

2021 Forest Health Annual Report



The Minnesota Department of Natural Resources Forest Health Annual Report was created by the forest health unit in the Division of Forestry.

Cover photo: Oak wilt pressure pads popping through bark.

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Minnesota Department of Natural Resources Division of Forestry Forest Health Staff

Forest health specialists conduct annual surveys for insects, diseases, and environmental agents that threaten forests and interpret associated data for forest managers. They respond to requests from forest managers and forest landowners to investigate threats to forests and for assistance with forest health management issues. Staff prioritize threats to state forests.

Forest health staff provide expertise in Minnesota Department of Natural Resources (DNR) policy development regarding forest health. They provide training not only for DNR employees but for other agencies and organizations as well. Staff create outreach products such as [webpages](#) and the [Forest Insect & Disease Newsletter](#) that reach a wide audience. Annual reports from 1969 to the present are available on the [Forest Health Annual Reports](#) website.

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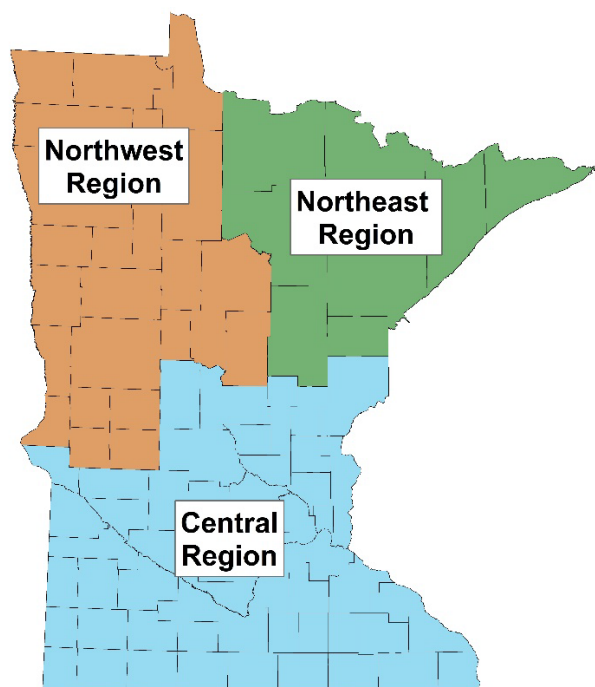
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Division of Forestry regions

Highlights of 2021

This report provides information about significant forest canopy damage recorded in our aerial and ground surveys and highlights other staff accomplishments. The report is of special interest to foresters who can use it to learn what is threatening forests they manage.

- Forest health staff collaborated with the DNR Resource Assessment unit and the U.S. Forest Service to aerially survey about 15 million acres of Minnesota's forests for tree damage. Some of this work resulted in detecting oak wilt and emerald ash borer beyond their known ranges; some of the detected problems will result in salvaged timber from state forests.
- Minnesota experienced its ninth driest April through September on record dating back to 1895.
- The severe drought aided pine engraver beetles attacking recently thinned pine plantations in northwestern Minnesota.
- Drought and heat in June caused widespread leaf scorch on oaks in central Minnesota.
- Spruce budworm damaged more acres than it has in 26 years.

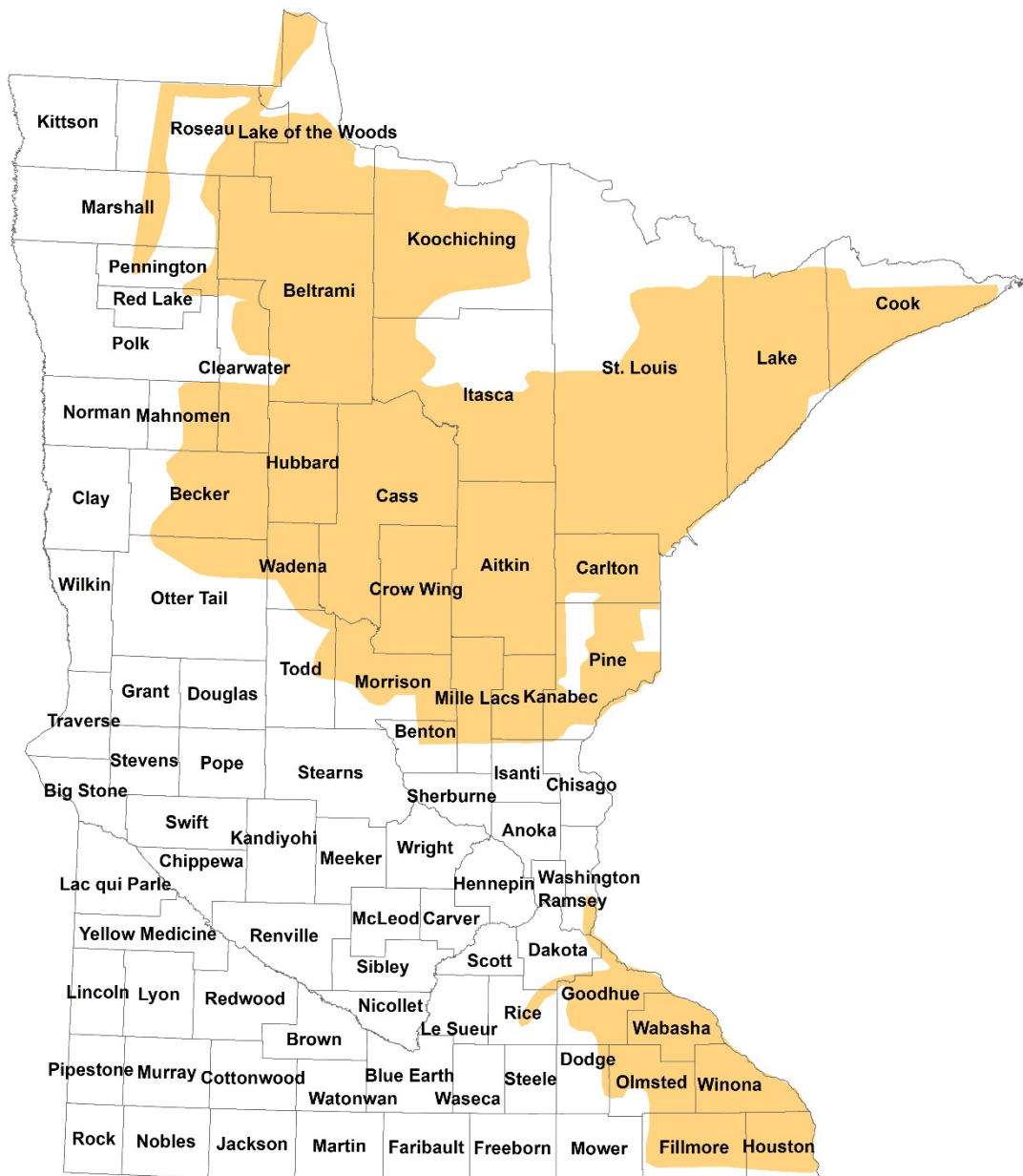
Annual aerial survey of forest canopy

Since the early 1950s, the DNR aerial survey has been a valuable tool for monitoring forest canopy health across 17.7 million acres of forest land. Surveys consistently record information such as large insect outbreaks, wind events, and fire damage. Other issues, such as forest damage from floods or wood-boring insects, do not always coincide with survey timing or they occur in areas not typically surveyed (e.g., in southwest Minnesota along the Minnesota River), so their impact is often underestimated. Some problems, such as root diseases, wilts, and tree declines, cannot be consistently detected from the air and are therefore not recorded in surveys.

Annual surveys are accomplished through the collaboration of the DNR forest health and resource assessment units and the U.S. Forest Service Region 9, St. Paul Field Office, State and Private Forestry (USFS). Survey results for 2016-2019 and 2021* can be found in the [Minnesota Geospatial Commons](#) (keywords "forest health").

*Due to COVID-19 and state social distance requirements, the aerial survey did not take place in 2020.

2021 coverage of the forest canopy health aerial survey



Comparison of aerial survey results from 2019 and 2021

Damage agent	Acres affected in 2019	Acres affected in 2021	Comments
Aspen and birch decline	16,905	29,108	
Arborvitae leafminer	165	0	Outbreak ended in 2019
Bark beetles on pine, spruce, and fir	2,778	1,107	
Basswood leafminer	Not surveyed	163	Basswood leafminer caused damage in 2019 but was not mapped.
Eastern larch beetle	244,302	252,100	
Emerald ash borer	Not surveyed	4,864	2021 figure is likely an underestimate. Since 2016, 10,163 acres of EAB damage have been mapped in southeastern Minnesota forests.
Flooding	9,073	3,710	
Forest tent caterpillar	1,295	9,081	
Jack pine budworm	609	0	
Larch casebearer	7,168	11,884	
Spruce budworm	201,711	383,685	This is the largest number of acres affected since 1995 when 506,000 acres were impacted.
Twolined chestnut borer	220	962	
Wind	5,255	1,955	

Forest Health Report

The following forest health report contains information on significant and notable causes of forest damage in 2021.

Insects

Aphids and scale insects

Warm, dry weather possibly caused increased populations of sap-sucking insects such as aphids and scales in 2021. Forest health staff noted damage in Aitkin, Crow Wing, Cass, Itasca, and St. Louis counties, but was likely present in additional counties.

Warm, dry conditions can accelerate the development of sap-sucking aphids and scales and can reduce the population of natural enemies such as fungi that require cool, moist conditions. Drought-stressed trees are also more susceptible to attack. These insects were primarily observed on broadleaf trees such as ash, aspen, oak, and black walnut. Sap-sucking insects excrete honeydew that is colonized by sooty mold, a black fungus that covers leaves, whole branches, and other plant parts. However, the fungus does not infect plants and is generally not a concern for tree health.

If similar weather conditions continue into 2022, we are likely to see more sap-feeding insects. High populations can result in twig and branch dieback, but numbers may be reduced once the population of natural enemies increases.



Scale insects on a small ash tree.



Aphids feeding on an aspen. Secretions of honeydew are present along with an ant that is attracted to the honeydew.

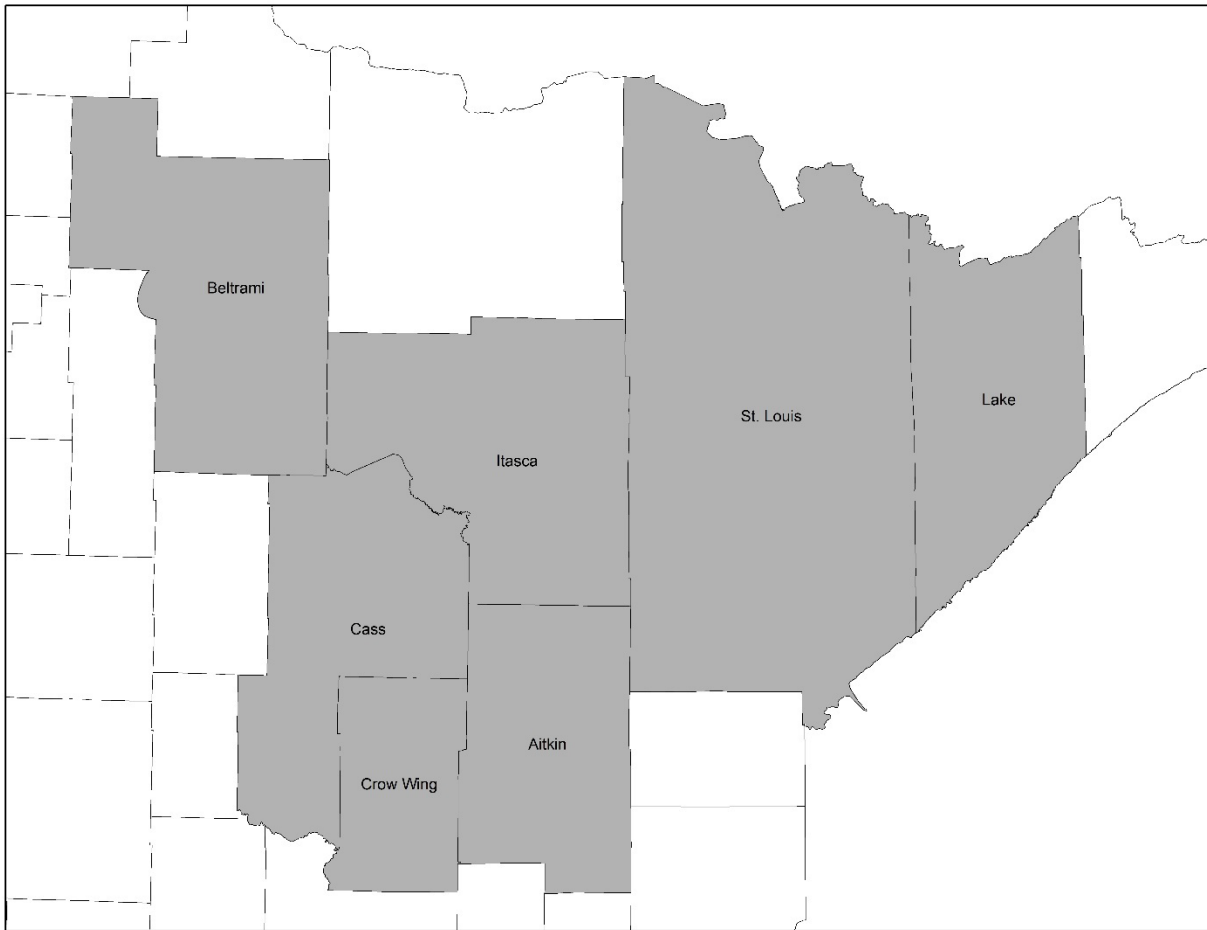
Aspen blotch miner

The aspen blotch miner (*Phyllonorycter tremuloidiella*) caterpillar feeds on the tissue between the upper and lower surfaces of aspen leaves. The feeding creates yellow blotches on the leaves, which eventually become brown in September. The blotches can be numerous and concerning, but trees can tolerate the damage; impact to aspen health and vigor is minimal. One possible concern is aspen trees stressed by both blotch miner and forest tent caterpillar could have compounded stress that might lead to dieback.

