Wisconsin DNR Forest Health 2020 Annual Report

Red headed pine sawflies on red pine
Linda Williams

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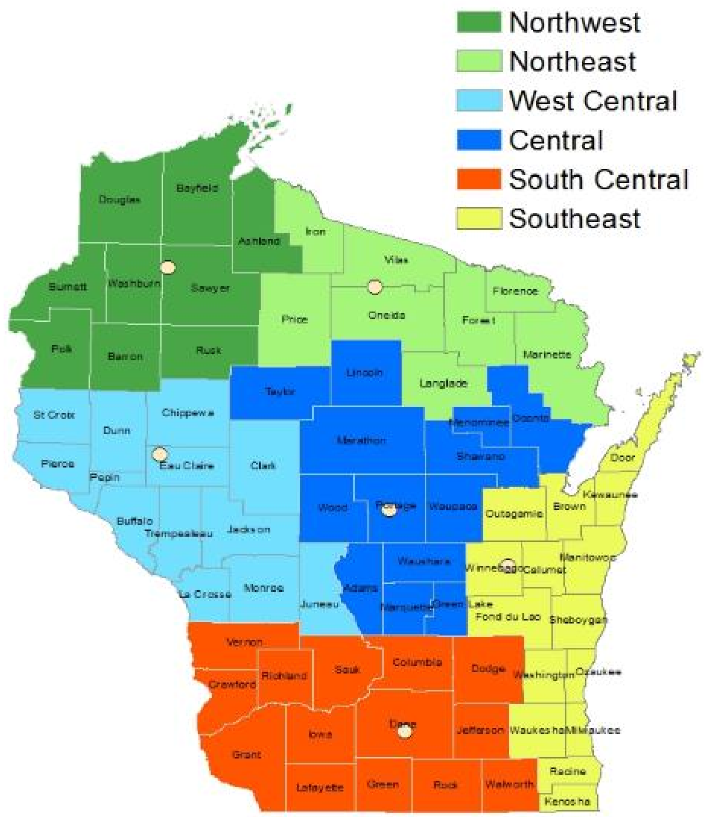

Figure 1. Locations and zones of forest health specialists as of Dec. 2020.

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Staff update

The Forest Health Program welcomed Eleanor "Elly" Voigt to the program as the summer lab assistant at the Forest Health Lab. Elly started on June 8, as soon as she and Kyoko Scanlon could enter the lab with COVID-19 precautions. She worked closely with the team members in the field, keeping them abreast on progress on their samples in the lab and consulting with them on additional observations from the site that could speed identification. Processing pathogen samples kept Elly busy full time until the late fall when she started transitioning into the role of Outreach and Communications specialist for the team for half of her work time. She's benefited from guidance by Marguerite Rapp who held the position until this spring when she transferred into the Forest

Economics and Ecology (FEE) section. It's been more *arrivederci* than goodbye with Marguerite as we continue to work with her as a colleague in her new position as Forest Ecology and Silviculture Specialist in the FEE section.

Marguerite Rapp

Strategic Direction of the Forest Health Program

The Forest Health Program provides technical expertise in the prevention, detection, assessment, management and monitoring of invasive plants, insects and diseases that damage trees and forests, and the benefits they provide. The program assists public and private landowners in their efforts to minimize the establishment and adverse impacts from invasive plants and destructive forest insects and diseases. Strategic planning for Forest Health has focused efforts on management guidelines, historical data analysis in the annual report and key intra-agency partnerships.

In 2020, two appendices were added to the "Emerald Ash Borer Silviculture Guidelines" to provide technical information on factors to evaluate when deciding on management of lowland ash stands and a lowland reforestation species guide. Additionally, the guide on "Organizing an Aerial Spray for Forest Pests" was revised to update information on state programs and regulatory requirements.

Reducing the spread of invasive species on Wisconsin DNR managed lands is a top priority. The Wisconsin State Parks welcome over 14 million visitors a year, and sometimes invasive species hitch a ride. The Forest Health Program partnered with the DNR Bureau of Parks and Recreation on multiple projects to control emerald ash borer (EAB) and support recovery efforts after ash mortality. Forest Health Program staff scouted sites to introduce biological controls for EAB at Peninsula and Kohler-Andrae state parks and secured permissions from them for introductions made by USDA-APHIS-PPQ. Funding was awarded to 7 state parks through the Sustainable Forestry Fund to provide $24,500 in assistance towards hazard tree removal and replanting due to ash mortality from EAB.

Impacts of COVID-19 on Forest Health Program

When COVID-19 first hit Wisconsin in mid-March, the governor issued the "Safer at Home" order and Forest Health field and lab work halted on March 25. Our field staff continued to provide excellent customer service via pest and disease identification and management guidance from their home offices using emailed and texted photos from foresters, forest owners and land managers. Team and committee meetings were rescheduled to online formats, conferences were canceled, outreach presentations and technical trainings went virtual and staff hunkered down to play our part in reducing the spread of the virus. The Forest Health

Team increased from routine monthly calls to weekly calls to share updates, discuss challenges and innovations, and support morale.

As many forest health issues are ephemeral, staff got creative in order to provide diagnostics and capture landscape level problems before they disappeared. Some creative solutions included "FaceTime" with foresters who were out in the woods to share real time information, recording training sessions in the Zoom format paired with live Q&A sessions, and Skype computer demonstrations. Another creative solution was devised to substitute for aerial survey since we couldn't go up with the pilots. After a devastating storm in northern Wisconsin, a pilot took a sequence of aerial photos as he surveyed the damage path. Our local forest health specialist then used the aerial photos, observations from emergency responders on the ground, and mid-summer site visits to translate the data into damage polygons. Additionally, a UW PhD student, working on a program that can detect changes on the forested landscape, helped target on-the-ground surveys to additional areas of storm damage that were previously undetected.

After 3 months, the state forest pathologist and lab assistant moved back into the lab on June 8 with many new safety measures implemented. Field staff hit the ground running on June 19 with the renewal of site visits, lab sample submissions and ground surveys. All staff worked diligently to ensure physical distancing, use of protective equipment and disinfection of lab equipment and vehicles. Apart from the two staff running the lab, all other Forest Health Program members continue to work from home when not conducting field work.

The Forest Resource in Wisconsin

Wisconsin's forests (Figure 2) are critical for providing wildlife habitat, clean air and water, reducing erosion, and improving the quality of life in urban and rural areas. Forests are also important to the economy of Wisconsin for wood products, recreation and tourism. Current information on the forest resource in Wisconsin is available at dnr.wi.gov.

The area of forestland in Wisconsin has steadily increased in recent decades and currently stands at approximately 17 million acres (Figure 3). This is an increase of 1.6 million acres since 1983. Wisconsin now has more forested area than at any time since the first forest inventory was conducted in 1936. Over 46% of the state's land area is forested, primarily in the northern and western areas of the state.

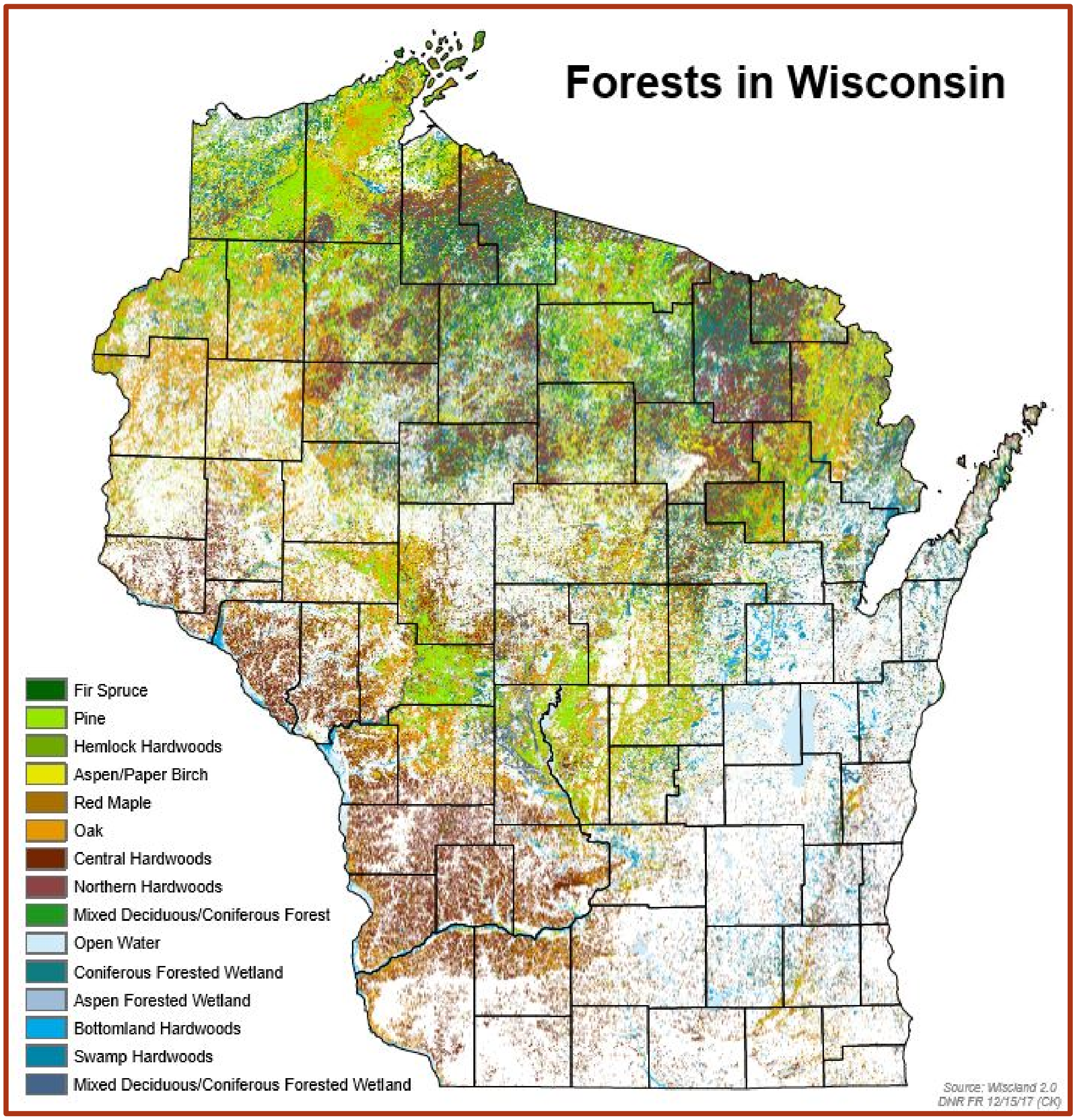
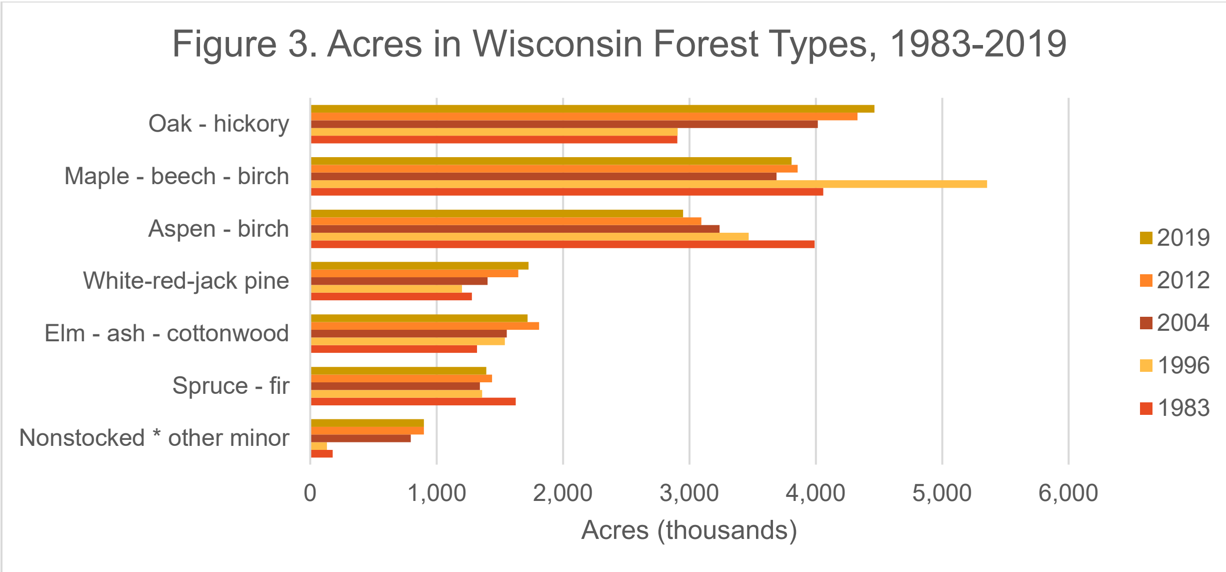


Figure 2. Wisconsin forest cover map. Source: WISCLAND land cover, Wisconsin Dept. of Natural Resources, 2017 (latest version).

