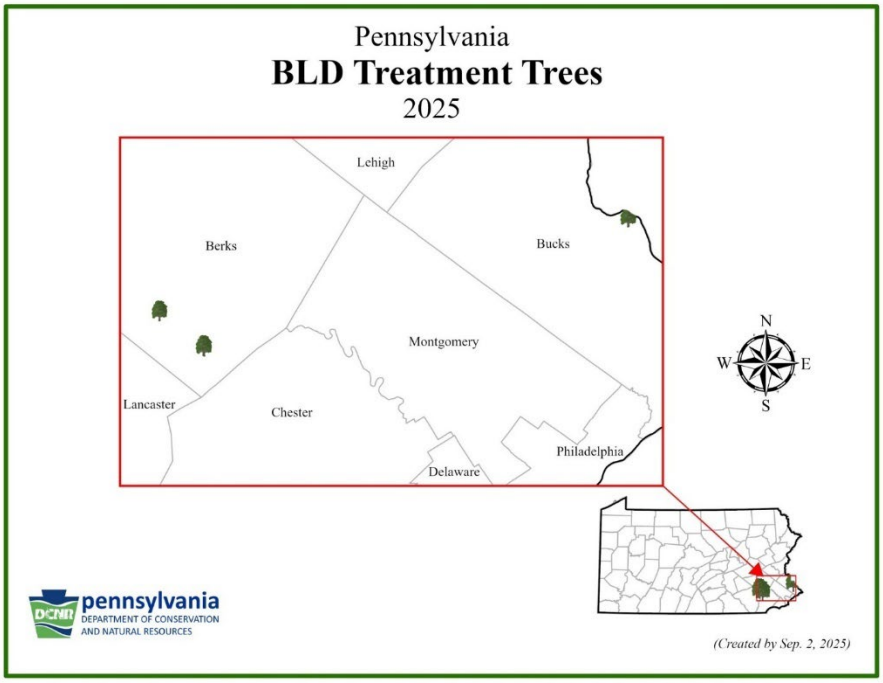


Figure 21. Arbotect 20S fungicide trials locations.

Another trial for beech treatment took place in Bald Eagle State Forest in October. Bud samples were taken from each treatment group to determine pre-treatment nematode levels and buds will be collected again in the spring to see if the fungicides reduce their numbers. The treatments were as follows:

Macroinejection of phosphojet - 6 trees

Macroinjection of phosphojet + microinjection of Imajet (for scale control) - 6 trees

Microinjection of arbortect 20s - 6 trees

6 control trees

With the rapid proliferation of BLD, beech populations have experienced severe impacts. DFH staff continue to monitor and maintain BBD-resistant orchards and plantings, including chemical treatments to manage BLD in select areas. Untreated plantings were assessed for health across genotypes to support ongoing investigations by partners at Holden Arboretum and USFS into potential BLD-resistance within BBD-resistance families.

Oak

Oak Decline Long-term Monitoring Plots

More oak decline areas are manifesting across the state and include many species of oak such as white, chestnut, red, black, and scarlet. Given what is known about oak decline, most likely a variety of past stressors are contributing to the decline. However, a multi-state effort is in place to set up long-term monitoring plots document the decline and its contributing factors over time and capture the change in oak volume and how much deviation there is from accepted baseline mortality. Four monitoring plots were remeasured in 2025 (Fig. 22).