Damage from aspen blotch miner can typically be observed most years and was very common on trembling aspen from July to October in northern Minnesota counties the past few years. The extent of damage in 2021 appears to have slightly decreased compared to 2019.



Aspen blotch miner damage on aspen.



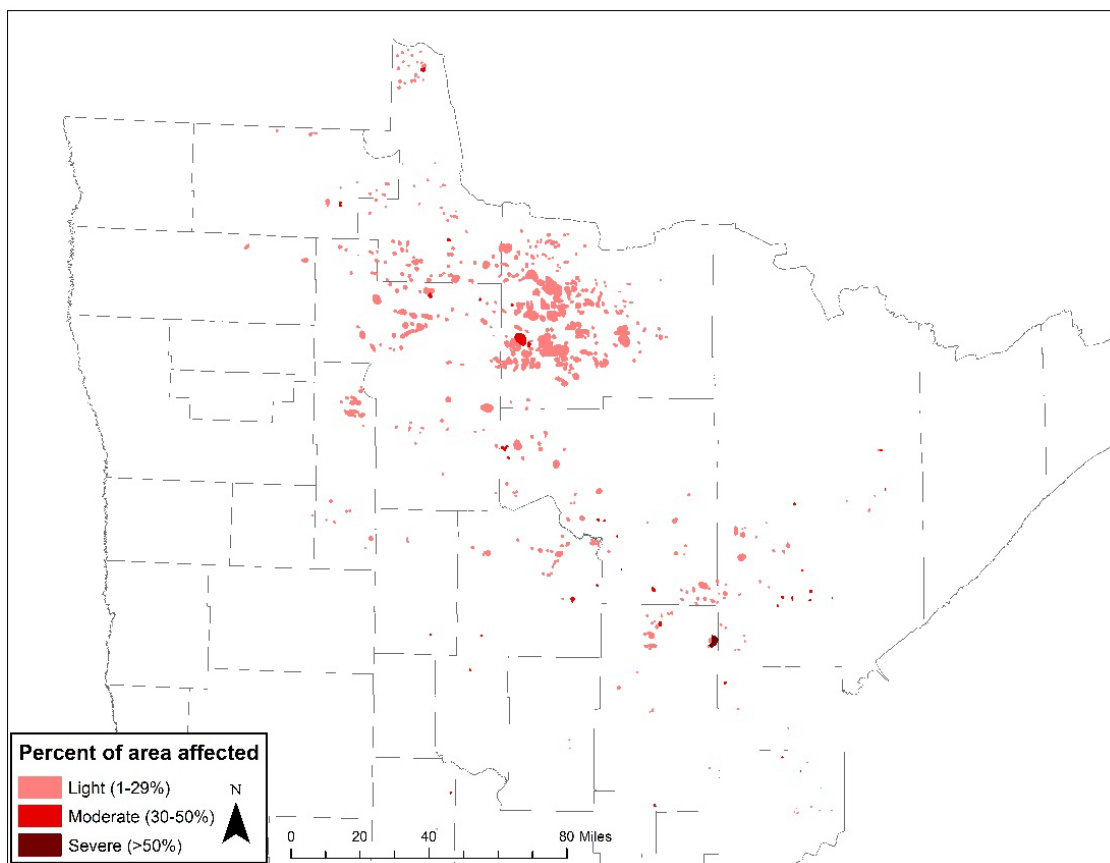
Counties with damage to aspen leaves in 2021 from aspen blotch miner.

Eastern larch beetle

Eastern larch beetle (*Dendroctonus simplex*) is native to Minnesota and is known to attack weakened tamarack. Due to longer growing seasons, more than one generation per year can develop. Historically, tamarack has not faced repeated second-generation beetle attacks in mid-summer. Since the beginning of the larch beetle outbreak in 2001, about 817,000 acres, or almost 60 percent of tamarack in Minnesota, have been impacted to some degree by eastern larch beetle.

In 2021 we found 252,000 acres affected by eastern larch beetle. From the aerial survey we saw that most of the stands are lightly affected, meaning 1-30 percent of trees in the stand show symptoms of infestation. An upward trend in damaged acres since the beginning of the outbreak in 2001 is occurring, and we expect the trend to continue.

The area of infested tamarack continues to grow. Future surveys will determine if the intensity of the larch beetle outbreak will continue at a similar rate. We have observed regeneration of tamarack (as well as other species) in many of the stands that were killed early in the outbreak, showing that infested tamarack stands can naturally recover from larch beetle devastation.



Eastern larch beetle damage in 2021.

Emerald ash borer

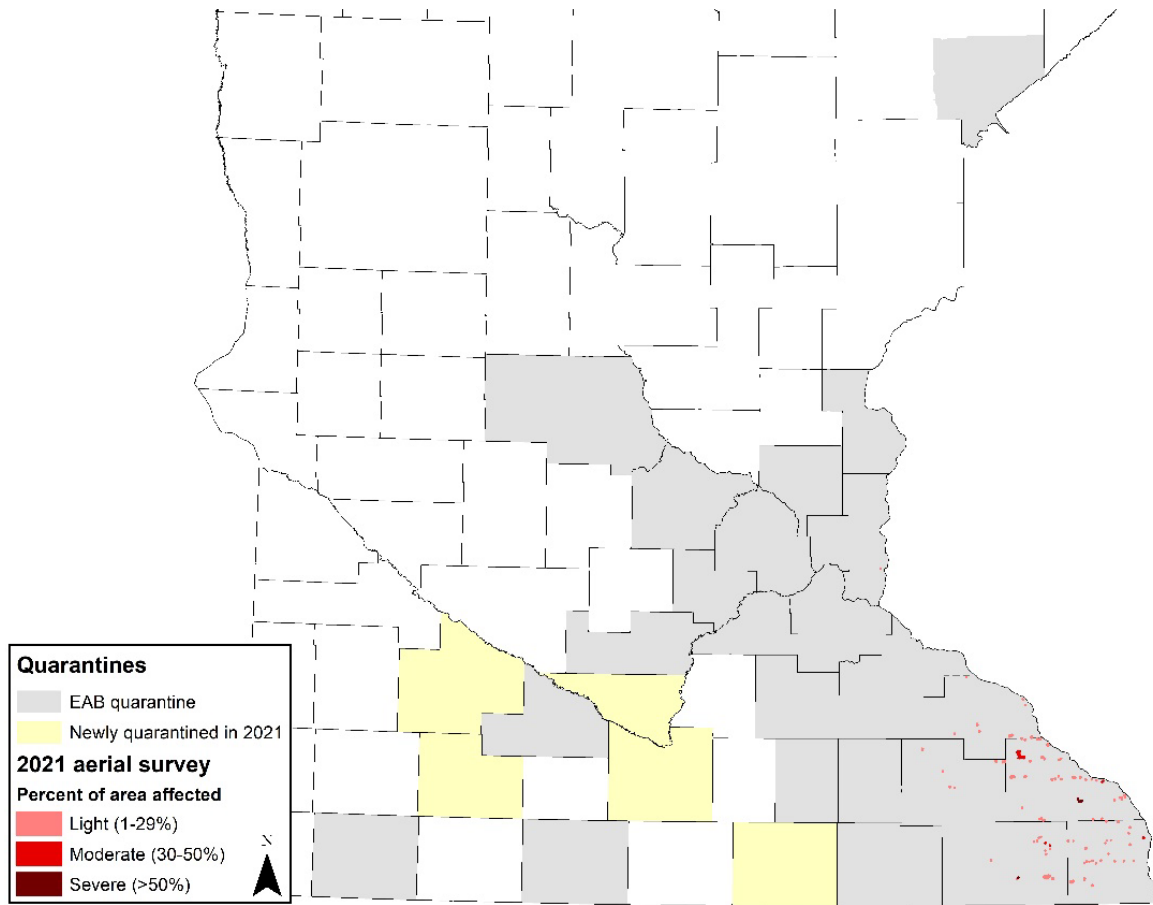
The Minnesota Department of Agriculture (MDA) is the lead agency for the emerald ash borer program in the state. They report that emerald ash borer infestations continue to grow at a quickening pace, especially in the Twin Cities metropolitan area and southern Minnesota. Thirty-two cities had infestations detected for the first time within their borders in 2021, and five new counties (Blue Earth, Cottonwood, Freeborn, Nicollet, and Redwood) were placed under the state's [Emerald Ash Borer Quarantine](#).

The Minnesota Department of Agriculture released 8,039 parasitoids (tiny wasps that kill other insects) at four release sites during the summer of 2021 (release numbers in the table below). *Tetrastichus planipennisi* and *Spathius galinae* were recovered from Lincoln and Central Parks in Duluth in northeast Minnesota. This is the farthest north in the state that parasitoids have been recovered and the first time *S. galinae* has been recovered in Minnesota. The USDA Animal and Plant Health Inspection Service Emerald Ash Borer Biocontrol Rearing Facility is starting to get back to normal parasitoid production levels after COVID-19 reductions, and the MDA anticipates releasing more parasitoids in 2022.

Site	<i>Tetrastichus planipennisi</i>	<i>Oobius agrili</i>	<i>Spathius galinae</i>
Fort Snelling 5 *	0	0	652
Grand Lake/Rockville	1295	1000	683
Joy Park	1735	1200	751
Whitewater Wildlife Management Area	0	0	723

* Only *Spathius galinae* was released here, as part of USDA study.

As part of the 2021 aerial survey, the DNR mapped forests infested by emerald ash borer. About 4,800 acres were visibly impacted from Houston and Fillmore counties north to Wabasha County, and roughly one quarter of this area had moderate or heavy damage (i.e., 30 percent or more of the trees displayed symptoms of infestation). When combining aerial surveys from 2016, 2018, and 2021, aerial surveyors have mapped 10,163 acres of forest with damage from emerald ash borer. This is an underestimate since our aerial surveys do not enable us to see all locations of emerald ash borer, and lightly infested or widely scattered ash cannot be detected from the air.



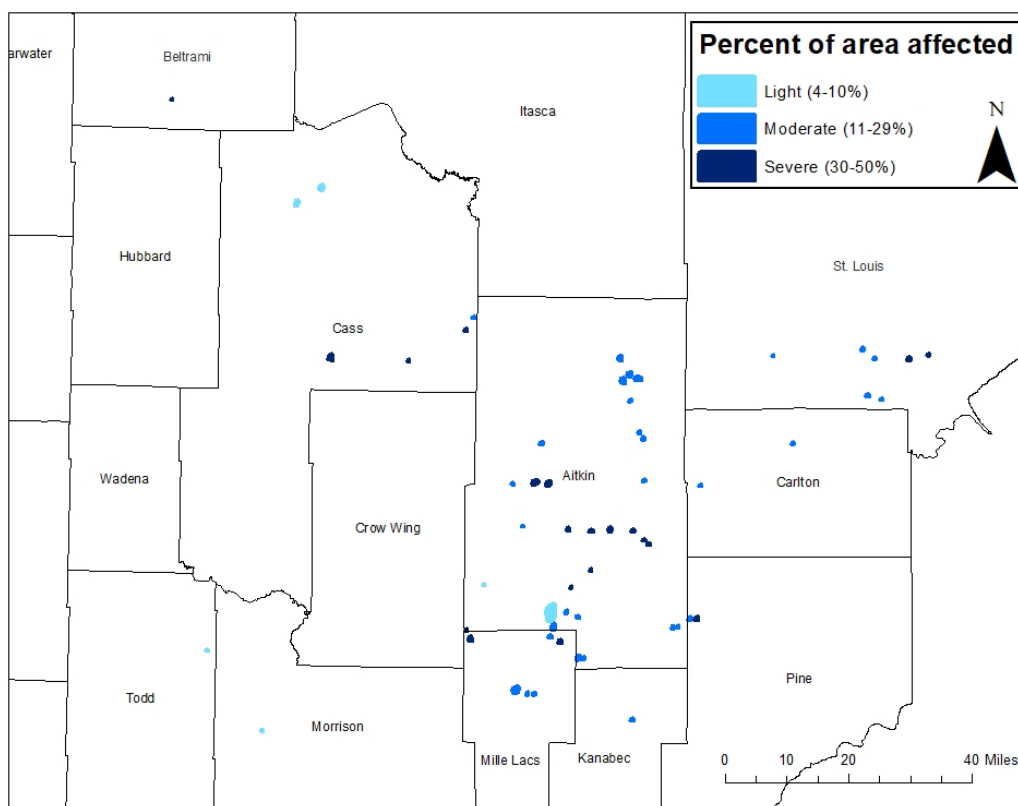
Emerald ash borer quarantine and damaged forests mapped in 2021 aerial surveys.