Wisconsin's forests are composed primarily of hardwood species. The most abundant forest types are oak-hickory at 26% of total forested acreage; maple-beech-birch at 22%; and aspen-birch at 17% (Figure 3). Lowland forest dominated by elm and ash account for 10%. Conifer types, mainly pine and spruce-fir, represent about 18% of the forested area. Wisconsin forests are for the most part mature with the greatest proportion of stands in the 61-80 year class. The decline in acreage of the early successional aspen-birch forest type is related to the maturing of Wisconsin's forests. About 70% of Wisconsin's forest lands are privately owned, 10% are federally owned, and the remaining is split among state, local government and tribal ownership.



Outreach and Education

The Forest Health Program continued to utilize traditional and social media platforms in 2020 to inform and educate the public on forest health issues in Wisconsin. Due to restricted communications caused by the COVID-19 pandemic, the Forest Health Program utilized social media far less than in 2019, and engagement metrics were unavailable due to staffing shortages. The team issued a total of five Facebook posts and two Twitter posts in 2020. The Twitter posts accompanied news releases, which were also used sparingly this year. The predominant form of external communication was the monthly newsletter. A total of 49 articles were distributed to subscribers, and the total number of subscribers during this time grew by 15% from 2,961 to 3,406. This was slightly less growth than in 2019 (21% increase in subscribers).

In addition to media platforms, other communication outlets were also used in 2020. The team embarked on an effort to create new and update existing factsheets for top forest health issues in Wisconsin. Existing factsheets that were updated included those on Heterobasidion root disease (HRD) and oak wilt. Four new factsheets were created on environmental causes of tree damage, Diplodia shoot blight and canker, diseases affecting spruce trees, and emerald ash borer. More factsheets are in the process of being created, and the effort will continue in 2021. Several members of the team also saw to fruition a video project on HRD and preventive stump treatments that was completed in February 2020. The 5-minute educational video covers HRD biology, its significance as a tree disease, signs and symptoms, as well as preventative measures that landowners can take to reduce its introduction and spread. This video has been shared amongst partners and has received over 1,400 views since its creation.

Non-native Forest Health Threats

Beech bark disease

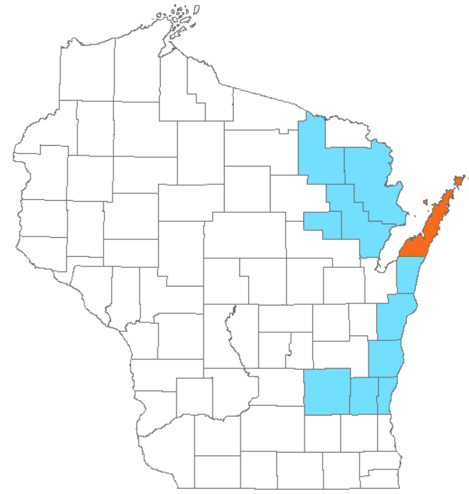


Figure 4. Counties with beech scale detections are shown in blue. Mortality from beech bark disease is limited to Door County in orange.

Beech bark disease is a fatal disease complex of American beech (*Fagus grandifolia*) composed of a scale insect (beech scale, *Cryptococcus fagisuga*) causing wounds that are subsequently infected by either of two related fungi, *Neonectria faginata* and *N. ditissima*. Both the scale and *N. faginata* are European in origin but *N. ditissima* is native to North America. In 2009, heavy infestations of beech scales and mortality of beech were detected for the first time in Wisconsin in Door County. In surveys done in 2012-13, beech scale was found to have spread through most of the Wisconsin range of American beech. The first confirmation of a *Neonectria* spp. on a beech tree in association with beech scale infestation and beech mortality in Wisconsin was in 2017 in Door County. Door County remains the only Wisconsin county where both components of beech bark disease have been found and where mortality from the disease has occurred in Wisconsin (Figure. 4).

Site visits in 2020 within the range of beech in eastern Wisconsin indicated that populations of beech scale remained very low everywhere other than Door County. Beech scale populations in Door County were variable and ranged from very low to very high even between nearby stands. Beech appears to be regenerating well in the portion of Whitefish Dunes State Park where many scale-infested mature beech were harvested in 2014.

Emerald ash borer (EAB, *Agrilus planipennis*)

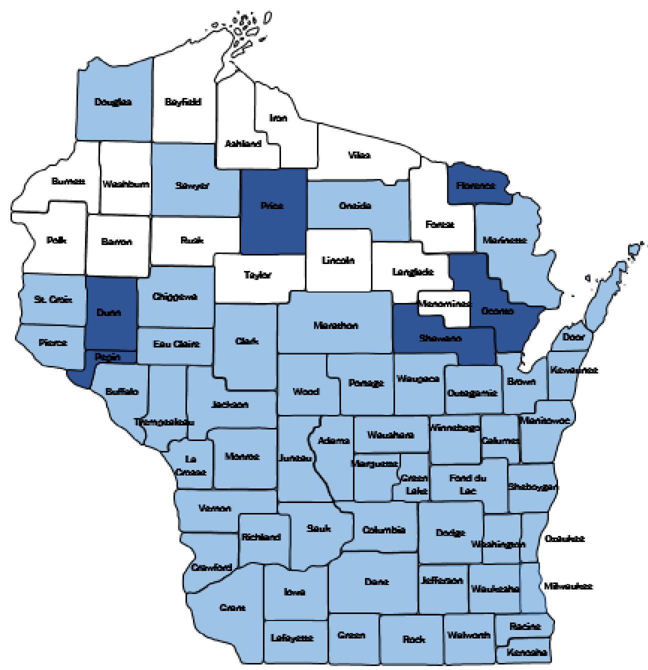


Figure 5. Wisconsin counties where EAB has been found. Counties in dark blue were confirmed in 2020. Those in light blue were confirmed in previous years.

Distribution of EAB in Wisconsin

In 2020, EAB was confirmed for the first time in Dunn, Florence, Oconto, Pepin, Price, and Shawano counties (Figure 5). The borer has now been found in 58 out of 72 counties in Wisconsin. The was no change in quarantine status as the entire state was placed under quarantine in spring of 2018. State agencies continue to record subsequent finds at the municipal level, and these indicate that EAB continues to spread within known infested counties (Figure 6). Subsequent confirmations are made from samples sent in by arborists, community foresters and the public and are identified by DNR or University of Wisconsin Extension staff. For a historical review of the spread of EAB in Wisconsin since its initial identification in 2008, see the report on this species in the Wisconsin DNR Forest Health 2016 Annual Report and subsequent annual reports. There was no trapping for EAB by federal or state agencies in the summer of 2020, though some counties trapped for EAB on their county forest land for use in planning harvests.

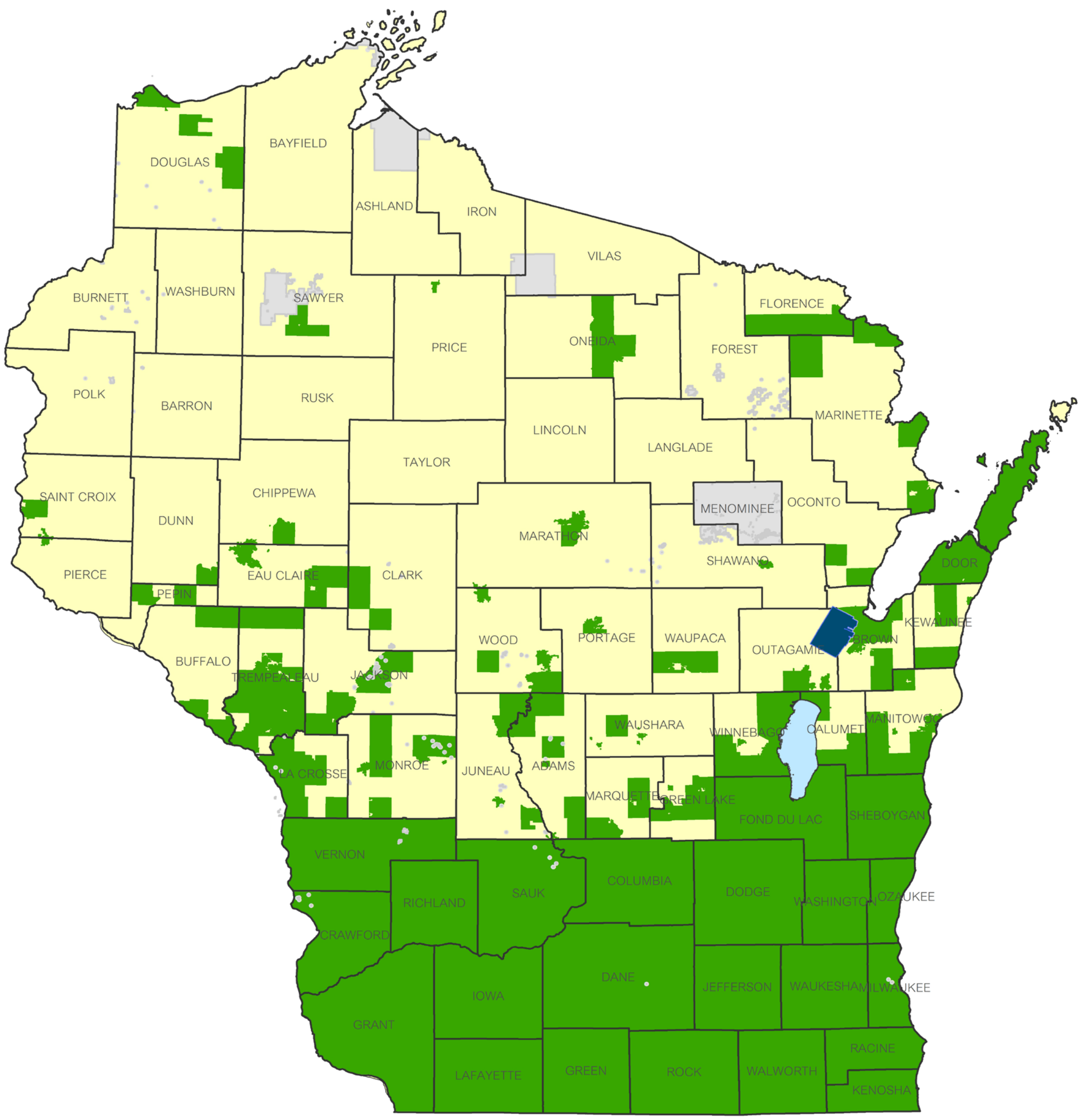


Figure 6. As of December 2020, EAB has been confirmed in municipalities indicated in green or dark blue for tribal land. Gray indicates a tribal jurisdiction where EAB has not been confirmed.