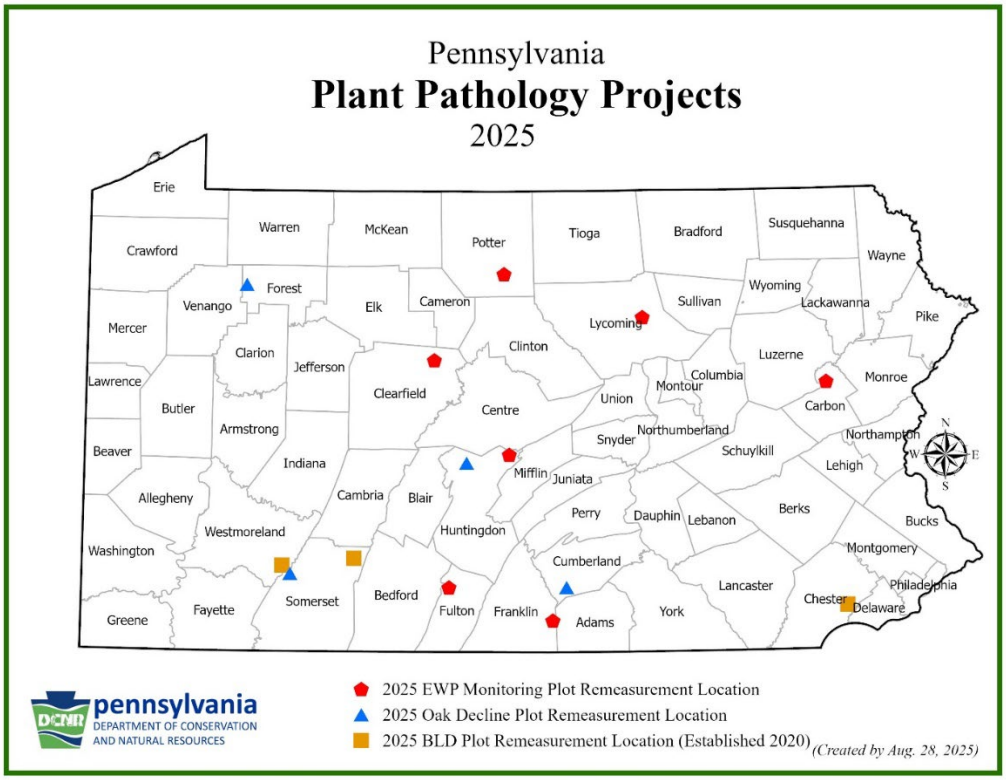


Figure 22. Long-term oak decline monitoring plot locations (blue).

Oak Soil Microbiome Project

The objective of this project is to determine if there are differences in the soil microbiome in the rhizosphere based on the health status of oaks (ranging from healthy, moderate decline to heavy decline. For example, are there more beneficial microbes in the rhizosphere soil surrounding healthy

oaks and has there been a shift to more pathogenic microbes in the rhizosphere soil surrounding declining oaks? In Spring 2025, the last 3 sites, which are part of the long-term oak decline monitoring plots were selected for soil sampling (Fig. 23). The health statuses for 8 trees/site were distributed as evenly as possible based on what oaks were available. Four subsamples of rhizosphere soil were collected approximately 2-4 meters from the bole of each tree in the 4 cardinal directions then bulked into one sample. One bulk soil sample was taken at each location to serve as a control. Soil moisture and temperature were tracked by HOBO dataloggers specific for those two variables. This project is to provide baseline information on what soil microbes are present in the rhizosphere. This information will serve as a springboard to more intensive studies if microbial species and patterns of interest are noted.

Final data analysis for the project will occur this winter.