Forest tent caterpillar

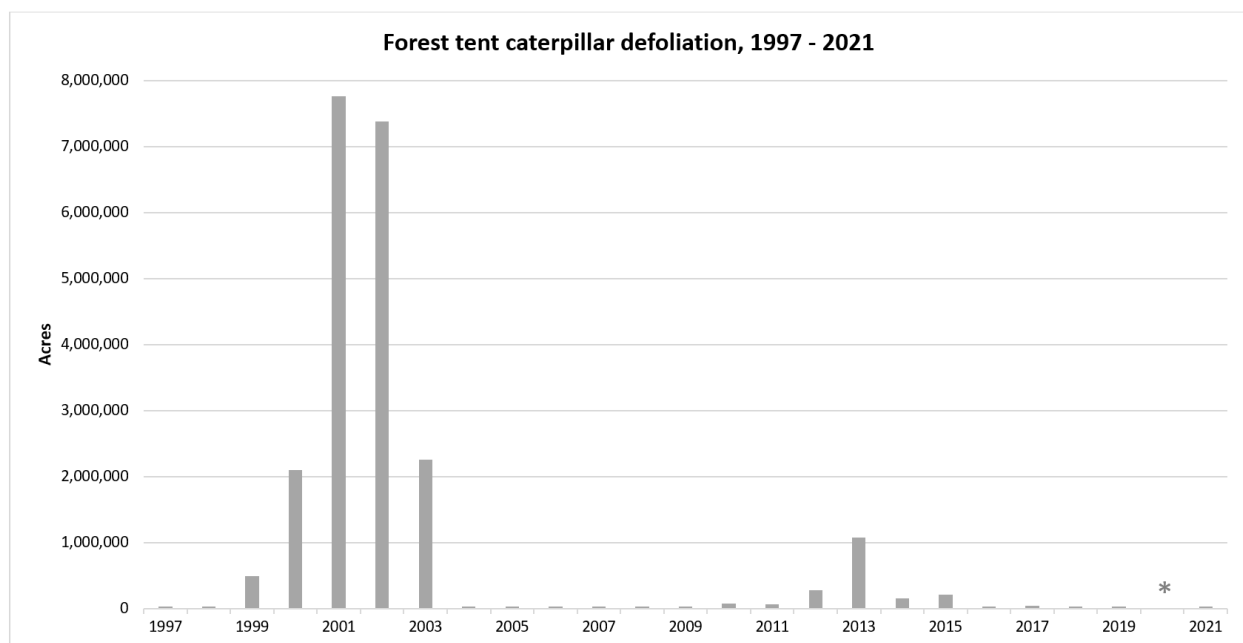
Forest tent caterpillar (*Malacosoma disstria*) is a native insect that primarily feeds on the leaves of aspen, oak, birch, and basswood. Forest tent caterpillar defoliated almost 9,100 acres of forest in 2021. Damage in most affected areas was light to moderate, but nearly 30 percent of the defoliation was severe. Most of the severe defoliation occurred in Aitkin County in north central Minnesota. In a Grand Rapids (Itasca Co.) neighborhood, the number of caterpillars was great enough to cover the majority of roads. Even a population of this size resulted only in trace defoliation that was not picked up in our aerial surveys. Overall, the number of caterpillars has increased in Grand Rapids over the past few years and is expected to continue increasing.

Healthy trees can typically withstand forest tent caterpillar damage, but multiple consecutive years of heavy defoliation could lead to mortality and reductions in growth. Stress from drought or other factors could make defoliated trees further susceptible to opportunistic pests and diseases.

Forest tent caterpillar damage has remained low across most of Minnesota in recent years, and defoliation decreased substantially from 2018 (28,078 acres) to 2019 (1,295 acres). Populations may peak again sometime between 2023 and 2029 based on a relatively small peak in 2013 and typical outbreaks occurring every 10-16 years.



Forest tent caterpillar damage in 2021.



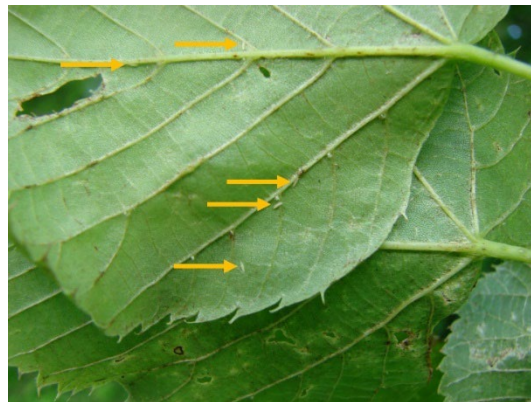
Annual forest tent caterpillar damage from 1997 to 2021. No aerial survey was conducted in 2020.

Introduced basswood thrips damage to basswood in central Minnesota

In late May, a resident in central Minnesota expressed concern for sickly basswoods near his home. Basswoods were missing many lower canopy leaves, and remaining leaves were curled and partially brown.



Heavily damaged lower canopy on a basswood from introduced basswood thrips.

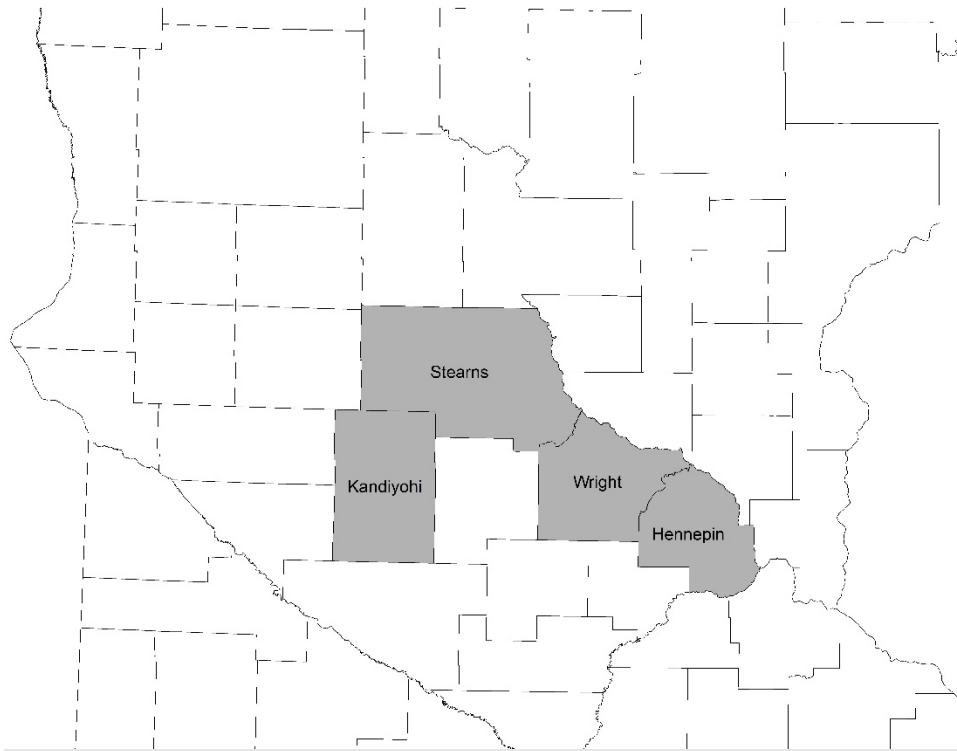


Introduced basswood thrips (at the ends of arrows).

Surveys revealed that from Lake Maria State Park (northern Wright County) west to Sibley State Park (northern Kandiyohi County) and north to Birch Lakes State Forest (northern Stearns County), quarter-acre patches of basswoods were 25 to 80 percent defoliated with only the outer rim of leaves remaining in the canopy. Nearly all mature basswoods at Birch Lakes State Forest were heavily defoliated (at least 200 acres of damage). We identified the culprit as an insect called the introduced basswood thrips (*Thrips calcaratus*).

We last documented problems with this non-native pest in Minnesota in 1995, and before then from 1982 to 1988. They feed on elongating leaves in the spring, causing leaf drop, curling, and tiny yellow-brown spots.

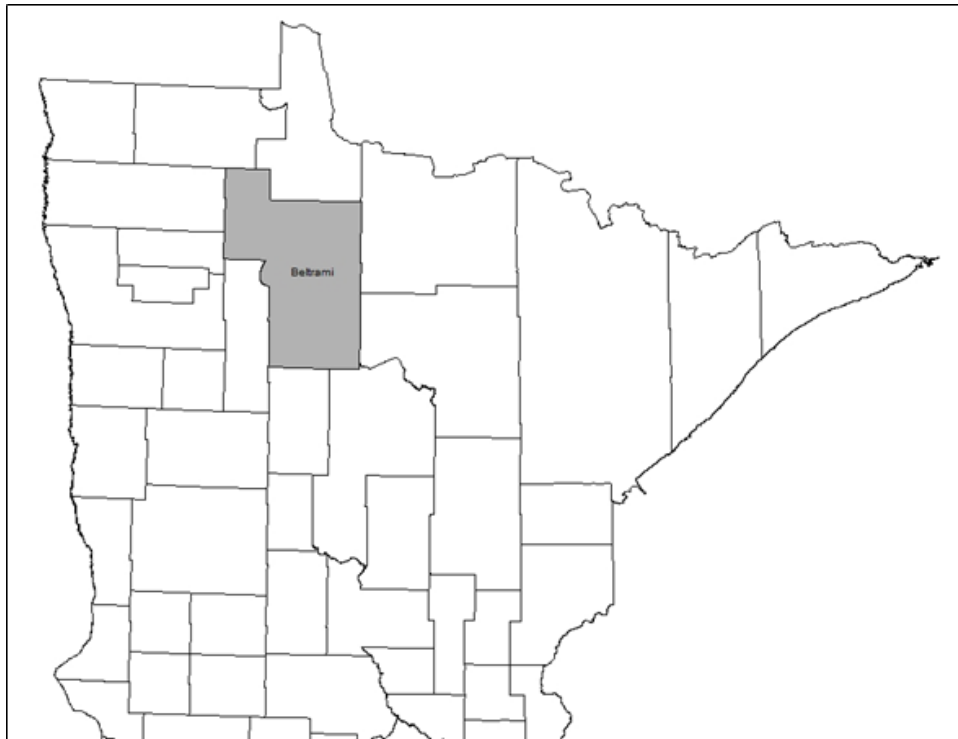
Introduced basswood thrips can affect basswoods in the same area for many years in a row, eventually stunting their crowns. We expect introduced basswood thrips to be active again in central Minnesota in spring 2022. After a few years, predacious insects or weather conditions will likely reduce populations. We are unaware of long-term negative impacts to basswoods across Minnesota from introduced basswood thrips.



Counties with damage to basswood leaves in 2021 from introduced basswood thrips.