Damage from EAB in Wisconsin

Ash decline and mortality continued its inexorable spread in 2020 (Figure 7). Last year was the first year we mapped areas where >95% of the ash population had died: ~77,504 acres in the southeastern counties of Ozaukee, Racine, Kenosha and Walworth (Figure 8). In 2020, that area increased to ~91,033 acres in those and adjacent counties of Fond du Lac, Sheboygan, Washington, Waukesha, Milwaukee, and Rock. In some areas, wet forests are converting to marshland as cattails and reed canary grass replace ash killed by EAB. Loss of ash is causing ecological impacts in southern counties, where only 29% of the ash volume in the state is located. Black ash dominated swamps cover vast acreage in the northern half of the state and the impact of EAB will be profound there in the coming years.

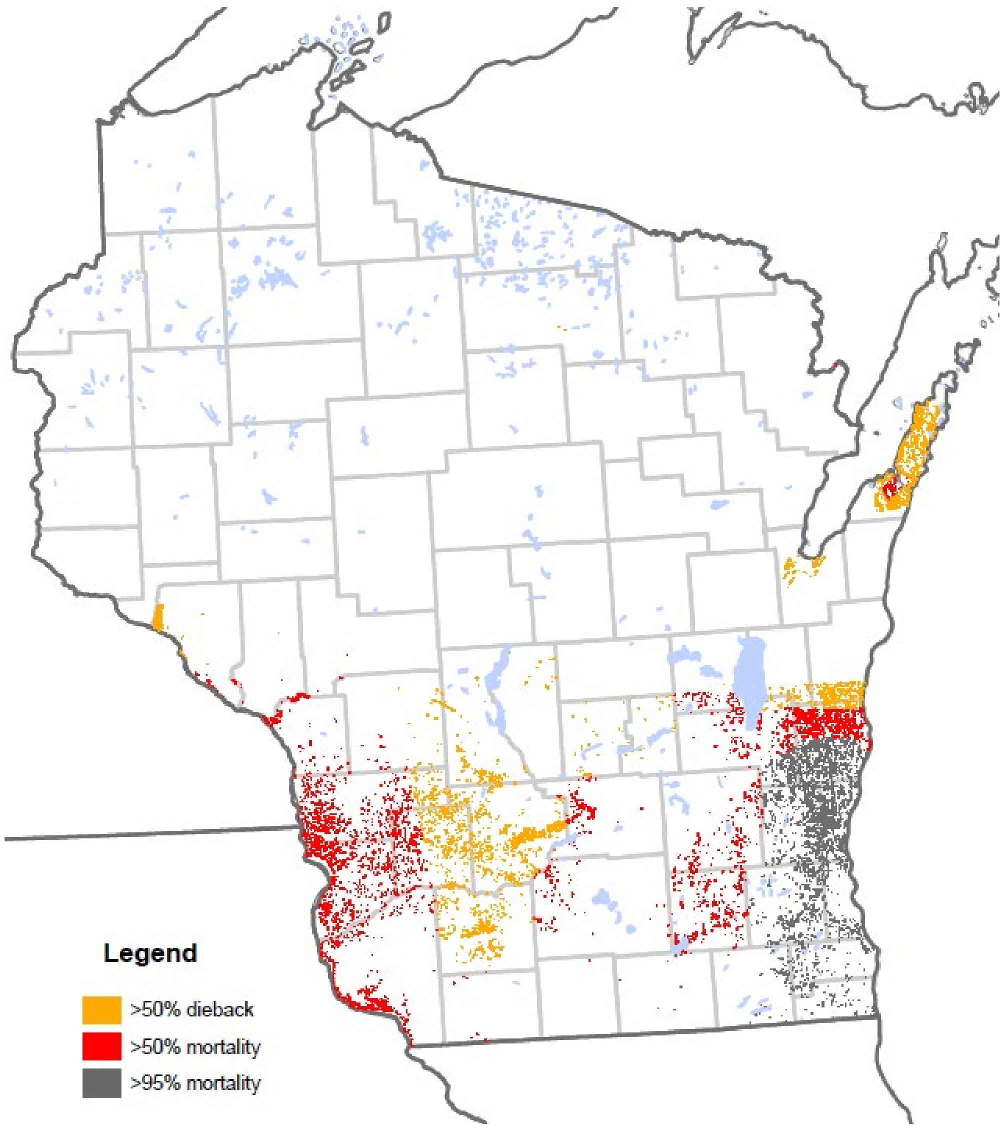


Figure 7. Damage from EAB to ash mapped in 2020. Area where damage occurred is overlaid with location of ash giving a stippled appearance. Crown decline predominated in areas marked in yellow. Mortality predominated in areas marked in red. Mortality in excess of 95% of the population, including mortality that occurred in previous years is tinted gray.

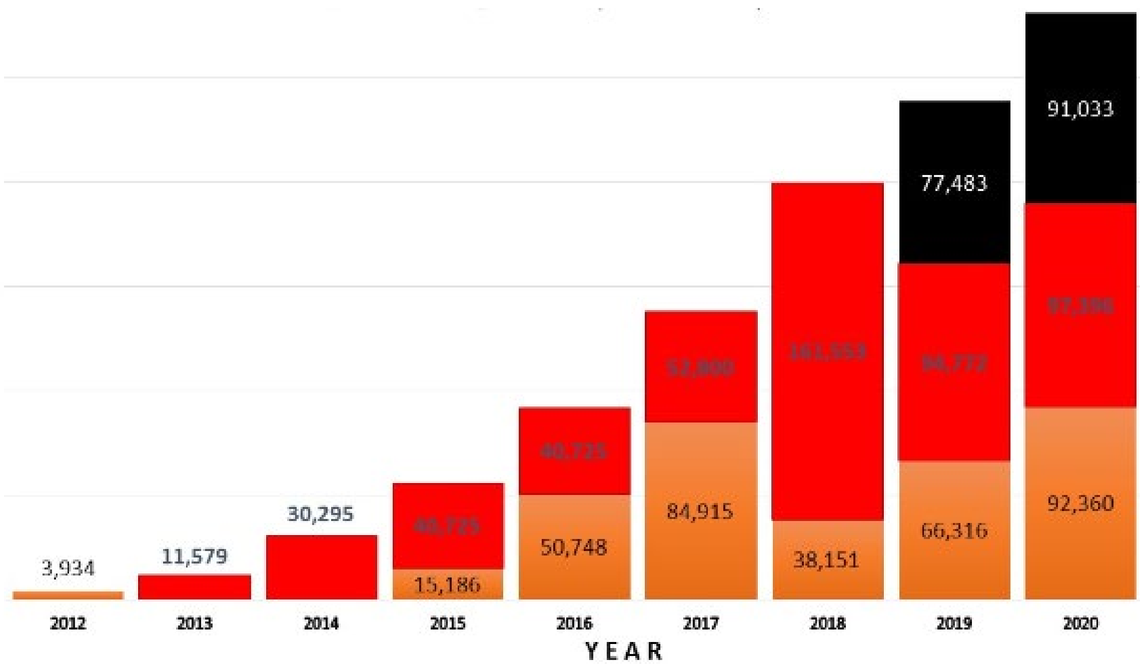


Figure 8. Acres of damage to ash caused by EAB from 2012, when damage was first mapped on the landscape scale, to 2020. Orange bars represent acres with >50% decline of ash, red bars represent acres with >50% mortality, and black bars represent cumulative acres where >95% of ash have died. Quinn Chavez, USDA FS

DNR Forest Health Program staff have mapped the extent of ash decline from EAB since it was first observable on a landscape scale in 2012. Mortality was added the following year, and mortality in excess of 95% of the ash population in 2019. To best represent the level of damage and distribution on the landscape an observer would experience, we have produced maps that show the distribution of ash at three course levels of damage. DNR staff defined polygons of three levels of impact on the ash population in an area: >50% dieback, >50% mortality, and >95% mortality. With the help of USDA Forest Service staff, the data on the distribution of ash collected by the Forest Inventory and Analysis Program was then layered onto the damage polygons to produce maps such as Figure 7. Together, we are producing maps on the progression of damage to ash from EAB over time to be presented as part of a story map on EAB, it's spread and impacts over time in Wisconsin. We expect to make this available to the public in 2021.

Biological control of EAB

2020 was the 10th consecutive year that natural enemies of EAB have been released in Wisconsin (Figure 9). All are tiny wasps, specific or nearly so to EAB, and the public is unlikely to ever see them due to their size. *Tetrastichus planipennisi, Spathius galinae*, and *Oobius agrili* were released monthly between mid-June and mid-September. The *Tetrastichus* and *Spathius* wasps attack EAB larvae beneath the bark, and the *Oobius* wasps attack EAB eggs on the bark surface. These introductions will provide downward pressure on EAB populations in the future, allowing for survival of ash trees with partial resistance to EAB. Parasitoids are reared by the USDA APHIS Plant Protection and Quarantine EAB Parasitoid Rearing Facility in Brighton, Michigan. The wasps are supplied to states with established populations of EAB at no cost.

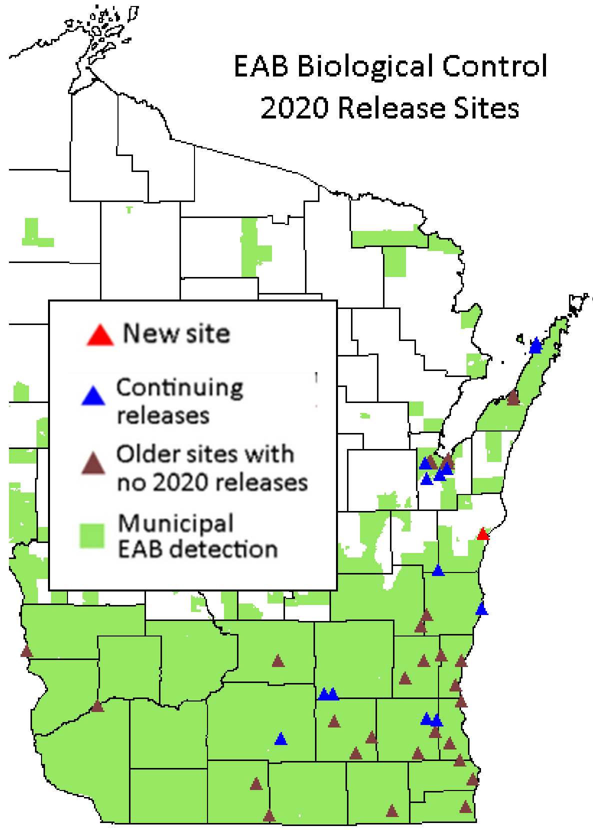


Figure 9. Map of release sites of EAB biocontrol agents 2011-2019 overlaid on locations where EAB has been confirmed present.

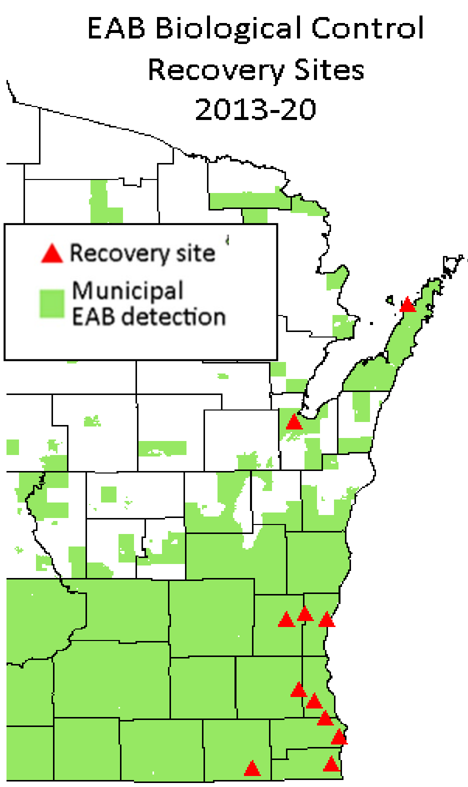


Figure 10. Release sites where *T. planipennisi* has been recovered.