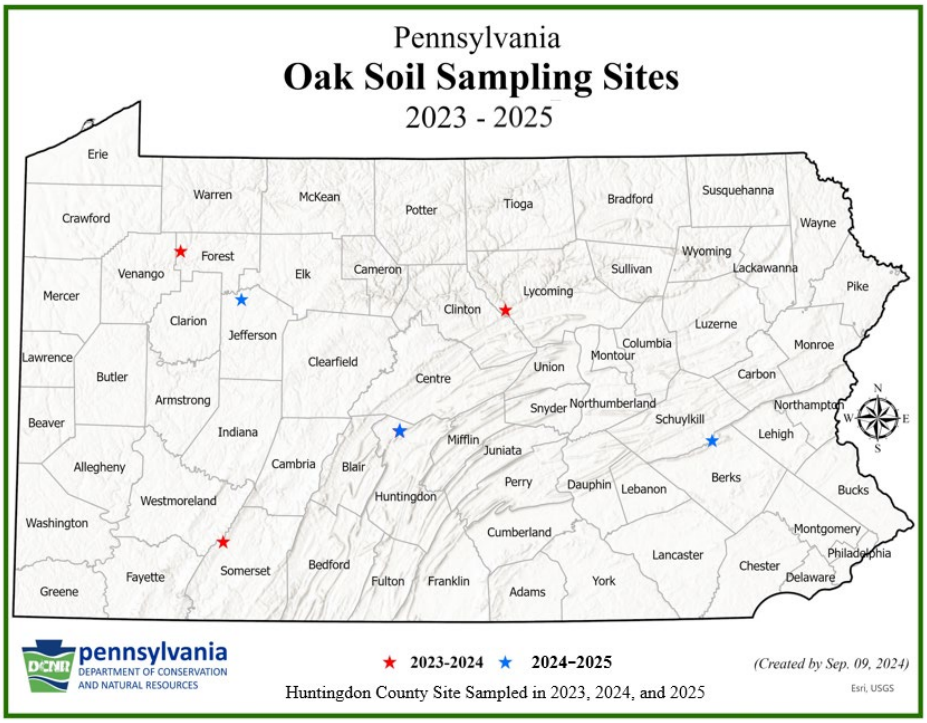


Figure 23. Oak soil sampling site locations.

Black Cherry

Prunus Necrotic Ringspot/Dwarf Virus

In May, black cherry trees on the Allegheny National Forest were sampled for Prunus necrotic ringspot/dwarf virus. 20 samples were collected from the original positive and resampled the positive tree from last year (Figure 24). Samples were sent to Agdia and John Hammond at USDA-ARS for processing. The same tree that was positive last year for PCR was positive again this year but with ELISA we are still waiting for the results from USDA-ARS.

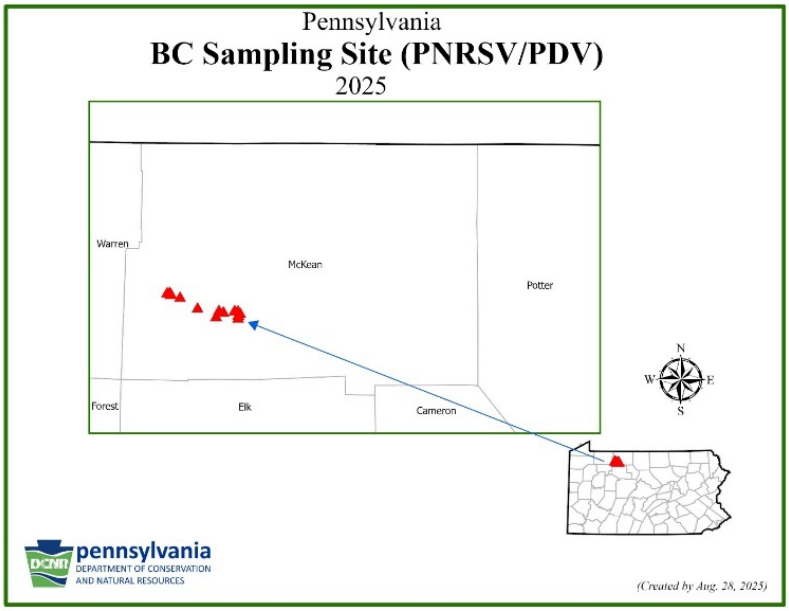


Figure 24. Black cherry PNRSV/PDV sampling sites.

Black Cherry Fungicide Trial

Additionally, soil sampling began as part of a larger black cherry project- Empowering Managers to Mitigate Habitat Declines in Regenerating Allegheny Hardwoods (funded by PGC; led by USFS, Univ. of Kentucky, PGC). This study will test the effects of fungicide and fertilization as management options for black cherry leaf spot. The fungicide will be chlorothalonil (PGC sites) vs FSC-approved fungicide (BOF lands), and fertilization will consist of nitrogen and sulfur. The study is aimed at mitigating habitat declines in regenerating Allegheny hardwood forests and BOF State Forests, and soil sampling will help shed light on the impacts of fungicides on non-target organisms (Figure 25).