Jack pine budworm

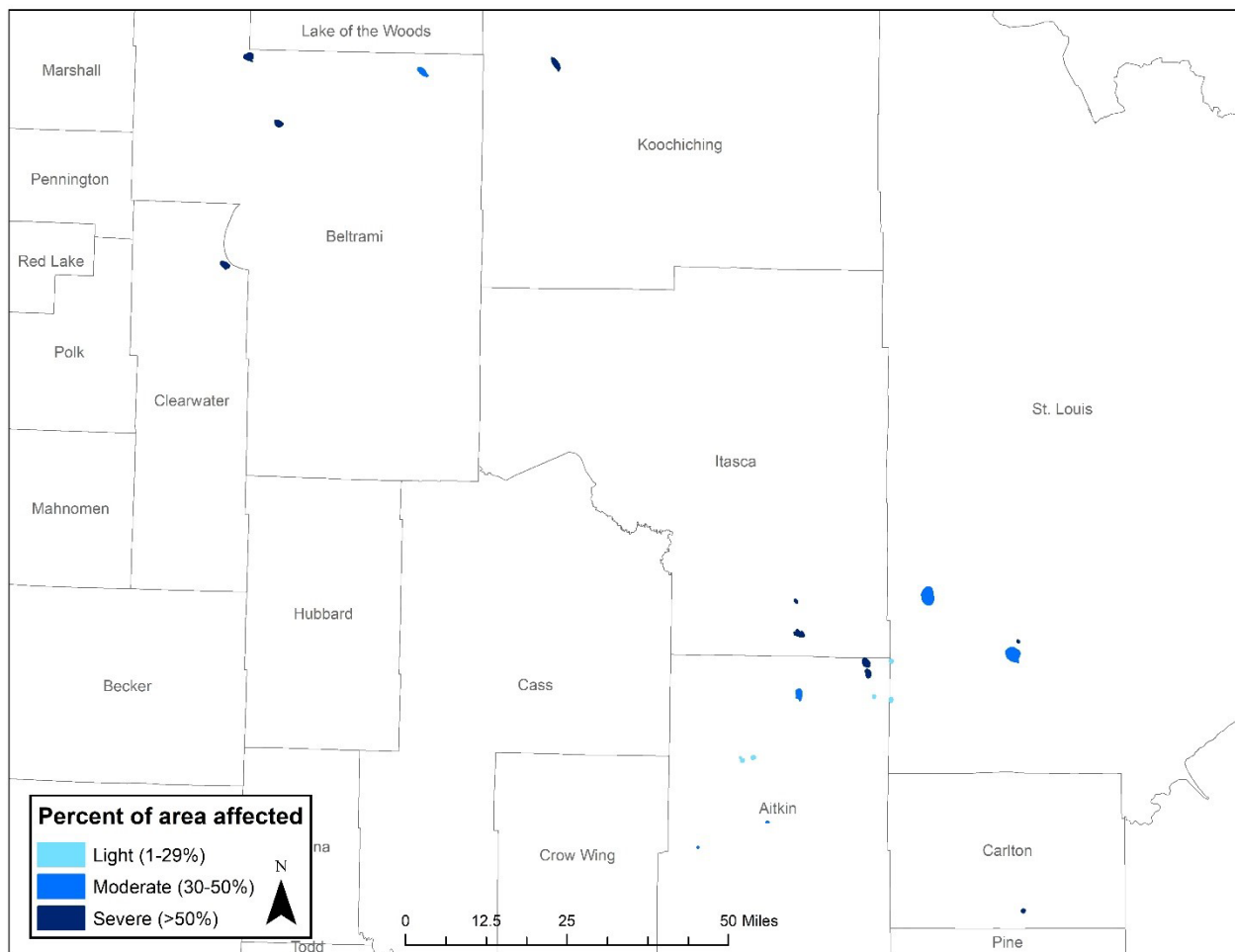
Jack pine budworm (*Choristoneura pinus*) is a native moth whose caterpillar feeds on jack pine. In 2021, aerial surveys detected no jack pine budworm damage; however, there were reports of damage in Beltrami County for the second year in a row. Jack pine budworm populations peak every eight to 10 years in north central and northwest Minnesota and about every 24 years in northeast Minnesota. Their populations may peak again sometime between 2023 and 2025 in north central and northwest Minnesota and around 2031 in northeast Minnesota.



Beltrami County was the only location with jack pine budworm damage in 2021.

Larch casebearer

Larch casebearer (*Coleophora laricella*) is a non-native moth whose caterpillar feeds on tamarack needles. In 2021 we mapped 11,884 acres of defoliation, an increase from the 7,168 acres mapped in 2019. An increase in damage occurred in Beltrami, Koochiching, and St. Louis counties. Some speculate that outbreaks of larch casebearer may be related to outbreaks of eastern larch beetle.



Larch casebearer damage in 2021.

Leaf beetle on willow

For the past three years, foresters have reported leaf damage on lowland and upland willow near Hibbing, Chisholm, and elsewhere in northern St. Louis County. Infestations were heavy again in July and August this year. The damage is likely caused by a leaf beetle; numerous species of leaf beetles feed on willow leaves. Both adults and larvae feed on leaves. Adults typically chew holes and notches in the leaves; larvae feed on both sides of the leaves between the veins, called skeletonizing. The skeletonized leaves cause the willows to look scorched or dead from a distance. Total browning of leaves in one season is rarely damaging, but if feeding continues for several years, willow health can deteriorate and result in mortality in rare circumstances.



Leaf beetle larva feeding on willow.

Lymantria dispar (formerly gypsy moth)

Trapping surveys

The Minnesota Department of Agriculture (MDA) coordinates and conducts the annual *Lymantria dispar* moth trapping survey.

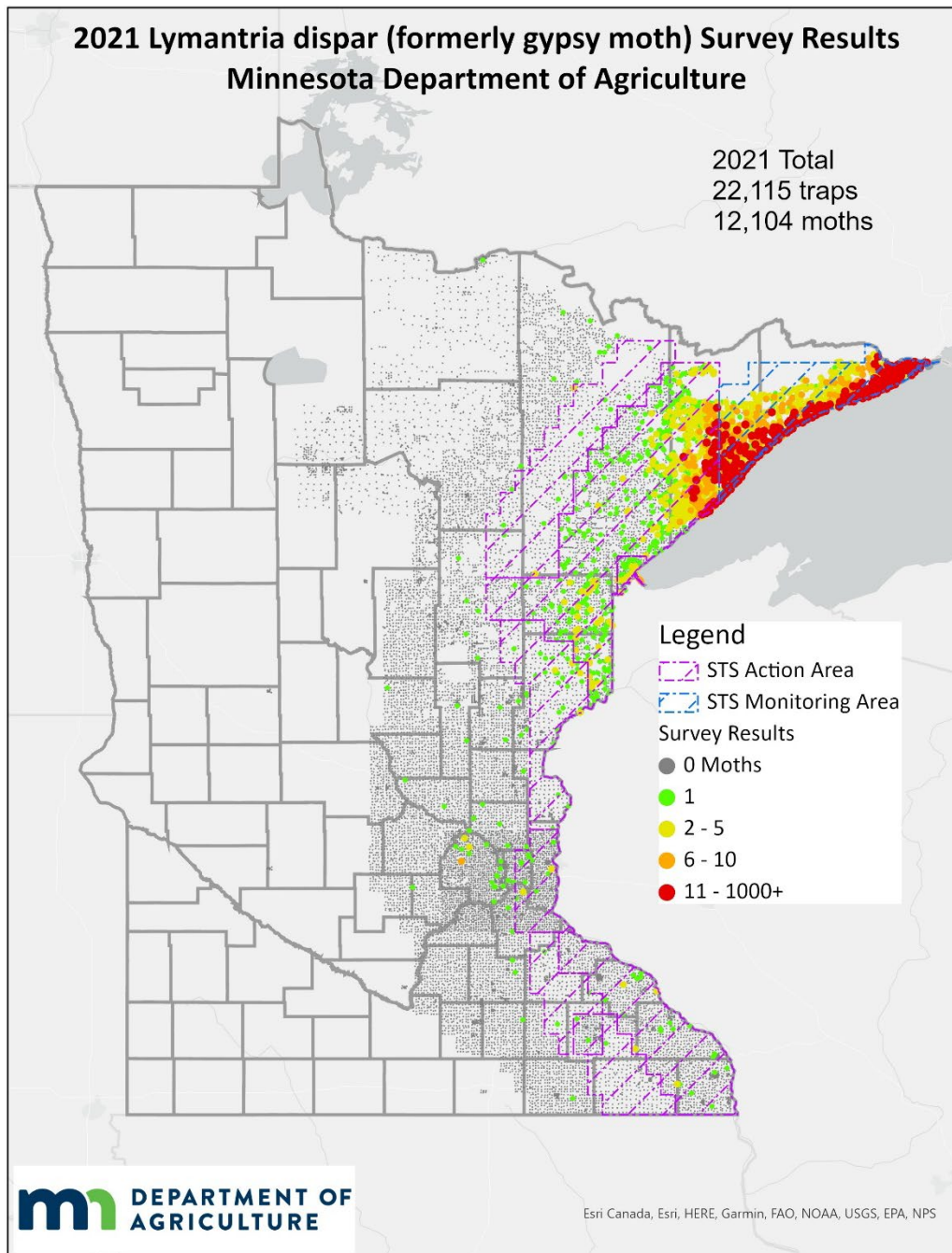
In 2021, MDA staff and cooperators placed 22,115 detection traps essentially in the eastern half of Minnesota with a focus on high-risk sites such as nurseries, mills, parks, and urban communities. Preliminary counts in December 2021 found that 12,104 moths were trapped. The number of captures statewide almost tripled since 2020.

A new infestation was reported by a state park visitor at Palisade Head in Tettegouche State Park. The site is north of Silver Bay in Lake County (quarantined for *L. dispar*) and is managed by the Minnesota DNR. This isolated population is one of the first documented in the Minnesota quarantine area. The MDA intensely surveyed the infested and surrounding areas and set up additional traps at high-traffic areas at North Shore state parks. Staff in the DNR Division of Parks and Trails and forest health unit conducted an additional survey and treatment at Palisade Head. Egg masses found were treated by applying Golden Pest spray oil. Most of the treatment area was in the vicinity of the parking lot at Palisade Head. Staff searched for egg masses outside the parking area and at the Tettegouche State Park visitor center, where one egg mass was found. More egg masses are likely in the Tettegouche State Park area along the shore. Treatments in the area will potentially occur in 2022.

Treatments

The MDA treated approximately 140,000 acres for *L. dispar* across 15 treatment blocks in seven counties in northeast and southeast Minnesota using three selective insecticides that target moths and butterflies: the biological insecticide *Bacillus thuringiensis kurstaki*, a mating disruptor, and the growth regulator tebufenozide. Two regulatory treatments were conducted at a nursery in southern Minnesota and at a mill in northeast Minnesota.

Additional treatments are planned for 2022. High trap numbers at a nursery site in Hennepin County led to the discovery of egg masses and other life stages on nursery stock. The area will be treated next year.



2021 *Lymantria dispar* (formerly gypsy moth) survey results Minnesota Department of Agriculture.

Spruce budworm

Spruce budworm (*Choristoneura fumiferana*) is a native caterpillar that prefers balsam fir but feeds readily on white spruce. When the budworm population is high, feeding damage can also occur on black spruce, tamarack, and pine. Unlike other parts of the U.S. where the budworm essentially disappears after massive outbreaks, the budworm population in Minnesota has a continuing population that has been observed in the Arrowhead region since 1954. The previous spruce budworm outbreak occurred from 1912 into the early 1920s, which is a more typical outbreak pattern for spruce budworm. In Minnesota, spruce budworm typically feeds in an area for six to eight years, which is about how long balsam fir can withstand defoliation before it dies. The population then moves to a different zone in northeast Minnesota.

Spruce budworm has defoliated or destroyed an average of 282,000 acres of fir and spruce forest per year in northeastern Minnesota since 2018. That's almost the size of Lower and Upper Red Lake combined.

Much of the present outbreak is in Lake County and the western part of Cook County. In this year alone, spruce budworm defoliated and killed 384,000 acres of fir and spruce forests. Most (roughly 303,000) of those acres were defoliated, and about 81,000 acres had a mix of mortality and defoliation. This is the highest number of acres the caterpillar has impacted since 1995, when it damaged 506,000 acres in one year.

The past few years of dry weather, particularly in the spring and early summer, may have magnified the spruce budworm situation. Scientists hypothesize that warm, dry weather increases the survival of budworm larvae. Insect diseases such as fungal pathogens need cool and moist conditions to thrive, so when the weather is warm and dry fewer budworm larvae are attacked.

Not only were large numbers of trees damaged or killed, but the drought coupled with spruce budworm damage possibly played a role in Minnesota's fire season. The drought in northern Minnesota this year led to an extended fire season, and with the large amount of dying and dead fir and spruce trees in northeast Minnesota, the question was raised whether this enhanced the risk of fire. The largest fire in 2021 was the Greenwood Fire, burning about 27,000 acres in Lake County. The fire was near Isabella, in the heart of the budworm outbreak, with a large amount of dying and dead fir and spruce trees. Fire can more easily burn through dense areas of standing damaged or dead trees compared to well-spaced healthy trees or decaying dead trees on the ground. Healthy balsam fir is extremely combustible as well. It seems probable that conditions caused by spruce budworm played some role in the Greenwood Fire.

The spruce budworm outbreak will probably continue to have a large impact next year as it moves farther into Cook County. Additionally, a small number of egg mass surveys were conducted at the leading edge of the infestation in 2021. A few egg masses were found in the Grand Marais area, indicating defoliation could be seen there in 2022.