This was the first year that USDA APHIS released wasps at sites identified by DNR or municipal staff. Parasitoids were released at 14 sites in seven counties (Figure 9). The site in the City of Manitowoc, Manitowoc County was the only new release site. This year's release was the second or third at all other sites. Wasps have now been released in 20 of Wisconsin's 72 counties. Total wasp numbers released this year were: 25,942 *Tetrastichus planipennisi*, 14,591 *Oobius agrili*, and 12,749 *Spathius galinae*.

Parasitoid recovery surveys begin two to three years after introductions to allow released parasitoid populations to increase to detectable levels. In 2020, recovery surveys were done at one site in each of Brown, Jefferson, and Washington and two sites in Door County. Yellow pan traps were used at the Jefferson County site to collect adult parasitoids. EAB infested ash were peeled at all other recovery survey sites to collect immature parasitoids. Bark samples were taken at Brown County site and at Peninsula State Park in Door County and are being incubated to try and recover egg parasitoid, *Oobius agrili*. *T. planipennisi* were recovered in former release sites in Green Bay and at Peninsula State Park. In previous years, *T. planipennisi* was recovered from introduction sites in seven southeastern counties: Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha (Figure 10). Native *Atanycolus sp.* parasitoids were found parasitizing 1-2% of EAB larvae at Peninsula State Park. Several unknown larval parasitoids were also recovered at Peninsula State Park and are being reared for identification as adults.

Gypsy moth (*Lymantria dispar*)

Gypsy moth is established in the eastern two-thirds of the state and 50 of Wisconsin's 72 counties are quarantined (Figure 11). Wisconsin's DATCP Slow the Spread (STS) program found reproducing but isolated populations in 10 non-quarantined counties. Those locations will be treated to reduce populations to levels where they cannot contribute to spread. Typically, a county is quarantined only when the STS program no longer treats reproducing populations detected there.

After two years of very low populations, indications are that the population is on the rise. There was an increase in reports of nuisance gypsy moth caterpillars, most from urban areas in the eastern portion of the quarantine region: Green Bay south to Kenosha and from the Madison area, though there were a few reports as far north as Eau Claire and Marinette counties. Moth catch was also up 62% from last year in the western counties trapped as part of the Slow the Spread program. A warmer winter in 2019-2020 and somewhat drier weather in the spring than we've had in the past two years likely contributed to higher survival of the pest and an increase in the population. While gypsy moth is rebounding, the population is still too low to cause significant damage. Only

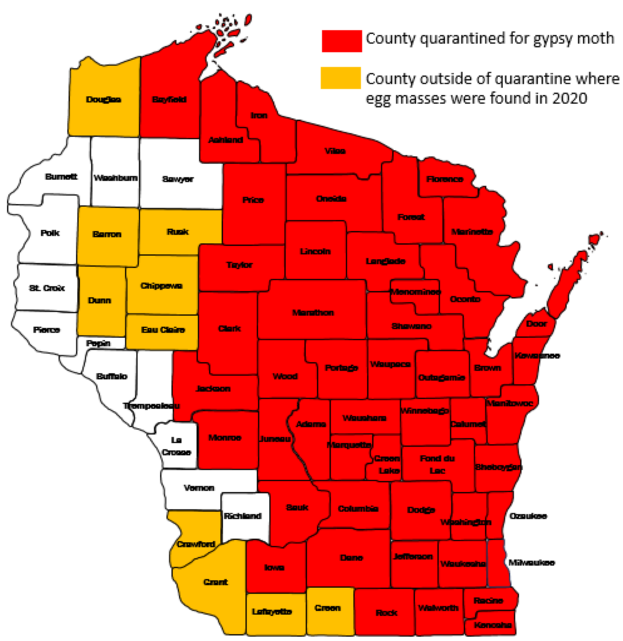


Figure 11. Wisconsin counties quarantined for gypsy moth (in red) and those outside the quarantine where egg masses were found in 2020 (in yellow).

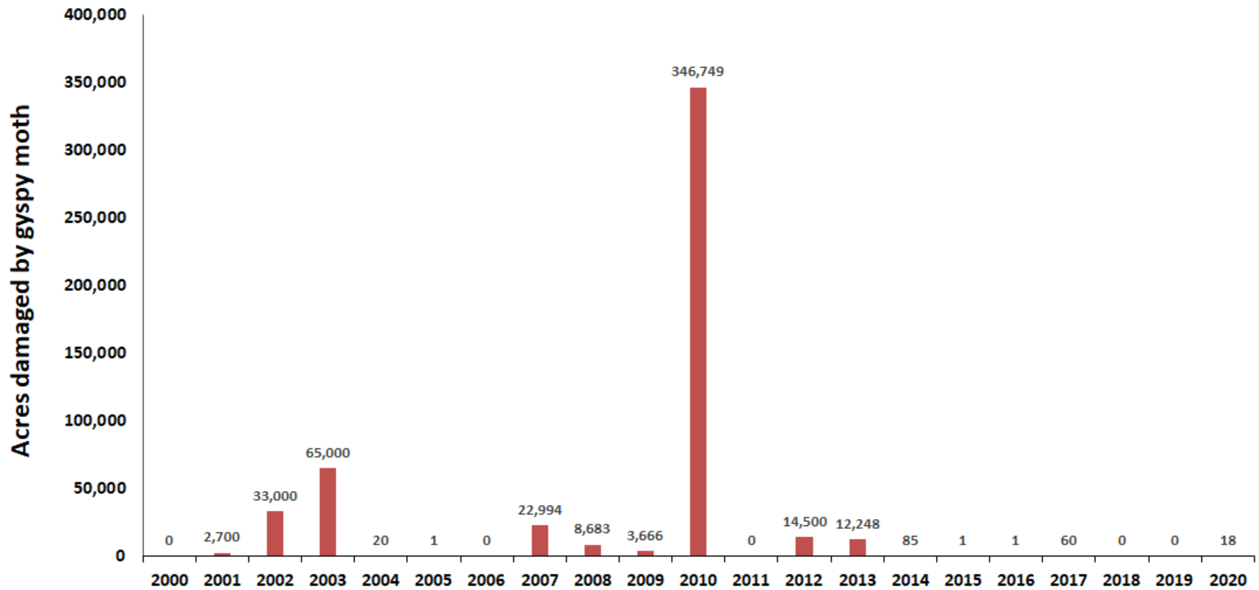


Figure 12. Acres damaged by gypsy moth each year since 2001 when first defoliation in Wisconsin was recorded.

18 acres of defoliation were mapped and those were of young reforestation plantings of red oak, swamp white oak, willow and tamarack (Figure 12). Because the trees were young and their volume of foliage small, they were defoliated by a gypsy moth population that was lower than would have been needed to cause visible damage to a mature woodlot.

An expanded revision of the DNR Forest Health Program's aerial spray recommendations was completed in June 2020. The revised "Organizing an Aerial Spray for Forest Pests: Recommendations and Regulations" guide is a resource for landowners, landowner groups, and local governments that are planning an aerial spray to prevent defoliation and mortality from gypsy moth or other defoliators. The guide was updated in collaboration with staff from several DNR programs and the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP). Revision of this guide completes the guidance on all options for management of gypsy moth from Wisconsin state agencies available at the Wisconsin gypsy moth portal, https://gypsymoth.wi.gov.

Heterobasidion root disease (HRD, *Heterobasidion irregulare*)

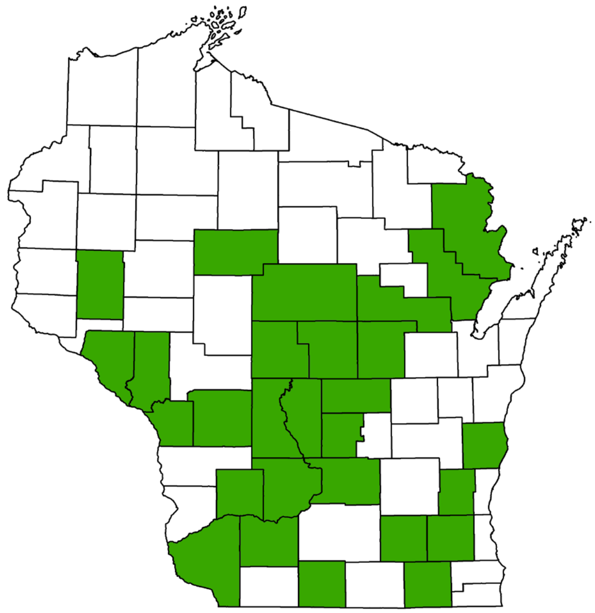


Figure 13. 2020 counties where HRD has been confirmed.

Heterobasidion root disease (HRD), caused by the fungus *Heterobasidion irregulare*, is one of the most destructive conifer diseases in temperate regions of the northern hemisphere. Trees with HRD exhibit thin crown, growth loss, wood decay and/or mortality. Mortality often occurs as an expanding pocket of dead trees. The pathogen is both an immediate and long-term concern because it can persist in a stand, making it difficult to regenerate the stand to desirable species.

HRD was first detected in Wisconsin in 1993 in Adams County. It is currently found in 28 of the state's 72 counties (Figure 13), in red and white pine and spruce plantations. No new infection sites were detected in 2020.

<u>Research on HRD</u>

Wisconsin DNR Forest Health Program staff worked with researchers at the University of Wisconsin – Stevens Point and Michigan State University to evaluate regeneration in HRD-infected red pine stands in Wisconsin and Michigan. Results indicate that most sites will likely convert to hardwoods over time due to continuing understory pine mortality from HRD. Demchik MC, Sakalidis ML, Hillstrom M, Scanlon K, Adams TA, Minnix KR. 2020. Evaluating Regeneration in Heterobasidion Root Disease Infested Stands in the Lake States**.** *Forest Science.* 66(2):141–144. The work was funded by an Evaluation Monitoring grant from the U.S. Forest Service.

The study to evaluate the efficacy of Cellu-Treat® and Rotstop™C, commercially available fungicides to prevent the spread of HRD, continued in 2020. This work is being done by researchers at the University of Wisconsin-Stevens Point and Michigan State University, with collaboration with Forest Health Program staff from the DNR's of Wisconsin and Michigan. This study is funded by a Pesticide Impact Assessment Program grant from the U.S. Forest Service.

<u>Outreach on HRD</u>

Forest Health Program staff created a short educational video of HRD that covers the disease's biology and preventive treatment. Staff also developed an interactive version of the HRD stump treatment guidelines to make it easier to obtain stand-specific recommendations. The user is asked a series of questions about the stand and a stand-specific recommendation is generated based on the answers. Both video and interactive guide are available at the Wisconsin DNR website pages on HRD.