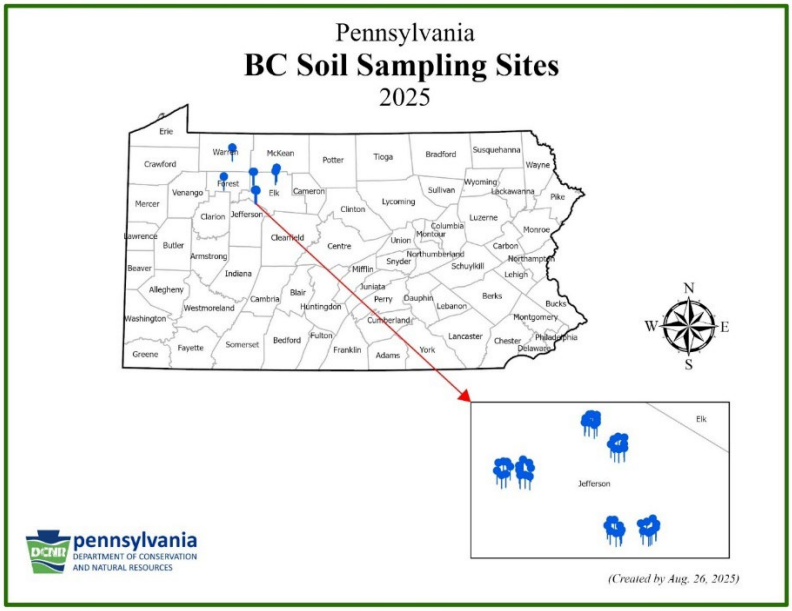


Figure 25. Black cherry soil sampling fungicide sites.

Butternut

In collaboration with USFS Region 9 staff and the Oconto River Seed Orchard, DFH is preparing to expand existing and establish additional clonebank seed orchards for butternut. About 60 families were originally established in the early 2010s at ANF (USFS) and Greenwood Furnace Nursery (PA BOF), but many plantings have since failed at one or both sites. Successful individuals will be sampled and grafted to create new clones and re-establish an orchard for USFS reforestation efforts on national forests in Pennsylvania and New York.

In addition to previously identified natural butternut in Pennsylvania, DFH staff cataloged roughly 100 new individuals and sampled 39 of them this summer. These samples are undergoing genotyping using a SNP array developed with partners at Purdue University's HTIRC. Results will help identify hybridization with non-native congeners and support a landscape genomics assessment to inform butternut conservation across its range in the eastern United States.

Staff also assisted researchers from Alfred University (NY) with a study investigating relationships among butternut (Juglans cinerea), arbuscular mycorrhizal fungal communities, and the progression of butternut canker disease. Protocols for this study were piloted in 2025; sampling and analysis will continue in the coming years.

DFH staff participate in regional butternut conservation efforts, including a monthly collaboration call involving academic institutions, non-profits, and state and federal resource agencies from the eastern United States and Canada. This interdisciplinary group addresses butternut conservation through forest pathology, disease dynamics, landscape genomics, tree breeding for disease resistance, and technology for disease and hybridization phenotyping. These meetings are coordinated by USFS staff from the

Northern Research Station and the State, Private, and Tribal Forestry RGNR (Reforestation, Nurseries, and Genetic Resources) program.

In addition, staff contribute to outreach for professionals and private landowners—such as presentations at the PA Rare Plant Forum and various landowner visits—to expand awareness of butternut conservation.

Elm Zigzag Sawfly

No new elm zigzag sawfly populations were observed in 2025 (Figure 26). Previously it had been observed in 11 counties in Pennsylvania (9 counties detected in 2023; 2 counties in 2024).