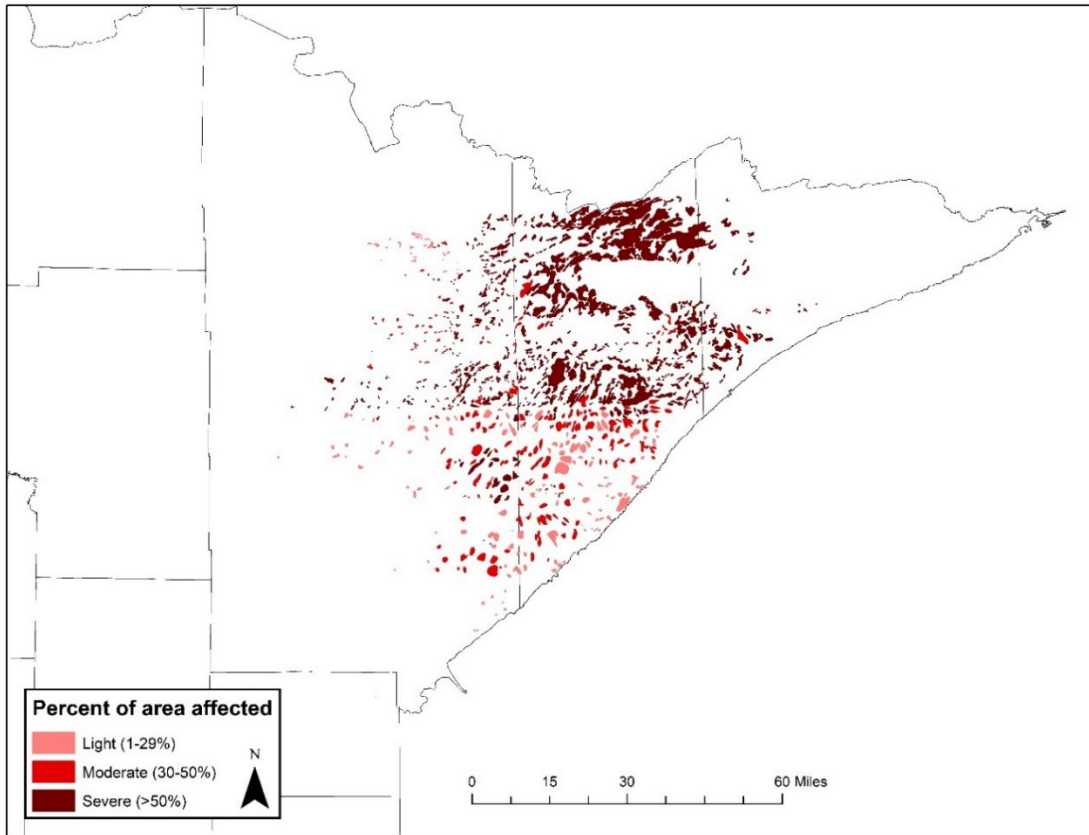
St. Louis County, the DNR, and the USDA Forest Service will incorporate the spruce budworm defoliation and mortality aerial survey data into Community Wildfire Protection Plans. This is wise community planning since the conditions that promote spruce budworm defoliation (lots of balsam fir, particularly older balsam fir) are the same conditions that increase the risk of quickly spreading wildfires.



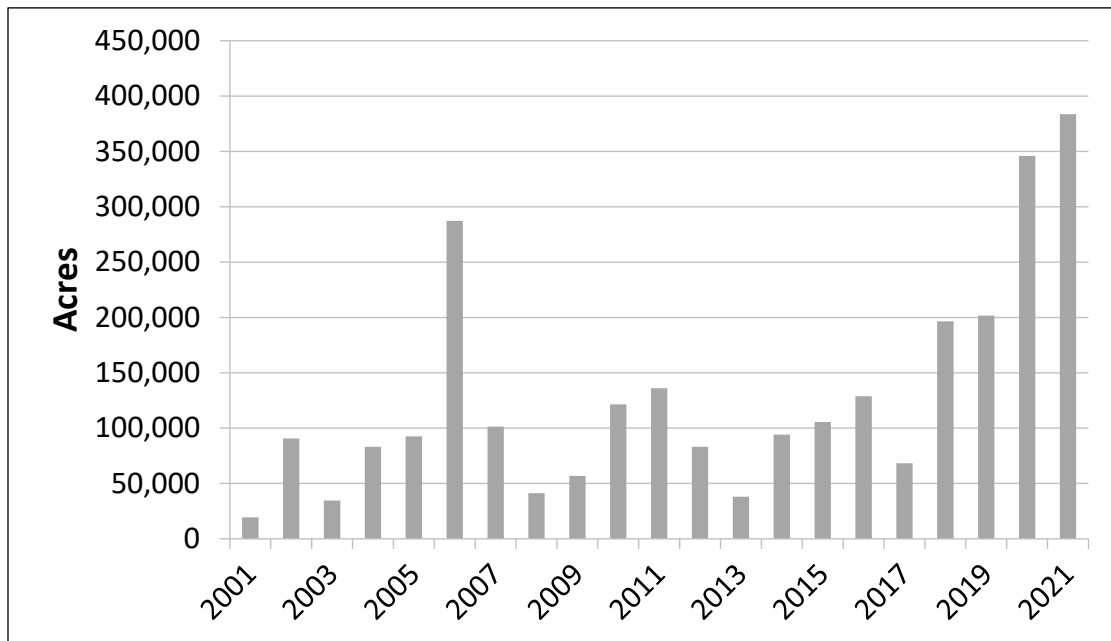
Spruce budworm caterpillar on balsam fir.



Spruce budworm moth, webbing, and excrement from caterpillars on balsam fir.



Spruce budworm defoliation and mortality in 2021.



Acres of spruce budworm defoliation from 2001 to 2021.

Twolined chestnut borer

Twolined chestnut borer (*Agrilus bilineatus*) is a native metallic wood-boring beetle whose larvae feed beneath a tree's bark. Oaks stressed and weakened by serious droughts, windstorms, soil compaction, or intense and repeated defoliation are commonly attacked.

In 2021, aerial surveyors mapped 962 acres of damage from twolined chestnut borer. This is an increase from 220 acres in 2019. The damage was scattered this year and primarily located in central Minnesota, similar to what was observed from 2020 ground surveys. We expect more twolined chestnut borer activity in 2022.

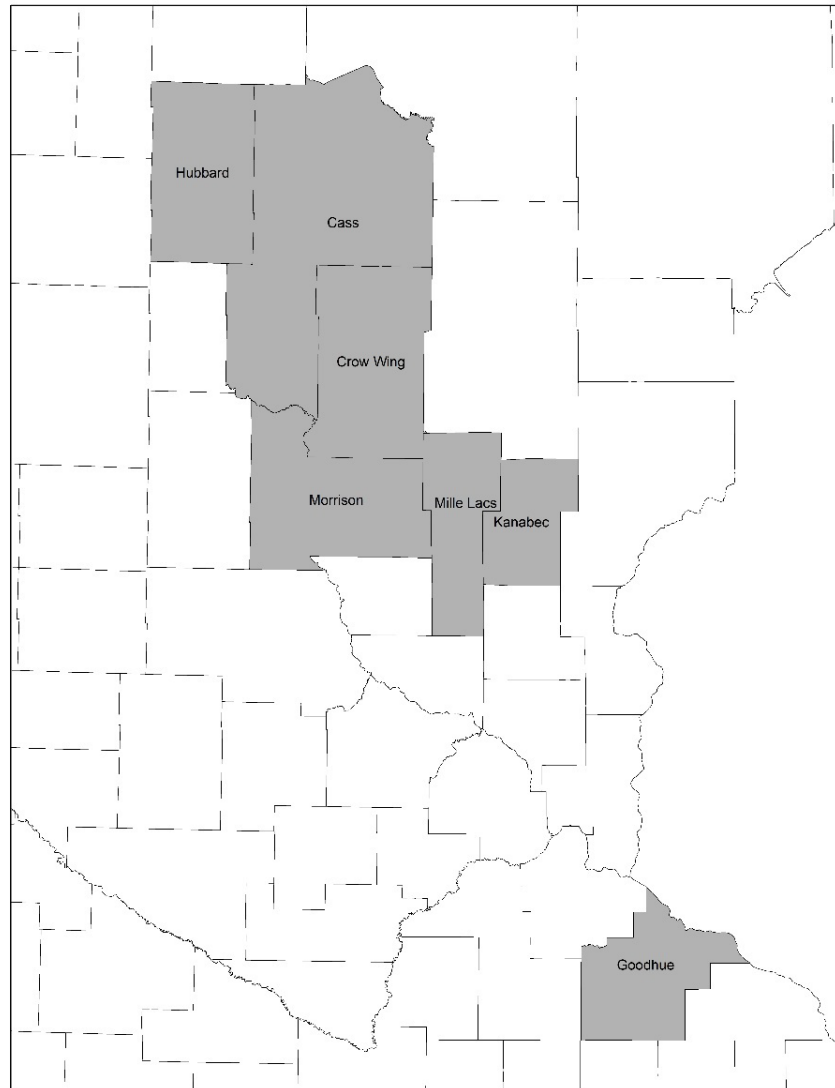
Twolined chestnut borer damage this year was made worse by drought, but past stressors predisposed oaks to further infestation. Moderately infested stands in Morrison and Mille Lacs counties had pockets of flood damage from prior years and twolined chestnut borer attack was concentrated around formerly flooded zones. In addition, a portion of a stand in Kanabec County thinned in early 2019 was heavily attacked. The extensive dry growing season in 2021 will most likely lead to more damage in 2022 and 2023; attack by twolined chestnut borer occurred for a few years after droughts in 1988 and 2012.



Twolined chestnut borer larvae killing the top of a Kanabec County red oak in 2021.

Oaks infested by twolined chestnut borer can die in a single year, but it usually takes two to three years for a tree to die. Additionally, stressed oaks are not only attacked by twolined chestnut borer but Armillaria root disease as well. Armillaria is an opportunistic pathogen that usually attacks a tree in combination with twolined chestnut borer.

The symptoms of twolined chestnut borer can mimic those of oak wilt, but a distinct difference is that dead leaves stay on the tree when attacked by twolined chestnut borer, while leaves quickly fall off trees with oak wilt. This is particularly true of red oak.



Counties with dieback and mortality from twolined chestnut borer in 2021. Twolined chestnut borer was not extensively surveyed for, so this is an approximate number of counties that had damage.

Walnut defoliation by *Gretchena amatana*

In the [2020 Forest Health Annual Report](#) we described how an unknown caterpillar defoliated black walnuts and encased some walnut trees in heavy silk across 60 acres in Fillmore County. An entomologist with the Wisconsin Department of Agriculture, Trade, and Consumer Protection identified the caterpillars as *Gretchena amatana*, a first report of this species damaging trees in Minnesota. Colleagues in Wisconsin and Iowa also found these caterpillars defoliating walnut.

This year in the same areas impacted in 2020, we collected caterpillars in early stages of development on June 24. The 0.2-inch-long caterpillars were found protected by silk on the undersides of leaves (see photo below). We reared them to a larger size and confirmed they were the same species that fed on black walnut last year. Local foresters reported caterpillars and noticeable defoliation on individual walnuts July 7, one year from the first report.

This year caterpillar feeding was not as extensive and was lighter in Minnesota, in contrast to a southwest Wisconsin DNR observation. The caterpillar was active in northeast Iowa this year as well.



Gretchena amatana (probable identity) in late June in southeast Minnesota.



Gretchena amatana on a walnut leaf in early July

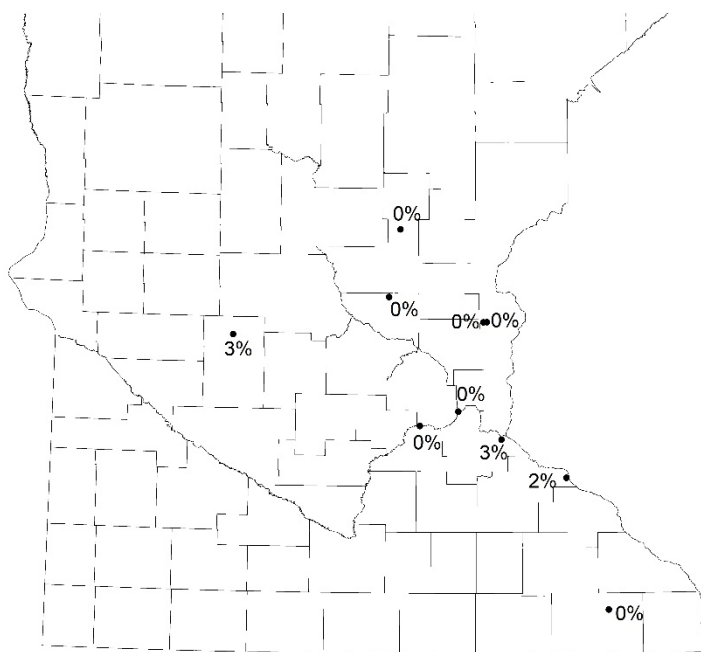
Diseases

Bur oak blight

Bur oak blight is a fungal disease of bur oak caused by *Tubakia iowensis*, which results in browning leaves that may drop prematurely in late summer. Trees almost always recover the following spring. Disease incidence and severity across the landscape increase when rainfall increases during leaf elongation, mostly in May.

We observed less bur oak blight in 2021 than in 2020. Only 1 percent of 477 bur oak trees surveyed across 10 sites were substantially defoliated by bur oak blight by early October (see survey results in the map below). The likely reason for this was a drier May than in 2020 in the Twin Cities metro area and southeast Minnesota plots.

We have conducted annual surveys since 2017 to determine how many bur oaks across the landscape are severely affected by the disease. Only a small minority of bur oaks in our surveys have been affected, never exceeding 5 percent in a year. The highest defoliation by early October in any plot was 14 percent. Our data show that bur oaks growing on highly used sites such as manicured public parks, boulevards, and yards have an increasingly greater chance of being severely affected by bur oak blight as May precipitation increases. Compaction on these sites would have been higher than the forested sites, resulting in a positive correlation with compaction and greater bur oak blight severity.