HRD is a disease with a short history in Wisconsin and its spread has caused concern and a need for a better understanding of the factors influencing that spread. To address this need, the Forest Health Program staff collaborated with researchers at the University of Washington and Western Carolina University to investigate establishment patterns and spread of HRD in Wisconsin. They evaluated the relationship between stand characteristics and establishment of HRD in the state in order to model the risk of infection at a given geographical area in Wisconsin in the absence of management interventions. The year HRD infected a stand was assumed to be the year thinning was done prior to when the disease was confirmed in the stand, since fresh cut stumps are the primary avenue to infection. Spatial and temporal analyses of HRD infections showed they are clustered in space but are not clustered through time. Locational clustering is likely related to stand characteristics; site-specific soil and water characteristics, such as percent of sand, available water capacity, and distance to open water were identified as variables associated with HRD infection. This project identified that a more robust dataset would be needed to model risk, and that objective was not completed. This work was funded by the Wisconsin DNR, Division of Forestry, Applied Forestry Bureau Fund.

Invasive Plants

The invasive plant specialists administer two funding programs to assist with the control of invasive plants throughout the state: Weed Management Area-Private Forest Grant Program (WMA-PFGP) and Forest Health Program's invasive plant suppression fund. WMA-PFGP provides funding for control of woodland invasive plants on non-industrial private forests of less than 500 acres. In 2020, WMA-PFGP awarded 5 grants to regional partner groups. Projects funded included: direct control of invasive plants, outreach and educational materials on specific species, and a workshop demonstrating the use of goats to suppress woody invasive plants. The invasive plant suppression fund is available for use on public lands and this year supported survey and control projects across the state including the following two projects.

Work continued on control of Amur cork tree in and near the Northern Highland American Legion (NHAL) State Forest, where it could have a significant impact on this huge area of northern hardwood forest. In 2020, surveys were completed in six high priority locations. The survey revealed 3 additional cork tree sites, including one population of approximately 50 trees along a popular hiking/biking trail on the NHAL. The Forest Health Program's invasive plant suppression fund paid for these surveys.

The invasive plant suppression funds were also used to control wild parsnip along the Bearskin State Trail in Oneida County. Wild parsnip can inflict burns on people exposed to its sap. Burns occur when chemicals in the sap react with sunlight and can be severe and leave persistent scarring. In many cases invasive plants are a threat primarily to native plants and communities, but in this case, there was the added concern of injury to the people using the popular trail.

Invasive Worms (*Amynthas* spp.)

Forest communities in Wisconsin evolved following glaciation which eliminated worms from soils across the state. As a result, many of our native tree and herbaceous species are dependent on the thick layer of slowly decomposing leaf litter on the soil that can persist only in the absence of worms. European worms have been slowly spreading in Wisconsin for two centuries, inadvertently brought by early colonists and spread by human agriculture. Movement of worms into woodlands has accelerated in recent decades as more people move into and recreate in the "Northwoods." Where present, European worms slowly consume the leaf litter layer resulting in reduced survival of native tree seedlings and wildflowers. In recent years, new non-native worms from Asia have been found in Wisconsin, this group of related species is referred to as "jumping" worms. Unlike the European worms, the jumping worms are parthenogenetic which greatly increases their ability to successfully establish from a small starting population, or even one individual. Population growth is rapid as is the consumption of the leaf litter and it is this accelerated stripping of leaf litter that is cause for our concern.

Figure 14. Tinted counties represent the distribution of jumping worms in Wisconsin 2020.

Jumping worms in the genus *Amynthas* were first identified in Dane County in 2013 and have since been reported in 45 of the state's 72 counties (Figure 14). There was no change in the known distribution of these worms in 2020. Verified species in Wisconsin are *Amynthas tokioensis*, *A. agrestis*, and the closely related, though larger, *Metaphire hilgandorfi*, first identified in September 2017. *A. tokioensis* is the most common of the three species. *A. agrestis* typically appears in combination with *A. tokioensis*. Jumping worms have so far been found primarily in urban or residential areas. This may reflect their long distance spread by people moving plants, mulch and soil for use around their homes. Or it may be due to reporting bias; there is no formal survey for jumping worms in Wisconsin. All specimens are submitted by the public and are typically collected near where the submitter lives.

<u>Research</u>

Since 2018, the DNR Forest Health Program has funded research on jumping worms as little is known about this group or its management. Brad Herrick and Marie Johnston (University of Wisconsin Arboretum) conducted two studies and expect to publish the results in 2021. Their findings include,

- *A. tokioensis* performed best on maple leaf litter relative to oak, pine, C4 grass, and no leaf litter,
- *A. agrestis* survived best in combination with *A. tokioensis*,

- Hatchling worms are found throughout the growing season and in years following removal and exclusion of adult worms, supporting the persistence of a viable "cocoon bank" of these *Amynthas* species which can lead to re-infestation following treatment to kill worms, and

- The organic, low-N fertilizer marketed as Early Bird was effective in killing worms when applied at 3, 10, and 25% dilutions.

Unfortunately, Early Bird fertilizer is no longer produced. A potential substitute, Castaway, which also contains saponins from tea tree oil, has become available and will be tested in 2021.

Oak wilt (*Bretziella fagacearum*)

Oak wilt disease is caused by the pathogenic fungus *Bretziella fagacearum* (previously known as *Ceratocystis fagacearum*). It kills oaks in the red oak group within a year of infection. Oaks in the white oak group can compartmentalize the disease but may also succumb from the infection over time.

It was not until 1964 that the WI DNR developed a disease distribution map by county, at which time oak wilt was found in the lower two-thirds of the state except the Door Peninsula and adjoining counties along the shoreline. Since then, forest health specialists have tracked the expansion of this disease northward in the state. For a map of the history of spread of oak wilt at the county level, see the Wisconsin DNR Forest Health 2019 Annual Report. Currently, oak wilt is known to be present in all but 7 counties in the central-north and along the Lake Michigan shore from the Door Peninsula south to Manitowoc County (Figure 14). In 2020, oak wilt was confirmed for the first time in the Town of Pine Lake in Oneida County and in the Town of Oakland in Douglas County. Vilas and Washburn counties were recognized as having oak wilt generally present after discussion with foresters, both public and private, as well as loggers in those counties. This consultation is done because this designation has implications for the need

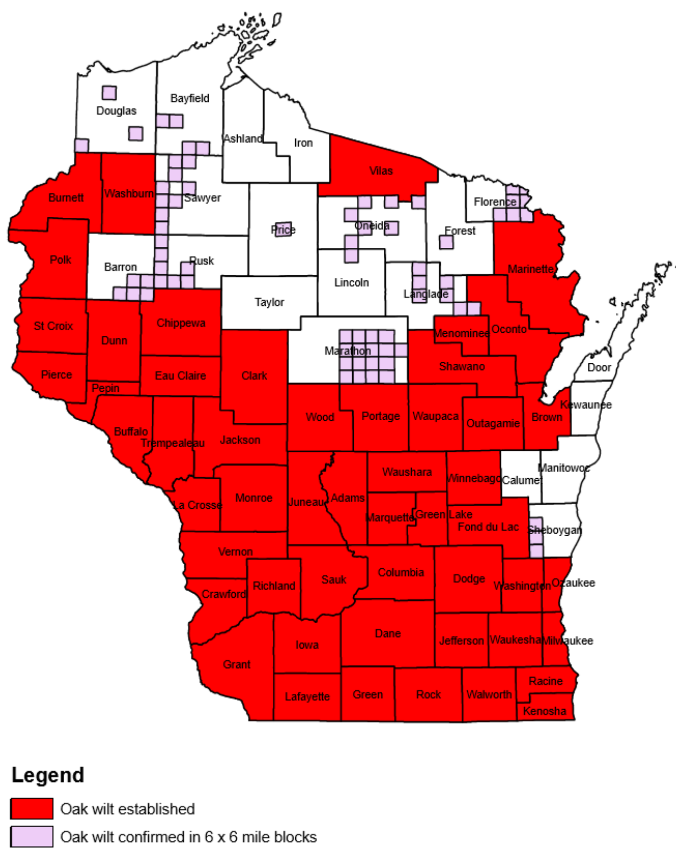


Figure 15. Oak wilt is generally established in counties tinted red. It has been confirmed in townships tinted pink in otherwise non-infested counties. Dec. 2020.

to take precautions to prevent oak wilt transmission during thinning or harvesting. See Oak Harvesting Guidelines to Reduce the Risk of Introduction and Spread of Oak Wilt available at dnr.wi.gov . Oak wilt continues to be the most important pathogen of Wisconsin's native oak species. Forest health specialists will continue to monitor the spread of oak wilt and stay abreast of new diagnostic tools and management options as they are developed.

Research on oak wilt

Once one tree in a stand is infected with oak wilt, the disease can spread through root grafts to kill all connected oaks in the stand. Oak wilt can be contained by breaking these root grafts to uninfected trees. This is currently done by trenching or uprooting oaks but these both require expensive equipment and access to the site which limits their practical use in forests. Some forest managers have tried creating a buffer of dead roots around infections by killing potentially connected trees with girdling and application of herbicide. To formally test this technique and make its use eligible for grant support from the USDA Forest Service, in 2015 DNR staff started a 5-year study to evaluate the effectiveness of this method. As some sites were not treated until 2016, data collection continued in 2020 to allow all sites a full four years of observation following the year of treatment. Data analysis is in process.

Phytophthora ramorum

Phytophthora ramorum is a fungus-like organism that causes the death of a wide range of trees and shrubs, but it is the destructive impact on oaks in states along the Pacific coast that lead to its common name, Sudden Oak Death (SOD). In 2019, the Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP) was alerted that 59 retail stores and nurseries in Wisconsin had received nursery stock possibly infected with *P. ramorum*. Unfortunately, notification came too late to retrieve all the stock shipped but DATCP was able to test plants from 43 businesses, and one sample tested positive for *P. ramorum*. This result is concerning as it suggests that some of the already sold plants may have been carrying the disease. The US Forest Service is supporting stream bait detection surveys in Wisconsin and other states who received potentially infected plants from the nursery that violated quarantine. These surveys target forested environments near retail stores and nurseries that may have received infected nursery stock. Surveys were scheduled to start in the spring of 2020, however, due to COVID-19 restrictions, no fieldwork was allowed until the end of June. Staff were able to collect samples at five sites before the water temperatures became too warm. Surveying restarted when temperatures cooled in fall and samples were collected at 14 more sites for a total of 19 sites surveyed in 2020. Samples from the five sites surveyed in spring have all tested negative for *P. ramorum*. Testing of samples from the fall collections is not yet complete. We are hopeful to continue the stream bait survey and sample additional sites during the spring of 2021.

Native Health Threats to Hardwoods

Bur oak blight (*Tubakia iowensis*)

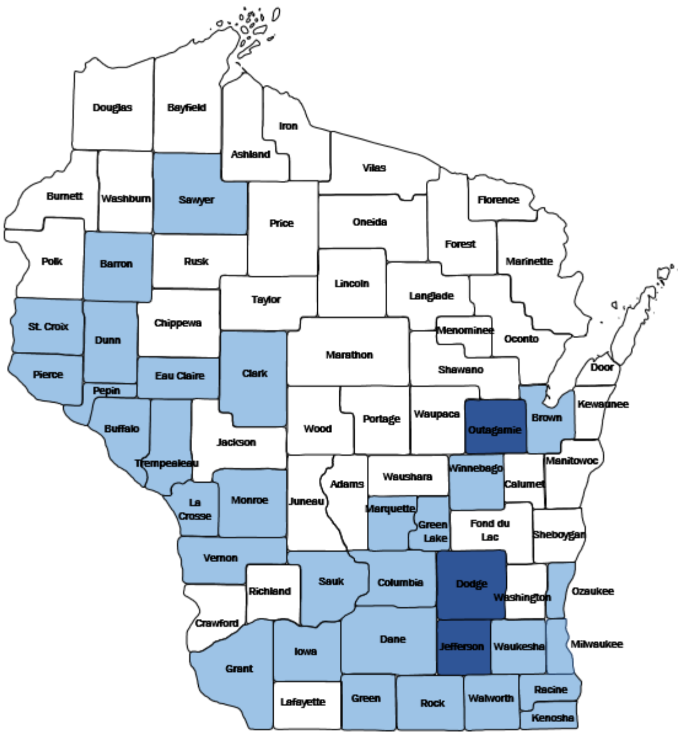


Figure 16. Counties where bur oak blight was detected in 2020 are tinted dark blue. Counties where it was confirmed in previous years are light blue.