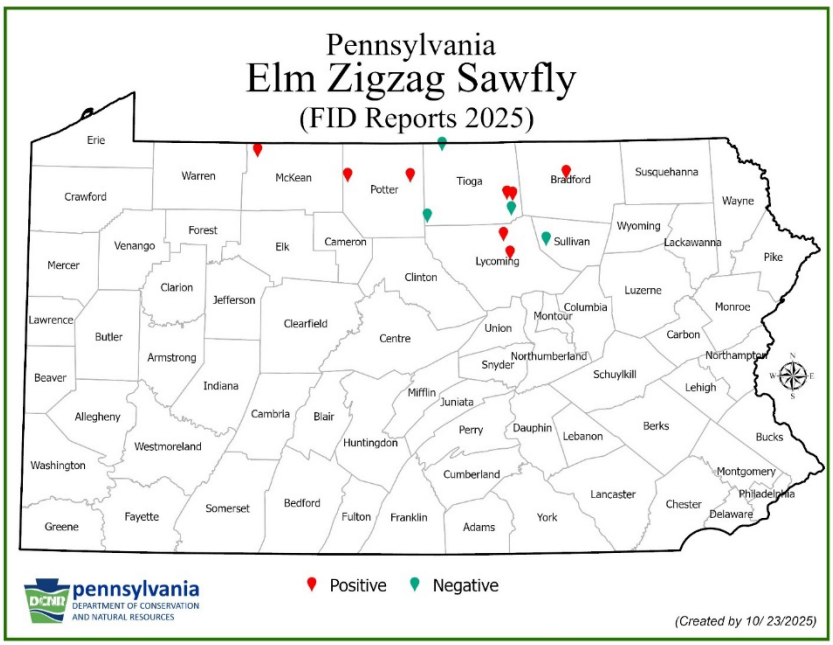


Figure 26. Elm Zigzag Sawfly Detections

Walnut Twig Beetle

Walnut twig beetle trapping took place in 2025, with traps placed at 6 locations in eastern PA (Nockamixon, Marsh Creek, French Creek, Susquehannock, Ridley Creek State Parks; Peace Valley Nature Center). No walnut twig beetles were recovered.

Fall Cankerworm

The fall cankerworm (FCW), *Alsophila pometaria* (Harris) (Lepidoptera: Geometridae), is a native pest of broadleaf trees and shrubs in North America. Preferred hosts include oak, maple cherry, ash, basswood, beech, apple, birch, dogwood, elm, hickory, linden, walnut, and willow. High population density results

in significant damage to the forest. Major outbreaks occur every 10-12 years in some areas. Population typically crashes after 1-2 years of severe defoliation as the result of natural control by natural enemies, food availability, and climate conditions.

At least nine major outbreaks have been recorded in Pennsylvania since 1932. The most recent one occurred in the Somerset area, with more than 12,000, 98,000, and 44,000 acres defoliated in 2023, 2024 (Figure 27), and 2025 respectively. A decision was made to suppress the FCW populations at some of severely impact locations to prevent tree mortality; 9,825 acres were treated with Bt in 2025 (Figure 28).

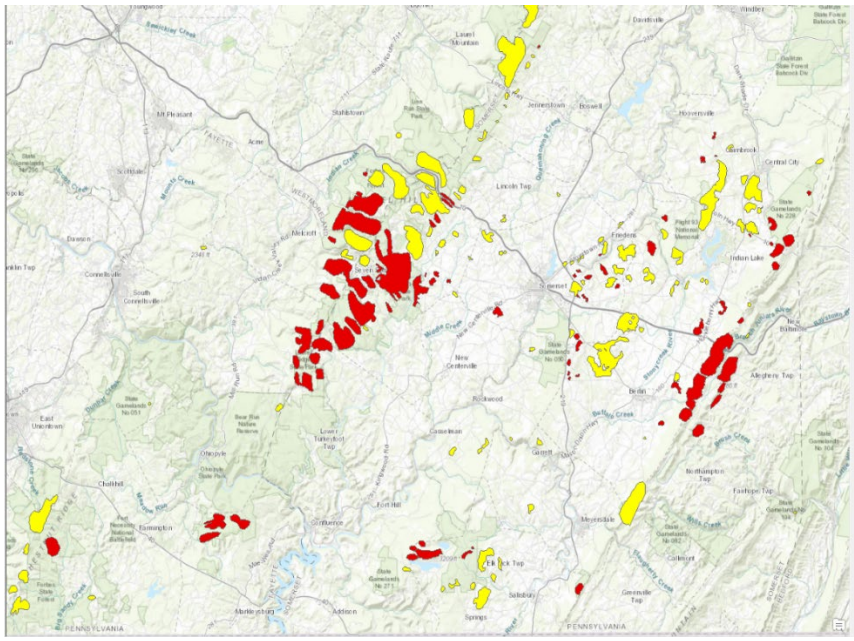


Figure 27. Fall cankerworm defoliation in 2024.