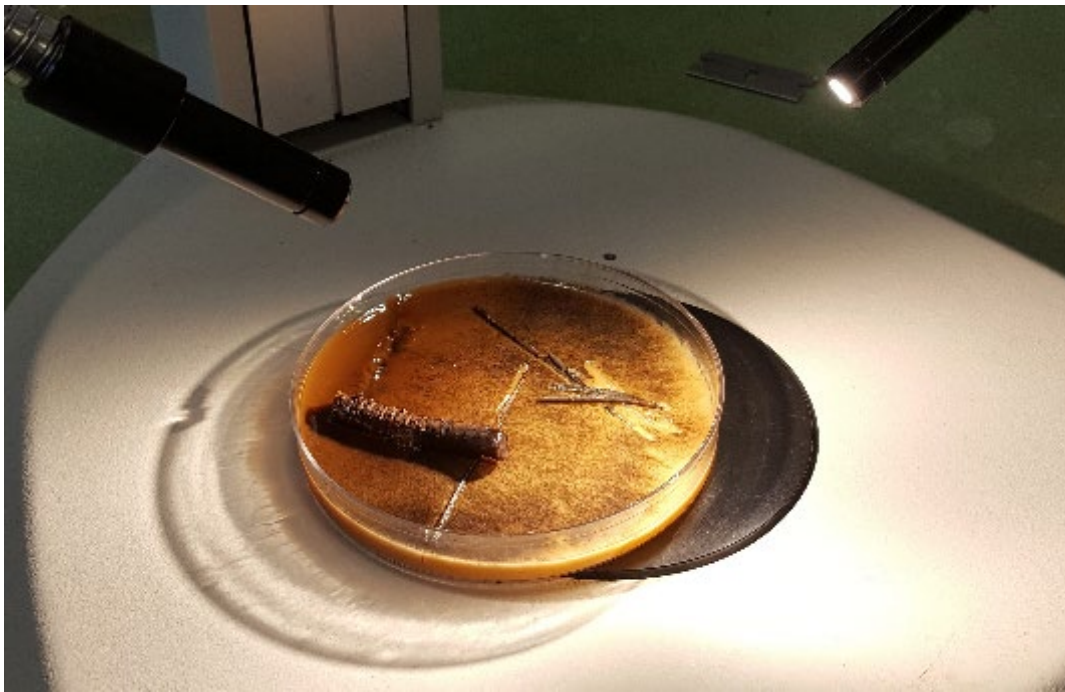


Plot locations of bur oak blight surveys and the percent of bur oaks *heavily* defoliated in 2021.

Diplodia assessment on nursery red pine

Diplodia sapinea is a fungal pathogen that kills red pine seedlings and saplings and causes crown loss and top-kill in stressed mature pines. *Diplodia* can also cause latent, or hidden, infections that do not have visible symptoms until trees become stressed. The Minnesota State Forest Nursery tests for latent *Diplodia* infections to avoid distributing diseased stock and does not sell red pine seedlings when latent *Diplodia* infections exceed 10 percent of the crop. Infected seedlings at the nursery surpassed this threshold in 2016, and 400,000-500,000 red pine seedlings with possible latent *Diplodia* infections were destroyed.

The State Forest Nursery has assessed levels of latent *Diplodia* infections annually since 2016. Preliminary lab testing results show that all seedlings tested negative for latent *Diplodia* infections in 2021 for the second year in a row. This is the fifth consecutive year where latent *Diplodia* infections at the nursery were at acceptable levels.



Segments of a red pine seedling being examined for latent *Diplodia* infection at the University of Minnesota Plant Disease Clinic.

Moldy seedling outplanting study at the State Forest Nursery

Storage mold nursery issue in 2019

In April 2019, State Forest Nursery staff discovered that several freezer-stored hardwood seedlings had developed extensive storage molds with significant root rot in some storage crates. Butternut, black walnut, red oak, white oak, bur oak, and nannyberry were all affected.

Development of mold on fall-lifted bareroot stock in freezer storage is a common issue at forest nurseries. Some storage molds may be superficial and harmless, but a thick mat of mold may smother and heat seedlings. Other molds can colonize healthy tissues, acting as pathogens. Abundant storage molds can also indicate poor storage conditions that may affect the growth capacity of seedlings.

The presence of some storage molds on hardwoods in freezer storage has been considered normal at the State Forest Nursery in previous years. While staff have tried to minimize the issue, DNR Silviculture and Forest Health program staff found that 10 to 90 percent of seedlings were moldy in some boxes of trees in spring 2019. Some of those seedlings had extensive root rot and necrosis nearly reaching the terminal bud. At plantings in southeast Minnesota, staff found an estimated 75 to more than 90 percent mortality in some boxes of 1-0 red oak, white oak, and butternut seedlings, based on observations of root rot and stem necrosis. Nannyberries also had heavy storage mold and root rot.

Samples submitted to the University of Minnesota Plant Disease Clinic found no common root pathogens, but the clinic identified several species of saprophytic fungi. Subsequent investigations of the health of the planted moldy seedlings found that oak survival was low and was consistent with the initial pre-planting assessments of high mortality. Red oak survival ranged from zero to 44 percent, walnut survival was 71 percent, and staff found no living white oak seedlings.



Storage mold-covered oaks. Most of the root systems were dead.

Out-planting study

Research on the effects of storage molds on the growth and survival of seedlings is limited, so the Forest Health Program evaluated the impact of storage molds on out-planted seedling health and mortality over two years in a small-scale study at the State Forest Nursery from 2019 to 2020. In late May 2019, 240 oak seedlings were planted in a spare bed in an active field.

The planted seedlings included 80 red oaks from a northern seed zone (zone 104), 80 red oaks from a southern seed zone (zone 106), and 80 white oaks from a southern seed zone (zone 106). Half the red oaks from both seed zones had heavy mold and half had light mold. All the white oaks had heavy mold. No control seedlings without mold were available for the study. Moldy seedlings of all species had varying degrees of root rot and necrotic stem tissue based on observations of other seedlings from the source bundles.



Moldy oak seedlings planted at the State Forest Nursery in May 2019.



Light mold (left) and heavy mold (right) on red oak samples.

Only 23 percent of the seedlings survived after two growing seasons. Almost all mortality (97 percent) occurred within two months of planting, indicating the severity of the root rot and stem necrosis. Nearly 92 percent of the initially surviving seedlings had only light mold on their roots. By the end of the second growing season, nearly 99 percent of oaks of all species with heavy mold died.

Survival and mortality of oaks of all species by mold abundance.

Group	Mortality
Total	77%
Light mold	34%
Heavy mold	99%

Southern seed zone red oak had the highest survival of all the oak groups, accounting for 61 percent of total survival at the end of two growing seasons. In total, 80 percent of the southern red oak survived, while only 53 percent of the northern seed zone red oak survived. The

reasons for this disparity are unknown, and no significant differences in mold abundance were observed. Differences in fall lift date and other factors may have contributed. The only red oak seedlings with heavy mold surviving at the end of the study were southern red oaks. No white oaks (all with heavy mold) survived after two growing seasons.

Oak mortality by species and mold abundance.

Group	Light mold	Heavy mold
Red oak (north)	48%	100%
Red oak (south)	20%	95%
White oak (south)	N/A	100%

Due to the storage mold issue, Covid-19 pandemic, and staff transitions, hardwoods have not been fall-lifted at the State Forest Nursery since 2018. The nursery and forest health group continue to investigate the cause of the issue and potential solutions.

Heterobasidion root disease

Heterobasidion root disease was confirmed at one site in Winona County in 2014. DNR staff eradicated *Heterobasidion* from that site in 2017 through sanitation and cover-type conversion. The University of Minnesota surveyed the site for *Heterobasidion* in 2020 and 2021 and did not find *Heterobasidion*.

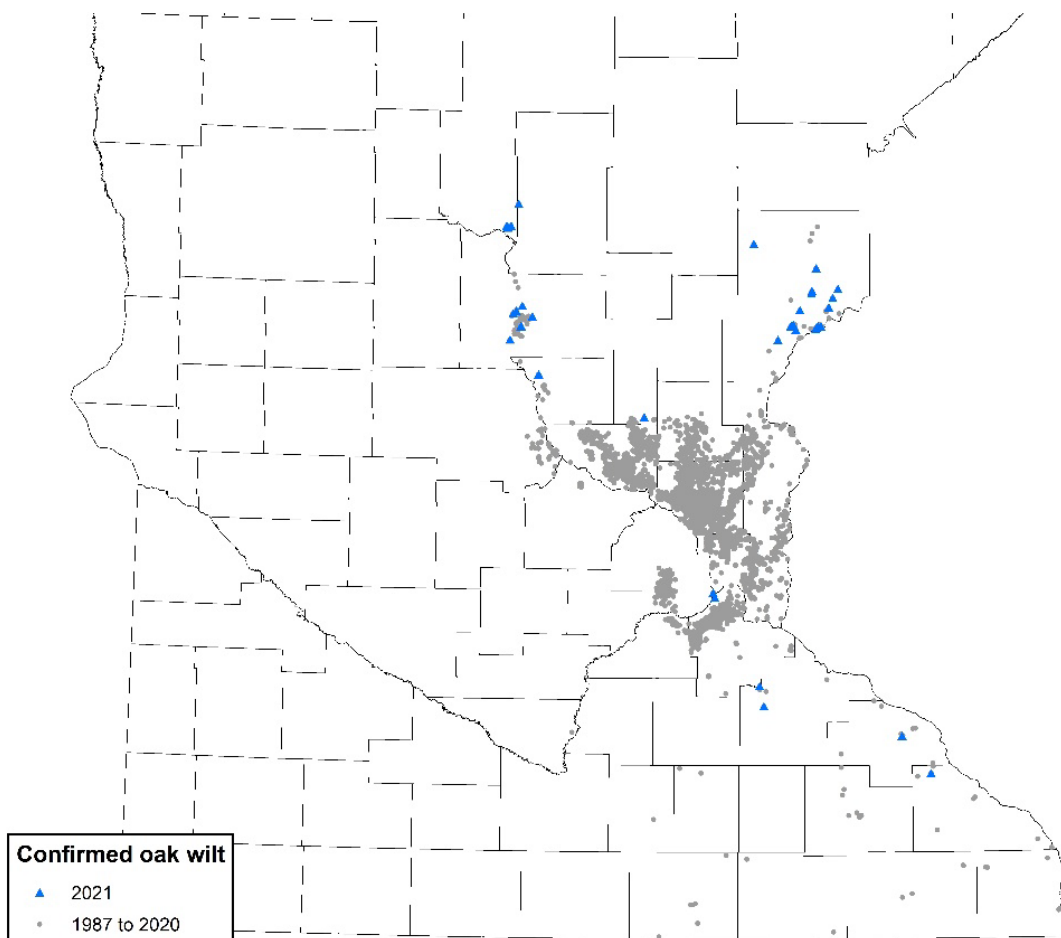
In addition to the Winona County site, we surveyed for *Heterobasidion* in 20 other pine disease centers in Beltrami, Chisago, Itasca, Pine, Roseau, St. Louis, Sherburne, and Washington counties in 2021. We found no *Heterobasidion* during any of the investigations.



Pocket mortality in a pine stand.

Oak wilt

Oak wilt is a non-native, fatal oak disease that has been spreading slowly northward in Minnesota since the 1940s. It can be devastating in nearly pure oak forests. The disease currently covers nearly 40 percent of the state's red oak group range and is common in east-central and southeast Minnesota.



To slow the spread of oak wilt northward into uninfected forests, we prioritize early disease detection, outreach efforts, and management in the northern three-quarters of Pine County and Morrison, Crow Wing, and Cass counties in central Minnesota.

Early detection

Forest health staff confirmed oak wilt this year for the first time in Cass and Crow Wing counties. We also confirmed an isolated oak wilt pocket in northwestern Pine County (Bremen Township) for the first time, only 4.5 miles east of Aitkin County. The finds were from ground and aerial surveys and reports by land managers and owners.

DNR staff investigated more than 165 potential disease locations in Morrison, Cass, and Crow Wing for the presence of oak wilt in 2021, confirming at least 15 new disease centers. DNR staff investigated 48 potentially new locations in Pine County, confirming 26 new disease centers.

Management

Five years of monitoring are necessary to determine if oak wilt is eradicated from a controlled spot. This year we determined that 11 oak wilt pockets in Pine County and two pockets in Kanabec County were successfully eradicated. We are unaware of more pockets of oak wilt in Kanabec County, but most of the county remains at high risk of infection.

Morrison County Soil and Water Conservation District (SWCD) continued their program to financially assist private property owners with oak wilt control in Morrison County and northward using a grant from the Environment and Natural Resources Trust Fund. DNR Forestry assisted the SWCD with disease detection, management advice, primary barrier line marking, and control monitoring. Many affected landowners in Cass and Crow Wing counties decided to control the disease. The SWCD financially assisted nine property owners in 2021.

Most of the known oak wilt in Pine County is in St. Croix State Park. Oak wilt increased rapidly there after a blowdown on July 1, 2011, a high-risk time for overland oak wilt infection. This year St. Croix State Park staff controlled 15 new pockets, and forest health staff continued to monitor 65 previously controlled pockets in the park.