Bur oak blight, caused by the fungus *Tubakia iowensis*, was confirmed in three new counties in 2020: Dodge, Jefferson and Outagamie. Bur oak blight has now been confirmed in 33 counties in Wisconsin since it was first detected in 2010. (Figure 15). Bur oak blight symptoms are most common in the lower half of bur oak canopies. Wedge-shaped yellow and brown patches on the leaves and purple/black leaf veins are the most obvious symptoms. Trees may decline over many years as the fungus spreads through the canopy. After several consecutive wet years, bur oak blight symptoms seemed more severe in 2020 than in past years.

Defoliators

After several years of low populations, defoliators of hardwoods were more common in 2020.

<u>Forest tent caterpillar</u>

Populations increased across northern Wisconsin but even locally high populations in Oneida County caused only light defoliation. The last forest tent caterpillar outbreak in Wisconsin ended in 2002 and in the 20th century they could be expected every ten years, so another large-scale outbreak is overdue. Eastern tent caterpillar populations increased slightly in 2020 but remained relatively low across Wisconsin.

Periodic native defoliators

Approximately 1000 acres of hardwoods were defoliated at Devil's Lake State Park (Figure 17). Hickory, maple and ash were 25-75% defoliated with only minor damage on other hardwood species. Elm and maple spanworms were responsible for most of the defoliation except on hickory where *Datana* spp. caterpillars were the primary defoliators. In northern Wisconsin, green striped mapleworm was found defoliating understory maple. Damage was scattered but severe in some locations. Linden looper was active in Rusk County Forest causing <50% defoliation on about 356 acres of mixed northern hardwood forest.

Figure 17. Defoliated deciduous trees at Devil's Lake State Park.

Basswood thrips

Surveys for basswood thrips occurred late because of COVID-19 restrictions but thrips damage is suspected in Forest, Marinette, and Oconto counties. Wisconsin has not had a basswood thrips outbreak for several years so more field work will be needed in 2021 to determine the status of this pest.

Sawflies

This foliage feeding hymenopteran larvae were more abundant in 2020 with a range of sawfly species feeding on deciduous trees. Damage was localized.

Cherry scallop shell moth

The outbreak of this species that started in 2016 continued this year, defoliating the same 1700-acre area of southeastern Wisconsin. It is unknown why this outbreak is persisting for so long in this location, but the accumulated stress is resulting in decline and mortality of cherry trees.

Novel damage to black walnut

Approximately 50 acres of moderate to heavy defoliation of black walnut occurred in Green County. Several defoliating insects were found in small numbers but none at population levels that explained the amount of defoliation observed. In addition, the walnut stems were heavily covered with suspected spider mite webbing. More investigation is needed as this is the first report of damage like this to walnut in Wisconsin. Discussions with Iowa and Minnesota forest health staff revealed they also had isolated areas of this novel damage in 2020.

Other oak health issues

Oaks continued to be afflicted with a variety of health issues in 2020. Insect issues were minor and included two-lined chestnut borer infesting flooded oaks at a few sites, localized twig dieback from kermes scale, a variety of leaf and twig galls (Figure 18) and an increase in native defoliator populations. Oak twig pruner damage was not recorded in 2020.

Continued wet spring weather resulted in numerous disease issues in 2020. *Botryosphaeria* impacted one quarter to one third of branch tips on more than fifty percent of northern pin and northern red oaks in some areas of northeastern Wisconsin. Damage from *Botryosphaeria* in other Forest Health Program zones was typically minor. An unexpected find was Coryneum twig blight and canker causing severe twig dieback on white oaks in Vilas and Marinette counties. Leaf pathogens, including *Tubakia* and anthracnose continued to be common in some areas.

Decline of mature white oak species continued to be discovered but damage seemed less severe in 2020. Drought followed by historically wet conditions and repeated spring frost damage are the primary abiotic stressors contributing to decline.

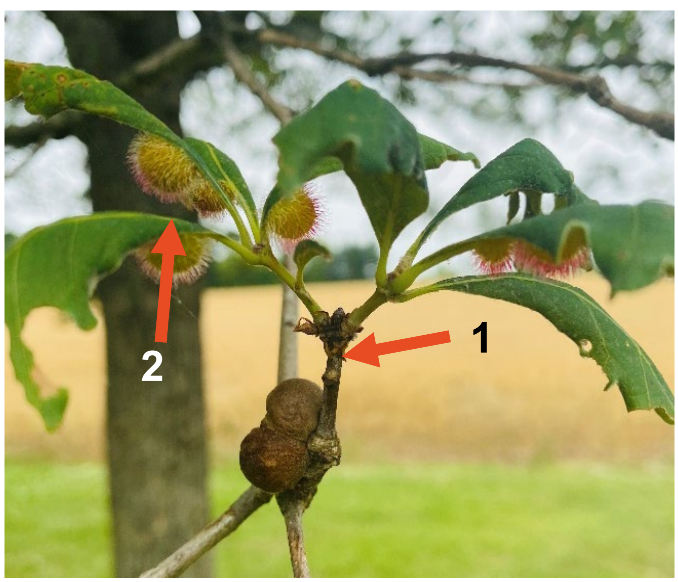


Figure 18. Oak twig with bullet galls (1), hedgehog galls (2), and herbicide damage to the leaves.

Phytoplasma (*Candidatus Phytoplasma fraxini*)

Phytoplasmas are plant-parasitic bacteria that lack cell walls. In host trees, infection symptoms include dense branch growth, formation of branch clusters (i.e., witches' brooms), dwarfed or malformed foliage, foliar discoloration (e.g., yellowing), growth decline, vertical bark cracks, crown thinning, dieback and/or mortality. Phytoplasma is commonly called "yellows disease" due to the often-observed foliage chlorosis it causes.

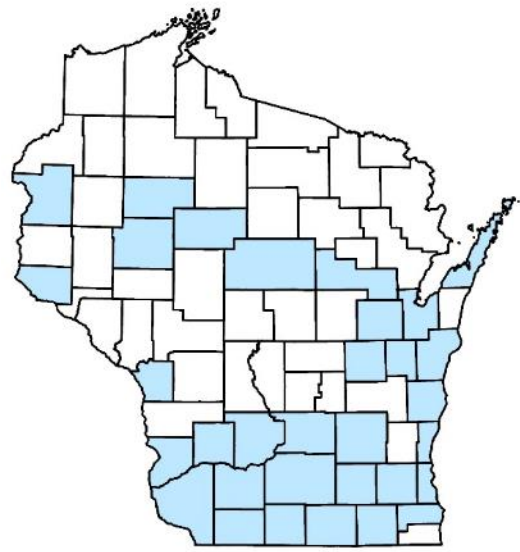


Figure 19. Counties in Wisconsin where phytoplasma has been confirmed are tinted blue.

Ash yellows is the most commonly known phytoplasma disease in Wisconsin. First confirmed on white ash in 1987, the disease has since been confirmed in 32 counties in Wisconsin (Figure 19) and in 16 tree and shrub species using the genetic testing method of polymerase chain reaction (PCR). Host species confirmed with phytoplasma include American beech, ash (black, green, and white), black walnut, butternut, chokecherry, elm, hazelnut, bitternut and shagbark hickories, lilac, red maple, white mulberry, white spruce, and swamp white oak.

<u>Research</u>

Wisconsin DNR Forest Health Program continued a partnership initiated in 2019 with the University of Wisconsin Plant Disease Diagnostic Lab to improve detections of phytoplasma on a variety of tree species in Wisconsin using molecular methods. Approximately 100 samples were collected and two molecular methods (endpoint PCR and qPCR) were compared for their sensitivity and specificity in phytoplasma species identification. Positive samples will be further identified to taxonomic groups/sub-groups, with results expected in 2021.

It is currently thought that one route of the spread of phytoplasma is by sucking insects acquiring and transferring the phytoplasma during feeding. We wanted to determine if the tests we were using to detect phytoplasma in tree tissue would also detect it in samples from insects. Seventeen leafhoppers and planthoppers were collected from several species of trees, some of which had tested positive for phytoplasma. Two of these insects tested positive and both had been collected from trees confirmed to be infected with phytoplasma. These results suggest that the endpoint PCR and qPCR could be used to investigate transmission of phytoplasma by insects.

Native Health Threats to Conifers

Caliciopsis canker disease (*Caliciopsis* spp.)

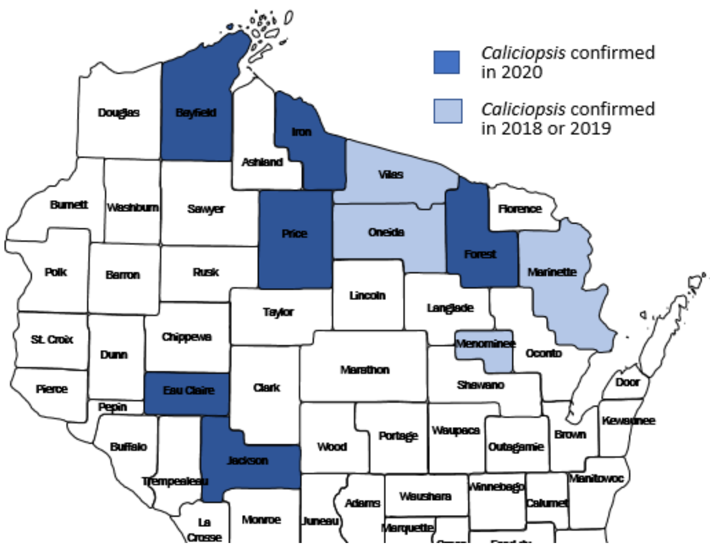


Figure 20. Counties where Caliciopsis has been confirmed in 2020 and previous two years

Caliciopsis canker is a recently detected disease complex in Wisconsin, though it has been causing branch loss in Eastern white pine since the late 1990's in the northeastern states, Quebec and Ontario. The first observations in Wisconsin were made in 2018 on pole-sized white pine in the northern part of the state. In 2020, Caliciopsis canker was found on eastern white pine in Bayfield, Eau Claire, Forest, Iron, Jackson and Price counties (Figure 20). Previously, it had been confirmed in Marinette, Menominee, Oneida, and Vilas counties.

Caliciopsis spp*.* causes small cankers and as the number of cankers increases, they eventually girdle the branch causing the foliage to brown and die. These symptoms can be mistaken for those of white pine blister rust. It appears that *Caliciopsis* spp*.* is associated with the native white pine bast scale (*Matsucoccus macrocicatrices*) as they often co-occur, though their relationship is not fully understood. Bast scale was seen associated with heavy flagging in northwestern Wisconsin this year. It is possible that Caliciopsis canker was involved, although none was confirmed in this area. Bast scale by itself has not previously been known to cause problems in white pine and there may be additional factors involved when branch mortality like this occurs.

As part of a study to determine the distribution and incidence of Caliciopsis canker on eastern white pine in the Lake States, Forest Health Program staff sent wood samples with fruiting structures of *Caliciopsis* spp. to Dr. Monique Sakalidis and her graduate student Rebecca Harkness, at Michigan State University. They will identify the species of *Caliciopsis* and provide a better understanding of this recently emerging disease in the upper-Midwest.