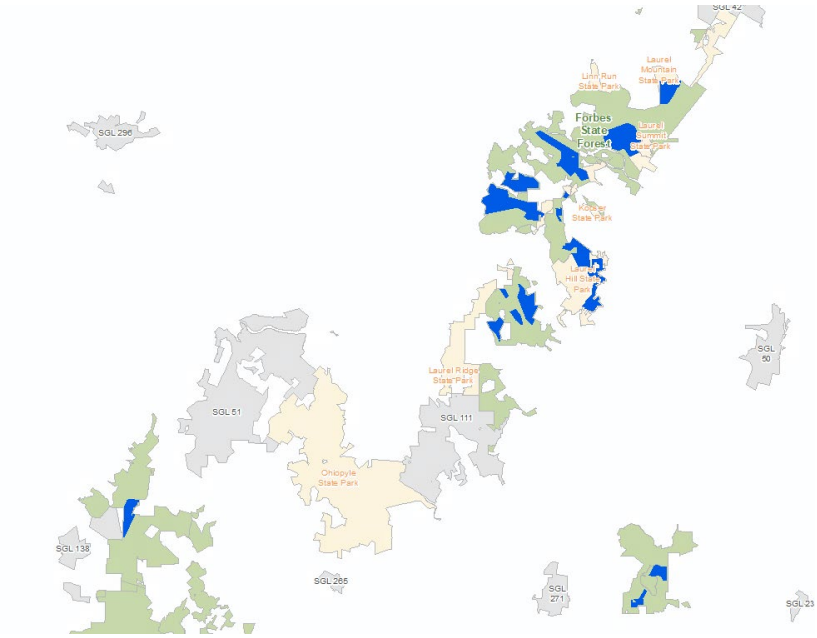


Figure 28. Fall cankerworm spray treatment blocks in 2025.

Additionally, a field study on its adult and egg populations was initiated in 2024 to facilitate the decision-making process. Bugbarrier trap was used to survey for adult population in 38 plots at 6 sites for 4 weeks in fall 2024, whereas survey for egg mass density was carried out at 10 sites in March 2025 with a time-searched protocol. Defoliation on red oak, red maple, and black cherry was also assessed at 8 sites in late May 2025.

Preliminary results showed that the average females caught on the Bugbarrier trap ranged from 486 to 882 females/trap for the 4-week trapping period at six sites surveyed. The commonly accepted treatment threshold for FCW in urban area is 45 moth/trap for the entire season.

Relative egg mass density ranged from 4.3 to 42.7 egg masses/person-hour among the 10 sites. Egg mass size ranged from 74 to 207 eggs/egg mass, with a hatch rate of 34 - 81%. Egg parasitoid *Telenomus alsophilae* played a significant role in egg population dynamics, with a parasitism rate of 0.3-21.2% recorded.

During this study, *Fusarium* was isolated from dead FCW collected in the field. Because *Fusarium* can be both a saprophyte (colonizing dead tissue) and an insect pathogen, a bioassay was needed to test pathogenicity (Figure 29). Mortality was not clearly different between treated and control groups → inconclusive evidence for pathogenicity. Therefore, further testing is needed to confirm whether this *Fusarium* isolate is a true pathogen or simply a secondary colonizer of dead insects. Although this bioassay was put together quickly, it gave us a starting point to develop a stronger, more refined approach moving forward including more quantitative methodologies.