This year oak wilt was confirmed for the first time on the St. Croix State Forest, also in Pine County. DNR staff in the Divisions of Forestry and Parks and Trails installed a primary barrier line and a logger harvested all oaks inside the line. Oak wilt was also confirmed for the first time on Pine County land and was controlled by stump extraction.

For several years, staff in the DNR Division of Parks and Trails and the forest health unit have surveyed for oak wilt in Lake Maria State Park. The park is at the western edge of known oak wilt pockets to date, another spot in which to focus control. In 2021, park staff controlled 20 known oak wilt pockets.

DNR forestry staff continued to work with landowners in locations at the leading edge of oak wilt to encourage them to control oak wilt and offer cost-share for control through the DNR stewardship program.

Declines and Abiotic Problems

Aspen decline

We mapped 29,108 acres of aspen damage in 2021, an increase from 2019 when 16,905 acres were recorded. Multiple factors typically contribute to aspen decline. Symptoms can include leaf discoloration and dieback, and in some cases mortality can result.

Aerial surveys in Minnesota have documented aspen and birch decline since 2004. Aspen and birch decline were regionally isolated in the past, particularly in the Arrowhead Region. Old age, flooding, regional drought, wind, and other stressors are probable causes of decline. Recent years of drought in northern Minnesota have likely contributed to decline. This is particularly true for northwest Minnesota, where the majority of aspen decline was mapped in 2021. The severe drought in 2021 possibly contributed to symptoms this year, but the impacts will likely be observed in the ensuing years.



Counties recorded with aspen decline in 2021.

Attack of the squirrels

Squirrels commonly strip off sugar maple bark in late winter and early spring. It is unusual to receive reports of squirrel damage earlier than February, but a DNR forester reported fresh squirrel damage on maples in mid-January at Camp Ripley in Morrison County this year. Reports of squirrel damage followed in the first half of February in central Minnesota counties (Crow Wing, Kanabec, Pine, and Todd), plus a report from Houston County in the southeast. Foresters stated that squirrel damage seemed more common than usual in Houston and Kanabec counties.

We saw ample clusters of scattered sugar maples with severe dieback in aerial surveys over Crow Wing, Morrison, and Pine counties in summer 2021 (see images). Ground-truthing of some of these areas proved squirrel damage was the culprit.

John Ball with South Dakota State University wrote in his January 6, 2021 [newsletter](#) that he received several reports of squirrels stripping bark from elms in early January in South Dakota. He suggested that warm and droughty conditions in autumn 2020 may have concentrated sugars in tree bark and attracted squirrels.

Each of Minnesota's climate zones with abundant squirrel damage (central, east-central, and southeast) had average monthly temperatures higher than the long-term average in November 2020, December 2020, and January 2021. From November 2020 through January 2021, these three climate zones combined had the fifth highest average temperature on record since 1896.

We also know that acorns are an important food source for squirrels. DNR bear-food surveys showed acorn production was at record or near-record levels in 2018 in areas with abundant squirrel damage. From the Twin Cities to Mankato, we observed extremely high levels of acorns in 2019, and another reporter from Otter Tail County recorded large numbers in 2019 and 2020 but not in 2021. It seems possible that the high acorn crops prior to 2021 increased squirrel populations in certain areas.

Other than weather and acorn records, all observations are anecdotal. Squirrel damage to sugar maples seemed earlier and worse than average. Whether that had to do with higher sugar content in maples due to the warm November through January or some other factor of forest or squirrel biology remains a mystery.



Flagging sugar maples from squirrel damage in Pine County.



Flagging sugar maples from squirrel damage (from the forest aerial photograph above).

The drought of 2021

Most of Minnesota except for Houston, Wabasha, and Winona counties in the southeastern toe of the state experienced a serious drought this year. It was hard on trees and the effects will last for several years. Drought-stressed trees are not able to resist attack from insects and diseases that would normally not cause serious problems. During and after a drought, trees generally are more susceptible to invasion by native pests like bark beetles, cambium borers, and root diseases.

The six-month period from April through September was the ninth driest on record for the entire state since 1895. The drought hit the northern third of Minnesota the hardest—such dry conditions have not occurred since 1976. To add to the 2021 impact on trees, northeastern Minnesota has experienced several consecutive years of dry growing seasons, not reaching long-term average growing season precipitation since 2017.

Central Minnesota experienced the third driest period from May through July on record (and the driest ever recorded from May through July for the northern third of the state).

Drought and heat effects on broad-leafed trees

The impact of drought was worse on previously stressed hardwoods on some urban lots, campgrounds, and pastures. Some urban maples in east-central Minnesota that developed dieback in prior years developed even worse dieback in June and July.

Extremely hot temperatures in June induced leaf scorch symptoms on oak, maple, and basswood in central Minnesota. Scorch was particularly severe on bur oaks growing on heavier soils in pastures flooded in earlier years in Morrison County. Central Minnesota hadn't experienced a hotter June since 1988, and east-central Minnesota hadn't experienced a hotter June since 1933. Leaf scorch on oaks was also documented in summer of 1988. We expect many bur oaks that exhibited leaf scorch to leaf out as normal in 2022, as they did in 1989.

From July through August this year, twolined chestnut borer affected oaks on widely scattered parcels in central Minnesota oaks. See the twolined chestnut borer article beginning on page 28 for details.



Leaf scorching on bur oak seedlings in Sherburne County, July 2021.



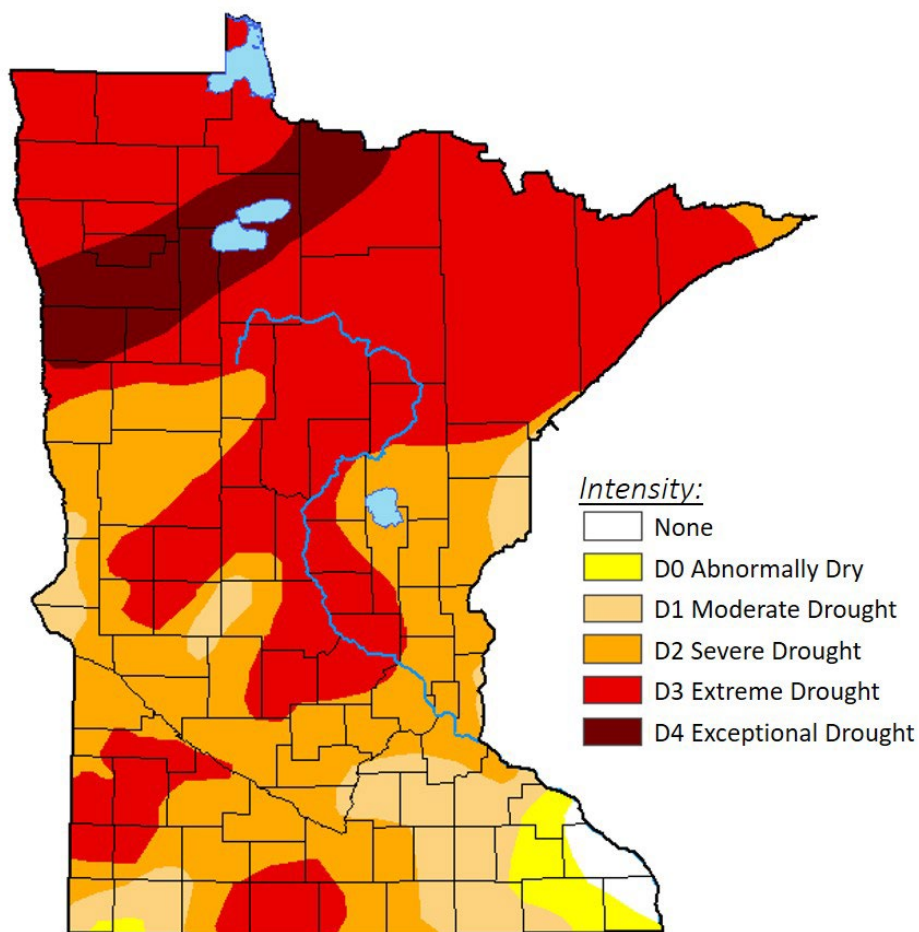
Scattered bur oaks in a pasture with whole-canopy leaf scorching, July 2021.

Drought effects on pines

In August we began receiving reports from Roseau and northern Beltrami counties that red pines were suddenly turning red. Needle discoloration generally started at the top of the tree and worked its way down through the crown. Many affected stands had been thinned earlier in the season. After visiting the stands, we were able to determine that pine bark beetles were causing the damage. This was not a widespread issue but was severe in some stands.

In normal weather conditions, bark beetles infest damaged trees and live in logging slash; healthy trees are not affected. During a drought, however, bark beetles can overcome the trees' defenses and cause mortality by creating galleries under the bark that cut off the flow of water and nutrients throughout the tree. The beetles also carry blue stain fungi that accelerate the death of the tree and turn the wood blue-green, which can lower its value.

Armillaria root rot is another issue in drought-stressed red pine. Armillaria is a native fungus that lives in the soil and decays the roots and lower trunk of a tree, eventually causing it to die. A healthy tree is less likely to be colonized by Armillaria, but a tree can be overcome when drought-stressed, resulting in mortality.



Minnesota drought conditions on August 24, 2021. US Drought Monitor, Curtis Riganti, National Drought Mitigation Center). This was the first time since the inception of the U.S. Drought Monitor in 2000 that the *Exceptional Drought* intensity was reported.

The severe drought in 2021 also led us to examine the possible impact on recently planted red pine trees in plantations. We visited only a small set of plantations and we plan to examine others in 2022. The table below summarizes the percent of young pines that died because of drought mortality.

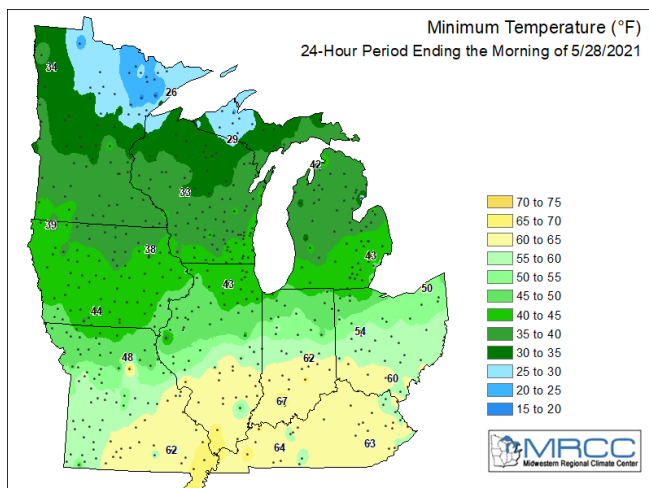
Location (Township- Range-Section)	County	Year Planted	Planting Stock	Drought Mortality
41-17-1	Pine	2017	Containerized	3%
34-27-15	Sherburne	2020	Containerized	2%
34-27-33	Sherburne	2017	Bareroot	1%
61-11-4	St. Louis	2020	Containerized	6%
62-11-34	St. Louis	2018	Containerized	12%
62-14-22	St. Louis	2021	Containerized	8%
53-13-16	St. Louis	2021	Bareroot	65%

Red pine plantation survival surveys for northern Minnesota.

Frost damage to oak and ash

A late spring freeze frequently kills oak and ash leaves emerging in early May. The damage doesn't seem to hurt trees over the long-term since it happens frequently and trees reliably re-leaf one to two weeks after freezing temperatures. This year, damaging temperatures of 31°F and lower were reported on May 28, 29 and 30 in many locations from Pine County west to Todd County and northward, killing oak and ash leaves. A fair amount of the damage on leaves was observed on trees growing on the edges of forests or in the understory. Even low-lying areas as far south as Sherburne County experienced freezing temperatures.

In 2020, a late spring freeze occurred in southern Minnesota on May 12 and 13 and in northern Minnesota on May 31.