Eastern larch beetle (*Dendroctonus simplex*) and Larch casebearer (*Coleophora laricella*)

Eastern larch beetle (ELB) is a native bark beetle that infests its host tree species, eastern tamarack, throughout its entire North American range. The beetle kills trees by tunneling and feeding under the bark, severing the nutrient flow. Annual mapping efforts over the last 20 years by the Wisconsin DNR Forest Health Program have shown an increasing acreage of tamarack mortality caused by ELB. While damage was not mapped in 2020, Forest Health Program staff observed additional mortality of tamarack scattered across northern Wisconsin owing in part to ELB infestation. High water levels in the preceding 3 years likely exacerbated tamarack mortality levels, along with an introduced, but now naturalized, needle defoliator—larch casebearer.

Larch casebearer (LCB) is an introduced defoliator of eastern tamarack whose larvae consume host needles early in the spring. Defoliation usually leads to the production of a second flush of needle growth in early summer but is energetically taxing to tamarack and causes additional stress; such stress may facilitate infestation by the ELB. Staff mapped a total of 764 acres with LCB defoliation, of which the most severe cases were observed in Vilas and Oneida counties. Between 10 and 20% of the defoliated tamarack was co-infested by ELB and consequently could not successfully complete a second flush of needle growth before being killed this year.

Jack Pine Budworm (*Choristoneura pinus*)

Jack pine budworm, a native defoliator of jack pine and other conifers, caused defoliation of its namesake scattered across 2,257 acres in the Town of Clearfield, Juneau County. Most of the defoliation was light to moderate though open grown jack pine along roadways had moderate to heavy defoliation. The difference in impact is probably due to greater sun exposure and warmth along the forest edge favoring larval survival and leading to higher populations and feeding impact along roadways. While jack pine budworm has fed on red pines in recent years, there was no evidence of defoliation in the adjacent red pine stand in 2020.

This summer a predictive egg mass survey was done in the same area where damage was recorded. Based on the number of masses found, moderate to severe defoliation of jack pine in this area can be expected again in 2021. The severity of the defoliation will depend on the overwintering survival rate of budworm larvae. Interestingly, egg masses were also found in the adjacent red pine stand which could result in light to moderate defoliation to the red pine.

Pine wood nematode (*Bursaphelenchus xylophilus*)

Pine wood nematode (PWN) was found to be infecting Scotch pine in Waushara County in 2019. There were no new reports of PWN affecting pine populations in 2020. Symptoms of pine wood nematode include rapid crown browning (within 3 months) in late summer, rapid drying of wood, and presence of blue-stain fungi in the wood. This pest causes a severe disease of pine in Japan; however, it is not known to cause the same severe disease here in pines native to the Midwest. But non-native pines planted in Wisconsin such as Scotch and Austrian are highly susceptible (Figure 21). Maintaining stand vigor and following Best Management Practices regarding order of removal will further reduce the risk for introduction.

PWN is native to North America but was first found in Wisconsin in 1980 and has since been found across the state. PWN is vectored and carried to susceptible trees by long horned beetles such as the White Spotted Sawyer Beetle, a native beetle to Wisconsin. Wisconsin's native long horned beetles usually only affect dying and dead trees suggesting that the potential for PWN to affect healthy native trees is relatively low. Additionally, PWN is closely associated with blue-stain fungi which they use as a food source. Blue stain fungi are also often brought into stressed pines by insects.

Figure 21. Scotch pine dying from pine wood nematode.

Rhizosphaera on spruce (*Rhizosphaera kalkhoffii*)

Rhizosphaera needle cast continued to impact many yard and forest trees in 2020 due to the continued above average rainfall since 2016. In the Northeast, Rhizosphaera was reported causing less damage than that seen in 2019. However, in the central counties, progression from mild to severe disease impact is being seen in as little as one year. Colorado blue spruce are the most susceptible, but white and black spruce are also heavily impacted. Infected needles turn a dull purple-brown color and are prematurely shed. It is common to see the bottom quarter to three quarters of a tree containing only one year's worth of needles. Some trees are completely defoliated and are likely to die as a result.

Sawflies

Several species of these foliage feeding hymenopteran larvae were more abundant on conifers, as well as deciduous trees, in 2020. Multiple reports were made of redheaded pine sawfly, white pine sawfly, and balsam fir sawfly defoliating pines. Damage was localized.

Spruce budworm (*Choristoneura fumiferana*)

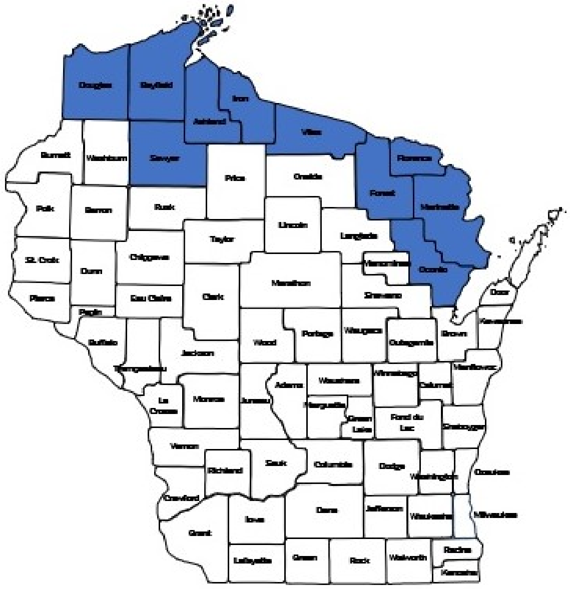


Figure 22. Counties shaded in blue had significant defoliation from spruce budworm in 2020, as well as some top mortality and whole tree mortality.

The current outbreak of spruce budworm (*Choristoneura fumiferana*) continued for another year (Figure 22). Defoliation greatly increased compared to 2019 and was severe in many counties in northern Wisconsin. Balsam fir was more heavily defoliated than spruce. Feeding by this native caterpillar for several years in a row can cause trees to start to decline and even die, which is occurring in areas of northern Wisconsin. Due to COVID-19 restrictions, Forest Health Program staff were not able to fly to map the defoliation in 2020.

Spruce budworm outbreaks typically last about 10 years. The current outbreak started in approximately 2012 and will probably continue for a few more years before collapsing. Literature indicates that some budworm populations will collapse once they have exhausted the food source in an area. This is happening in some places where severely defoliated trees are now dead or dying.

Outbreaks of this insect occur every 30-50 years. Our last outbreak in Wisconsin occurred from 1970-1980 with 180,000 acres impacted in the final year of the outbreak. Spruce budworm does not completely disappear in between outbreaks and there are often a few areas of defoliation that can be found each year somewhere in the state, but this is different than the vast areas of significant defoliation and tree mortality that occurs during an outbreak.

For the second year in a row, Forest Health Program staff noted a few balsam fir sawflies in areas where spruce budworm is defoliating balsam fir stands. These balsam fir sawflies were all the “dark morph” color (Figure 23). Balsam fir sawfly hatches later than spruce budworm and feeds on the previous year’s needles. In these areas, spruce budworm is still the primary defoliator so it’s unclear how much of a problem this is although a Canadian Forest Service document mentioned an association between the two. It’s worth noting that balsam fir sawfly has not been a significant issue in Wisconsin since 1995 when a stand was lightly defoliated in Door County. Wisconsin also saw what might be called outbreaks of balsam fir sawfly in the late 1950s and again in the late 1980s.

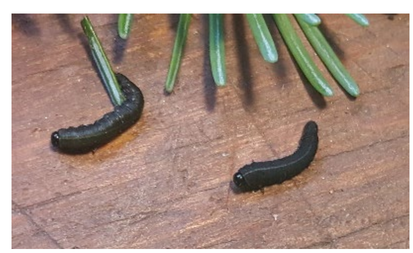


Fig 23. Balsam fir sawfly (dark morph phase) has been reported in some areas already defoliated by spruce budworm.

State nursery studies

Asymptomatic infection by *Diplodia sapinea* in state nursery stock

Asymptomatic infection by *Diplodia sapinea* in red pine seedlings can result in failure of the plantation if the disease becomes symptomatic after planting. To prevent this, healthy-looking red pine seedlings from the Wilson State Nursery are tested annually to assess for asymptomatic infection prior to sale. Asymptomatic infection rate must be 10% or less or the stock will not be sold.

- In October 2020, one-year old red pine seedlings had an asymptomatic infection rate of 3.1% (287 seedlings tested). This was higher than the rate in one-year old seedings in 2019 of 1.4% (255 seedlings tested)

- The infection rate for 2-year old seedlings (252 seedlings tested) was 6.3%. It was an increase in the asymptomatic infection rate from 1.4% of the same cohort as 1-year old seedlings in 2019. This 4.9% increase in infection is higher than the historical average for the same growth stage and investigation on potential cause(s) is in progress.

- The infection rate for 3-year old seedlings (279 seedlings tested) was 5.7%, down from 7.6% for that cohort in 2019.

Survey of galls on jack pine seedlings at the Wilson Nursery

The incidence of galls on jack pine seedlings caused by rust fungi has typically been very low at the Wilson Nursery and only one species of rust has been identified there, *Cronartium quercuum* (pine-oak gall rust). Annual surveys conducted in 2009-2012 found a 0%-0.5% incidence rate on one-year old jack pine seedlings. However in 2017, the rate of galling on one-year-old jack pine seedlings jumped to 2.9% (1000 seedlings sampled). In response, Wilson Nursery implemented fungicide applications to control this problem during the 2017 and 2018 growing seasons. In 2018, no galling was found in samples of 1000 seedings of each of the 1 and 2-year-old cohorts of jack pine. In April 2019, this survey was repeated for 1-year-old seedlings at the time of lifting and the gall incidence rate was 0.2%. In the spring of 2020, 1000 seedlings of each of the 1 and 2-year-old cohorts of jack pine were visually inspected for the presence of galls at the time of lifting. The gall incidence rate was 0.2% for 1-year old jack pine and 1% for 2-year old jack pine. This rate is still higher than desired and for this reason, monitoring for galling will continue for 1-year-old cohort of seedlings lifted in spring 2021.

Cherry leaf spot (*Blumeriella jaapii*)

Severe necrosis and defoliation on choke cherry were observed this summer in the Wilson Nursery. Based on the leaf symptoms, spore morphology, and presence of oozing conidia in cirrhi, the causal fungus was identified as *Blumeriella jaapii*. Cherry leaf spot caused by *B. jaapii* is a major disease of cherry in the Great Lakes region and the nursery typically treats to prevent it with myclobutanil, a sterol demethylation inhibitor fungicide. However, local resistance to sterol demethylation inhibitor fungicides was recently reported in populations of *B. jaapii* and we suspect the emergence of this disease on treated choke cherry may indicate resistance is developing in the fungus population at the nursery. To prevent this, in 2021 the nursery staff will switch to treatments of a fungicide of a different class. Mancozeb, thiophanate methyl, or chlorothalonil are being considered.

Root rot on tamarack (*Fusarium oxysporum*)

A light level of tamarack seedling mortality was observed this summer at the nursery. Discolored roots were cultured on selective media from symptomatic tamarack seedlings and *Fusarium* spp. grew from 4 out of 7 seedling samples. DNA sequencing identified the species as *F. oxysporum*. Several *Fusarium* species, including *F. oxysporum*, cause seedling root decay, seed decay, stem cankers, and wilt.

White pine health issues

Throughout the state, white pines showed off-colored foliage, twig flagging, thinning crowns and overall decline in 2020. The above average precipitation of this year and the past four years was a major contributing factor to these symptoms, as excess precipitation can create or exacerbate soil issues and promote the growth and spread of fungal pathogens.