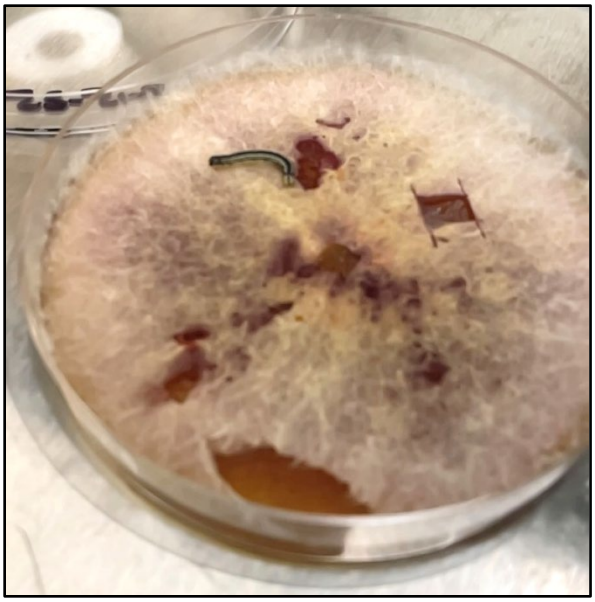


Figure 29. Fusarium pathogenicity testing.

Defoliation observed was different between sites and tree species, with higher defoliation rate at the Blue Hole and Pondfield divisions in Forbes State Forest and Blue Knob State Park. Red oak suffered the most with 10-58%, followed by red maple (10-52%), and black cherry (8-28%).

Adult trapping with Bugbarrier continued in fall 2025, with 49 traps deployed at 9 sites in southwestern and central PA.

Invasive Plants

Early in 2025, the PA Division of Forest Health (DFH) hired an Invasive Plant Ecologist to help manage the threat of invasive plants in the state's forests. This new position has begun to improve upon the Bureau of Forestry's efforts on training, prevention, chemical and mechanical treatments, and biological controls.

In 2025, the Bureau treated 2,307 acres of invasive plants on state forest land. Some of these were smaller EDRR species points; others were larger infestations of forest invasive plants (barberry, stiltgrass, bittersweet, etc).

A particular priority for invasive plant management in 2025 was wavyleaf basketgrass (*Oplismenus undulatifolius*), a relatively new invader of forest lands in Pennsylvania. Resource agencies across the state are treating this species as an early detection, rapid response priority wherever it is found. DFH and other DCNR staff also helped survey over 200 acres of the state forest and state park lands (Michaux, Buchanan, and Rothrock State Forests; Tyler, Codorus, and Gifford Pinchot State Parks) (Figure 30); an additional survey of 18.5 miles of the Mid-State Trail found no new infestations. Wavyleaf basketgrass was treated whenever it was located. A new infestation in Rothrock State Forest—the northermost observation—was reported by a citizen scientist on iNaturalist and iMapInvasives, then speedily addressed.

Figure 30. Wavy leaf basketgrass survey (purple tracks) and treatment points (red dots) in Gifford Pinchot State Park.

DFH staff also started the first releases of the bohemian knotweed psyllid (*Aphalara itadori*) in Pennsylvania. Surveys of many knotweed populations across the state were undertaken in order to identify the specific species (giant, bohemian, Japanese), with many locations determined to be giant knotweed (Figure 31).

Figure 31. Giant knotweed infestation in Gallitzin State Forest.

Fortunately, a location in Harrisburg was determined to be bohemian knotweed and a suitable site to introduce the psyllids (Figure 32). Unfortunately, partway through the growing season the site was mowed by maintenance workers. It is hoped that some psyllids survived in the surrounding knotweed, and monitoring will continue in 2026. Additionally, 12 new releases of mile-a-minute weevil (*Rhinoncomimus latipes*) and 2 new releases of spotted knapweed weevils (*Cyphocleonus achates* and *Larinus obtusus*) took place at multiple locations across the state.

Figure 32. Knotweed psyllids.

Other Genetic Efforts

- Chestnut: DFH staff (along with state nursery operations team) coordinate collaboration between primary partners, such as TACF. In 2025, PA BoF staff shared multiple observations of long-surviving wild American chestnut trees with TACF and collected seed and data on these individuals. Staff worked with TACF to establish a new chestnut seed orchard of superior genotypes hosted on state forest land, as well as a large, multi-year field trial at Penn Nursery.
- Seed sourcing and diversity of planting stock: Several efforts to promote diversification of species and genotypes used for seedling production at state nursery are planned or underway.
    - Assessment of seedlot data from the past 75 years,
    - Supporting research for species-specific seed transfer guidelines and climate-based seed sourcing strategies
    - White oak provenance trial
    - Shortleaf pine assisted range expansion trials and genetic assessments