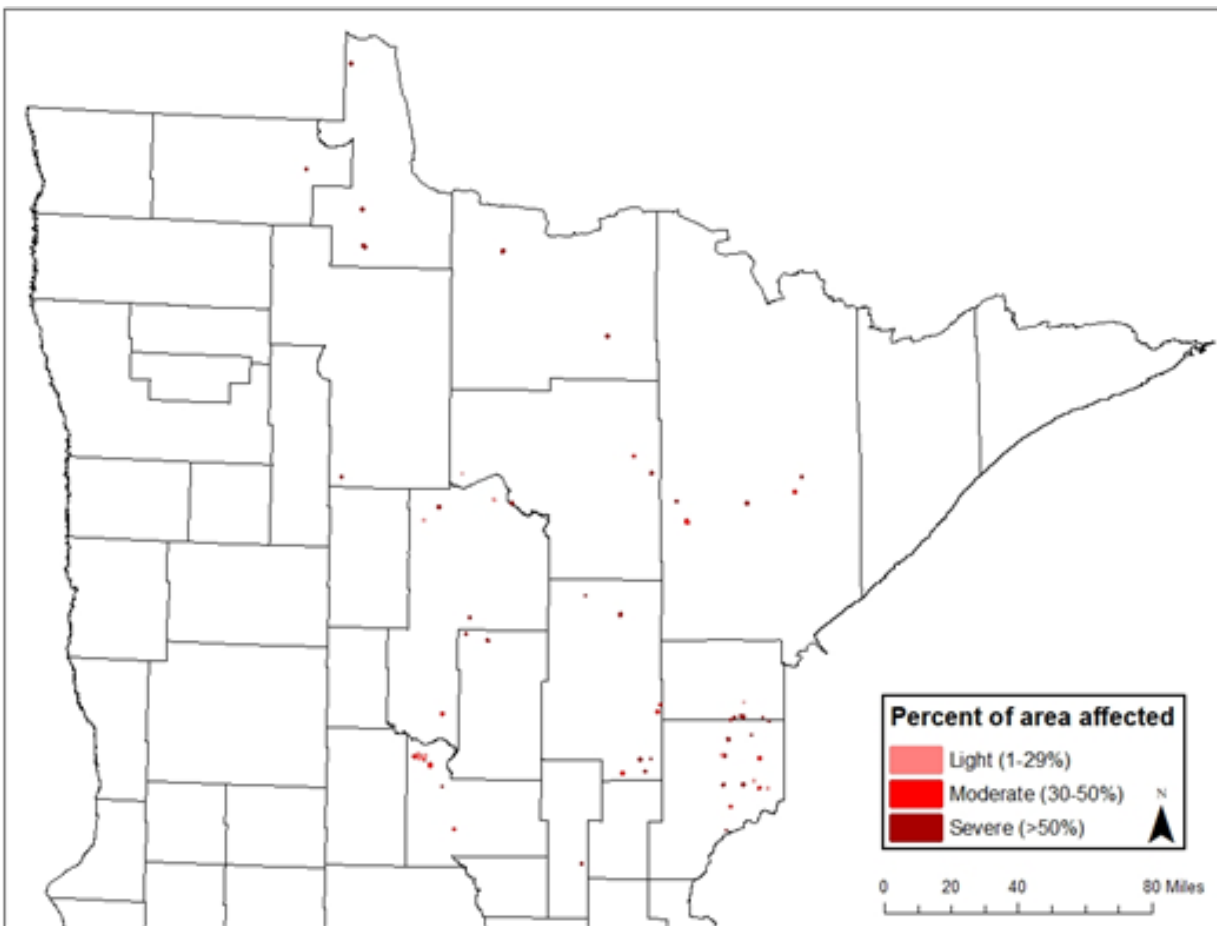


Frost damage on leaves of an understory ash tree.

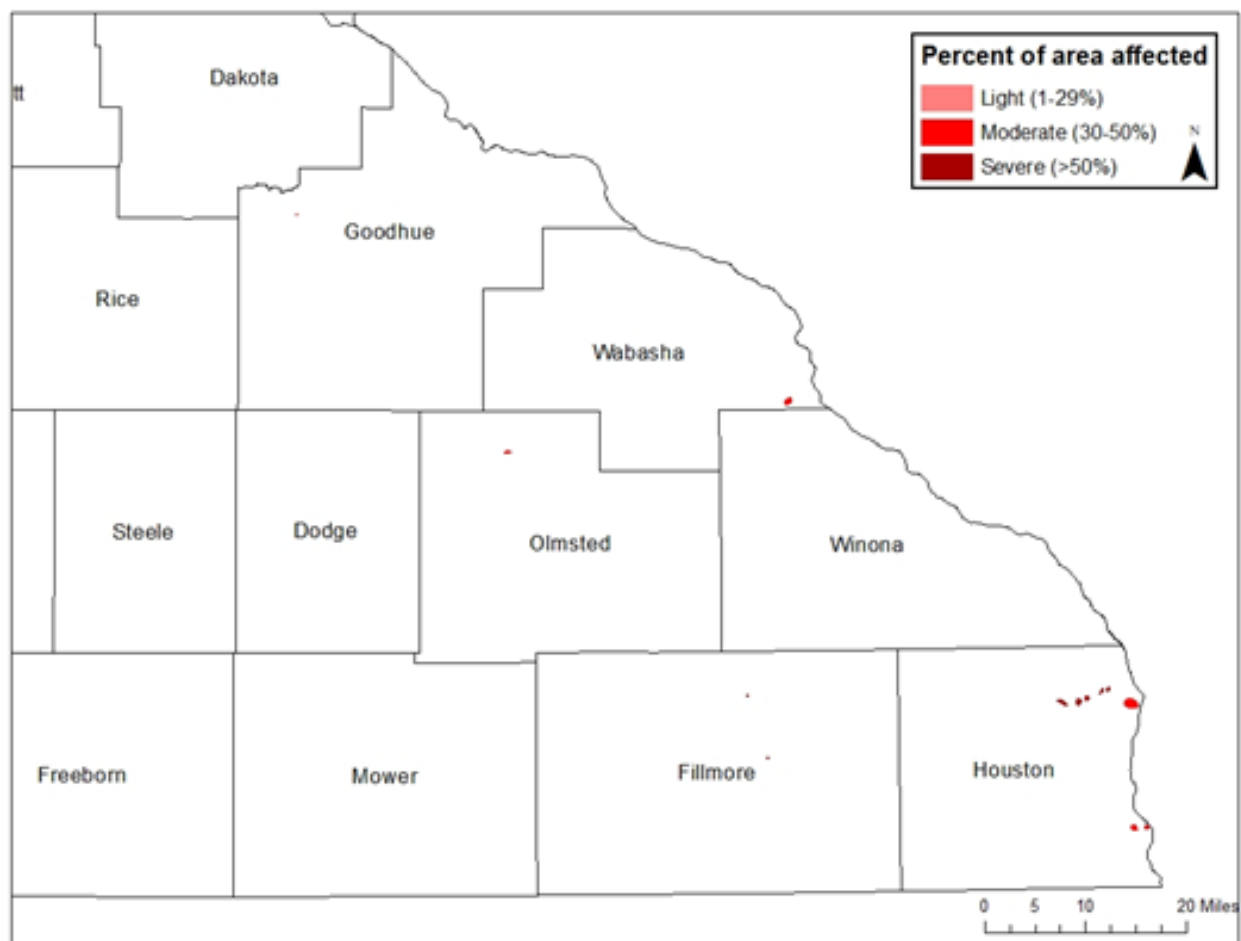
Flood damage

Aerial surveys detected 3,710 acres of flood damage in 2021, primarily in central and eastern Minnesota. Most of the damage was moderate or severe. Trees continued to show symptoms of stress or finally succumbed to flood damage after extreme levels of precipitation in 2019, a year of record rainfall.

Most areas in Minnesota were in drought from May through July 2021, but some areas received abundant rainfall in the spring and in late summer. The Minnesota State Climatology Office reported that both March and April had slightly higher than average precipitation statewide, with rainfall unevenly distributed statewide. Following deep drought in many parts of the state, extremely heavy rains in late August soaked much of southern Minnesota and small zones in central and northwest Minnesota. Some of these rains led to flash flooding in southwest Minnesota. The late summer deluges occurred after aerial surveys were completed.



Flood damage in northern Minnesota in 2021.

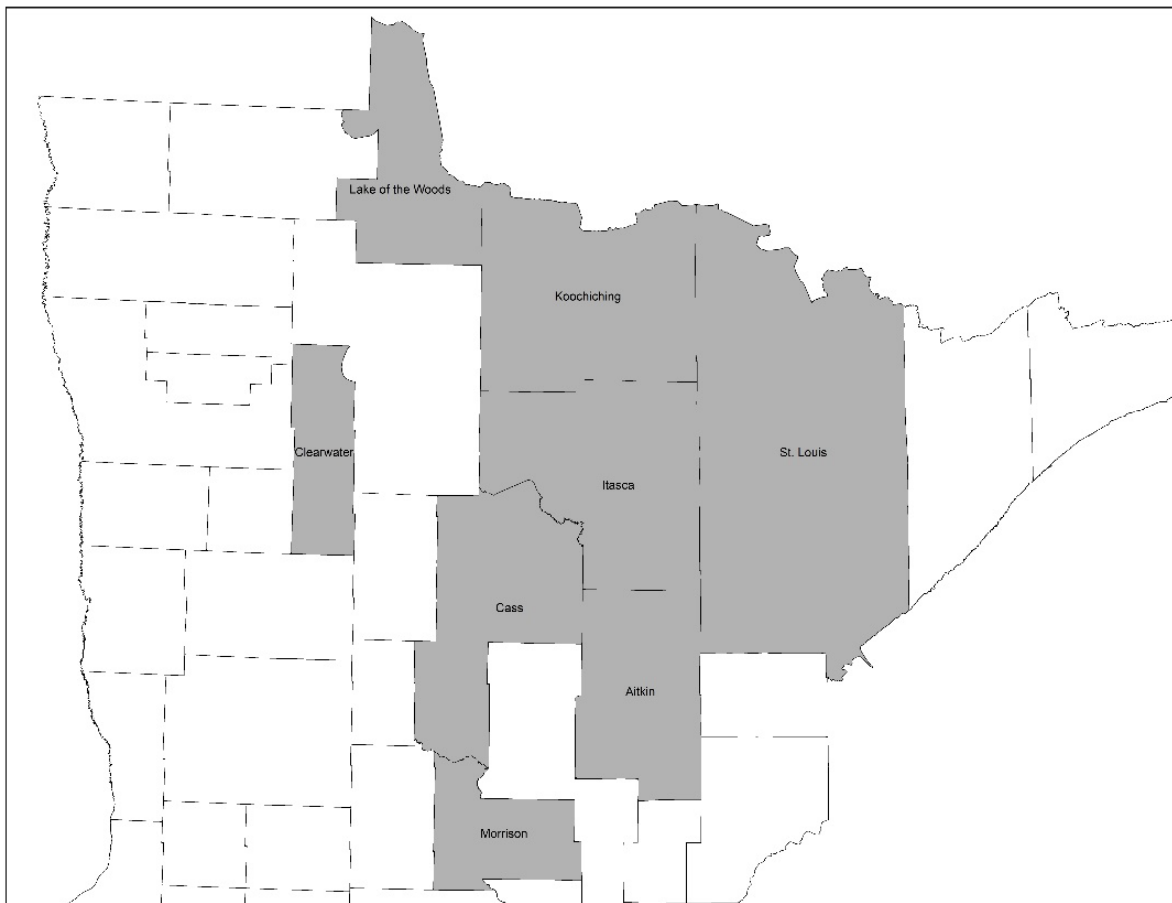


Flood damage in southeast Minnesota in 2021.

Wind

DNR forest health staff mapped about 2,000 acres of wind damage in aerial surveys in summer 2021. Aitkin, Clearwater, Koochiching, and Lake of the Woods counties had more than 100 acres of contiguous wind damage.

Due to timing and location, some wind damage is missed in our surveys. The most notable wind damage was an outburst of tornadoes in southern Minnesota on December 15. Never before had tornadoes been recorded in December in the state. Twenty tornadoes were confirmed, occurring in Fillmore, Freeborn, Goodhue, Houston, Mower, Steele, Wabasha, and Winona counties.



Counties where wind damage was observed in summer 2021 via aerial survey.

Other tree pest and tree health events noted in 2020 and 2021

Pest or event	Pest stage or cause	2020 (county in which observed)	2021 (county in which observed)
Ash: Sudden leaflet drop	Anthracnose	May 23 (Goodhue, Rice, Sherburne)	Not observed
Oak: deformed leaves	Anthracnose	June 5 (Rice) June 6 (Chisago)	Not observed
Oak: shoot blight	<i>Diplodia corticola</i> on bur oak	Early September (Chisago)	Early September (Chisago) (lower severity than in 2020)
Eastern tent caterpillar	Caterpillars 0–0.5 inches long	May 6 (Goodhue)	Not recorded
European pine or red pine sawfly on jack pine	Caterpillars, 0.5–1 inch long	June 10 (Cass, Crow Wing, Morrison) June 17 (Pine)	Not recorded
Fall webworm nests	Caterpillars	Observed in various areas in southern Minnesota (more than in 2019)	July 15 (Pine)
Forest tent caterpillar	Caterpillars, 1–1.5 inches long	June 5 (Morrison) June 11 (Mille Lacs)	May 25 (Itasca) June 2 (Mille Lacs) June 7 (Aitkin)
Hickory mortality (bitternut and shagbark)	Hickory bark beetle (<i>Scolytus quadrispinosus</i>)	Not recorded	July 28 (Houston)
<i>Lymantria dispar</i>	Female moths laying egg masses	Not observed	August 19 (Lake)
Oak wilt	Spore mats	Not recorded	July 23 (Cass) September 2 (Pine)
Oak wilt	Wilting noted for the first time	June 16 (Chisago)	June 9 (Mille Lacs, Sherburne)
Red pine: shoot blight	Red pine shoot moth	July 10 -14 (Metro area to Pine County to Bemidji area)	June 29 (Isanti) June 30 (Ramsey) July 1 (Carver) July 23 (Cass)
Spruce budworm	Caterpillars 0.75-1 inch long	June 11 (Cook)	June 23 (St. Louis)