White pines prefer soils that are well drained, light, and somewhat acidic. When planted in dense, wet, or alkaline soils, or planted improperly, white pines are stressed and more susceptible to insects and disease. Soil issues were a predisposing factor to disease or pest attack at many sites, while at others they alone were the primary cause of decline. The latter was especially the case on marginal sites with alkaline soils in southern and central counties of the state, as high soil pH makes nutrients present in the soil harder for plants to absorb. This issue was exacerbated by high precipitation, which leached nutrients from the soil. Wet weather in this and the past four years, in addition to directly stressing pine with saturated soils, allowed the build-up of a variety of pathogens including,

- Brown spot needle blight, a needlecast disease caused by *Lecanosticta acicula* (previously known as *Mycosphaerella dearnessii*), was observed in northern and southwestern areas of the state in higher than normal levels (Figure 22).
- Dook's needle blight, caused by *Lophophacidium dooksii* (previously known as *Canavirgella banfieldii*) was isolated from symptomatic trees in the west-central part of the state.
- Phomopsis canker (caused by *Phomopsis* spp.), normally uncommon on white pine, was observed in west-central counties.
- Caliciopsis canker (caused by *Caliciopsis* spp.) and associated white pine bast scale (*Matsuccocus macrocicatrices*) were seen both in northeastern counties where they had been observed since 2018 and in counties in the northwest and west-central areas where they were confirmed for the first time. For details see the section on Caliciopsis above.
- Cytospora canker, white pine blister rust, Armillaria root rot, and woodboring beetles contributed to the decline and death of pines in southeastern Wisconsin.

Figure 24. White pine showing discoloration of needles from brown spot needle blight.

Damage from Abiotic Causes

Flooding Mortality

Precipitation in the state has been above the 1981-2010 normal rate since 2016, in some years, much higher. While rainfall was lower this year than it was in 2019, (which set a new state record), it was still over the 30-year norm for much of the growing season (Figure 25), giving only some relief from persistent saturation. Standing water was generally able to recede from wet sites earlier than in the past few years but several heavy rainstorms locally re-inundated sites during the growing season.

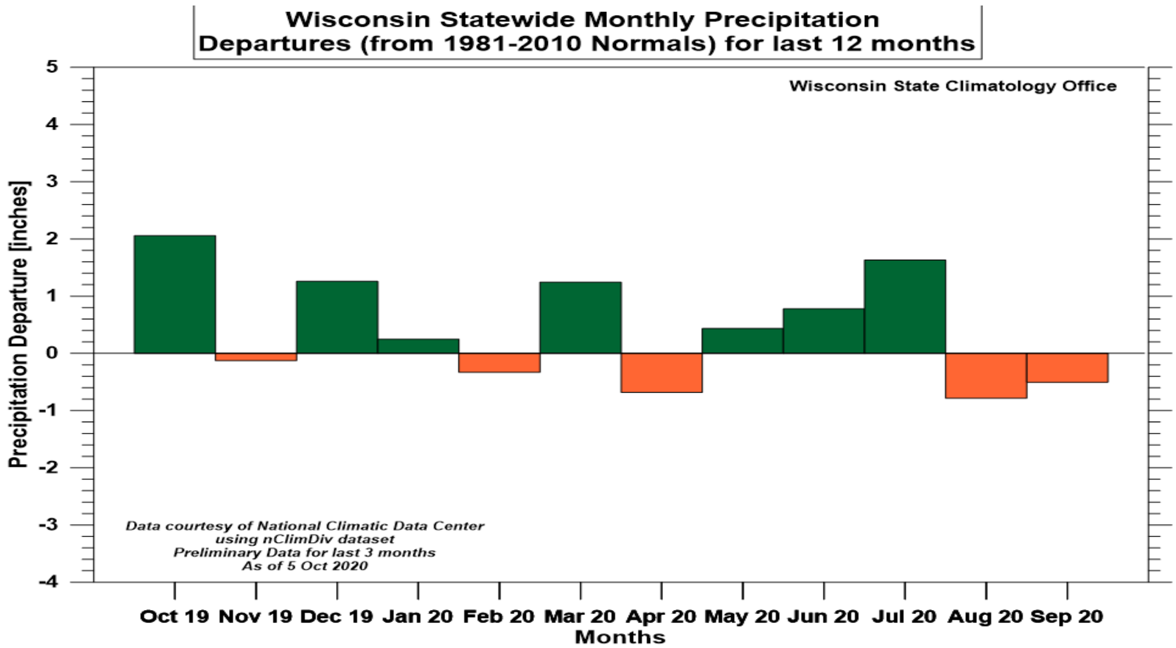


Figure 25. Twelve-month statewide precipitation departure from average between October 2019 and September 2020.

Heavy decline and mortality among many tree species continued at low-lying sites across Wisconsin. Mortality is likely due to a combination of new and lingering flooding stress, and concurrent infestation by insects such as emerald ash borer (ash species), two-lined chestnut borer (oaks), and eastern larch beetle (tamarack). Even flood-tolerant species such as silver maple and tamarack have been impacted over large areas of Wisconsin. Mortality has also been common along the edge of lakes and ponds that have much higher water levels than a few years ago. There is currently only limited ability to conduct active forest management at many of these sites, due to poor pulpwood markets and the difficulties of conducting forest management on wet sites.

Frost damage

Widespread frost damage occurred in central and north central Wisconsin this spring following a stretch of overnight freezing temperatures from May 9-15. Due to a late spring in the north, bud break had not occurred in many areas of northern counties at that time, so less damage was observed there. Late frosts have been occurring nearly every year for the past decade.

Rapid balsam fir mortality in the spring

During the first week of June, Forest Health Program staff started getting reports of balsam fir trees rapidly dying. The trees turned from green to tan to rusty brown color in just 2-3 weeks. These reports continued through the first week of July when further mortality ceased. The symptoms of this sudden mortality of balsam fir were very similar to the balsam fir mortality

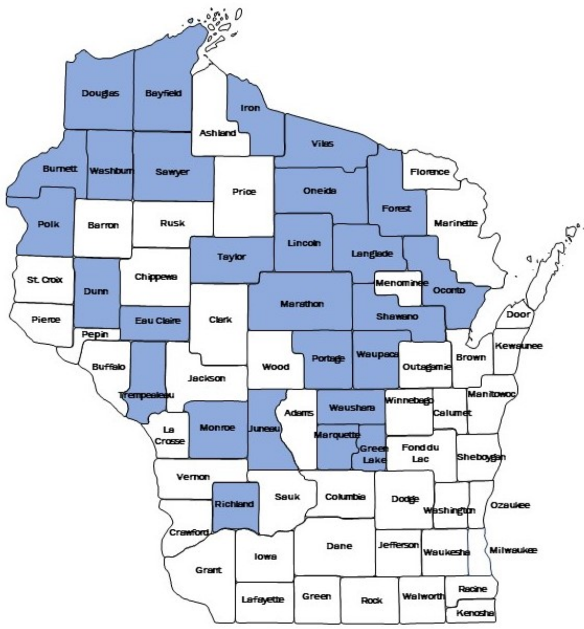


Figure 26. Counties where sudden balsam fir mortality was reported and observed in 2020.

event that was observed in the spring of 2018. This year there were fewer trees that died but they were distributed over a larger area of the state compared to the 2018 event (Figure 26).

Symptoms were reported primarily in counties in northern and central Wisconsin, shown in blue on in Figure 24, but may have been more widespread. Due to COVID-19 restrictions, Forest Health Program staff were not able to get out in the field until the fourth week of June and had to rely on calls and emails about this issue until then.

The symptoms noted were not typical winter desiccation, although that could have played a part in this event. The winter of 2019-2020 was mild. Many warm days in January were followed by a few bitterly cold days and nights in March and April. Mild winter weather, if it includes sunny days, can spur unseasonable photosynthesis in trees, which leads to needles releasing water and drying out at a time when the roots cannot replenish that water. Additionally, if trees lose their winter hardiness too early, the cold temperatures that follow can have severe impacts.

Searching the weather information for all locations reporting mortality, one commonality seems to be extremely cold temperatures that occurred throughout the state on April 15. This may have been too much of a shock to the trees and may be the primary reason causing mortality. By the end of April, temperatures had jumped to the 60’s and 70’s, and during that warm-up Wisconsin also had several days with very low relative humidity levels, which further desiccated the needles and increased stress on impacted trees. Some areas of the state had much lower relative humidity levels at this time, while others were more moderate, so it is uncertain how, or if, relative humidity factored into the mortality event. Temperatures also dipped below freezing in early May across the state, putting additional stress on the trees.

Signs and symptoms noticed in 2020 were much the same as in 2018:

- Up to two-thirds of the crown, or sometimes the whole tree, died quickly within 3-4 weeks.
- Margins between dead tops and live bottoms of trees were not defined by canker margins, indicating that this mortality was not caused by a fungal pathogen.

- Needles remained on the tree and turned rusty-reddish in color. These needles did not drop as the season went on (Figure 27).
- Trees most impacted were found in open conditions, forests, plantations and yards, while only some trees in the understory were affected.
- Some dying trees were located next to trees that didn't appear to be impacted at all.
- No insect or disease pests were identified as the main cause of mortality, although bark beetles and Armillaria root disease were noted in a small number of the dead trees.

Figure 27. Top kill of balsam fir that occurred during the spring of 2020.

Further examination of weather data from the winters of 2016/17 through 2019/20, shows that in late winter of 2018 and 2020, after which we saw balsam fir mortality, Wisconsin had dramatic temperature swings with one to several nights of temperatures well below freezing, followed by a rapid warm-up. This was not the case in the winters of 2016/17 and 2018/19, which were years when there were no reports of rapid balsam fir mortality. Climate change may be playing a part in these events by making weather more erratic.

Snow load damage during winter 2019/20

During the winter of 2019/20 heavy ice and snow loads in northeastern counties caused significant problems for trees, especially young conifers, whether in the understory or open grown. Trees with wounds or damage from insect and disease can be more susceptible to breaking when loaded with snow. Jack pine galls, caused by eastern pine gall rust, can be a weak point where the tree or branches can break. Pine root collar weevil damage at the base of the tree, or damage to the roots caused by Armillaria root disease, can make the tree unstable as well and trees may tip or break at ground level. Jack pine and red pine seedlings and saplings were the most heavily impacted in northeastern Wisconsin. Some young trees, if not broken or cracked, were able to return to an upright position over time. White pine and balsam fir were the best at recovering, although in some cases it was mid-summer before they were fully upright. In Marinette County, at a site planted to red pine in 2017, the young pines had been completely flattened by the snow and were manually straightened and staked by the landowner.

Tornado and wind damage

On August 9, 2020, an EF1 tornado developed over Star Lake in Vilas County, coming aground at the Star Lake Campground and travelling northeast nearly 6 miles through forested land including state, county, and private forests. It then made a 5-mile jump before creating a small patch of damage near Heart Lake, then made another jump before causing significant damage in Michigan’s Upper Peninsula. Forest Health Program staff mapped 640 acres of damage along the main path of the tornado. On August 9, there was also wind damage that occurred along a 6-mile-long corridor near the border of Oneida (Towns of Cloverland and Lincoln) and Vilas (Town of Sugar Camp) counties. Forest Health Program staff mapped 115 acres of damage in this area. A third event on August 9 occurred when an EF1 tornado was on the ground for approximately 3 ½ miles in northern Forest County, before crossing into Michigan’s Upper Peninsula. Forest Health Program staff mapped about 160 acres of damage in northern Forest County. A straight-line wind event that occurred July 19 took down single trees as well as several small patches of trees over a 14-mile stretch, starting in the Town of Sugar Camp and traveling east into the Town of Three Lakes, in Oneida County. Forest Health Program staff mapped 6 acres of damage related to this straight-line wind event. Wind damage in Chippewa County (July 21), Dunn County (July 21), and Pierce County (July 19) caused only minor damage to forested areas.

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