2016 Forest Health Annual Report

Minnesota Department of Natural Resources
Division of Forestry
Forest Health Unit

The Minnesota Department of Natural Resources Forest Health Annual Report was created by the Division of Forestry Forest Health Unit.

Cover photos, clockwise from left: jack pine budworm damage, twolined chestnut borer damage, forest tent caterpillars

Photo credits: photos and other images are from DNR forest health staff unless indicated otherwise.

Projects were funded in whole or in part through a grant awarded by the US Forest Service, Northeastern Area State and Private Forestry.

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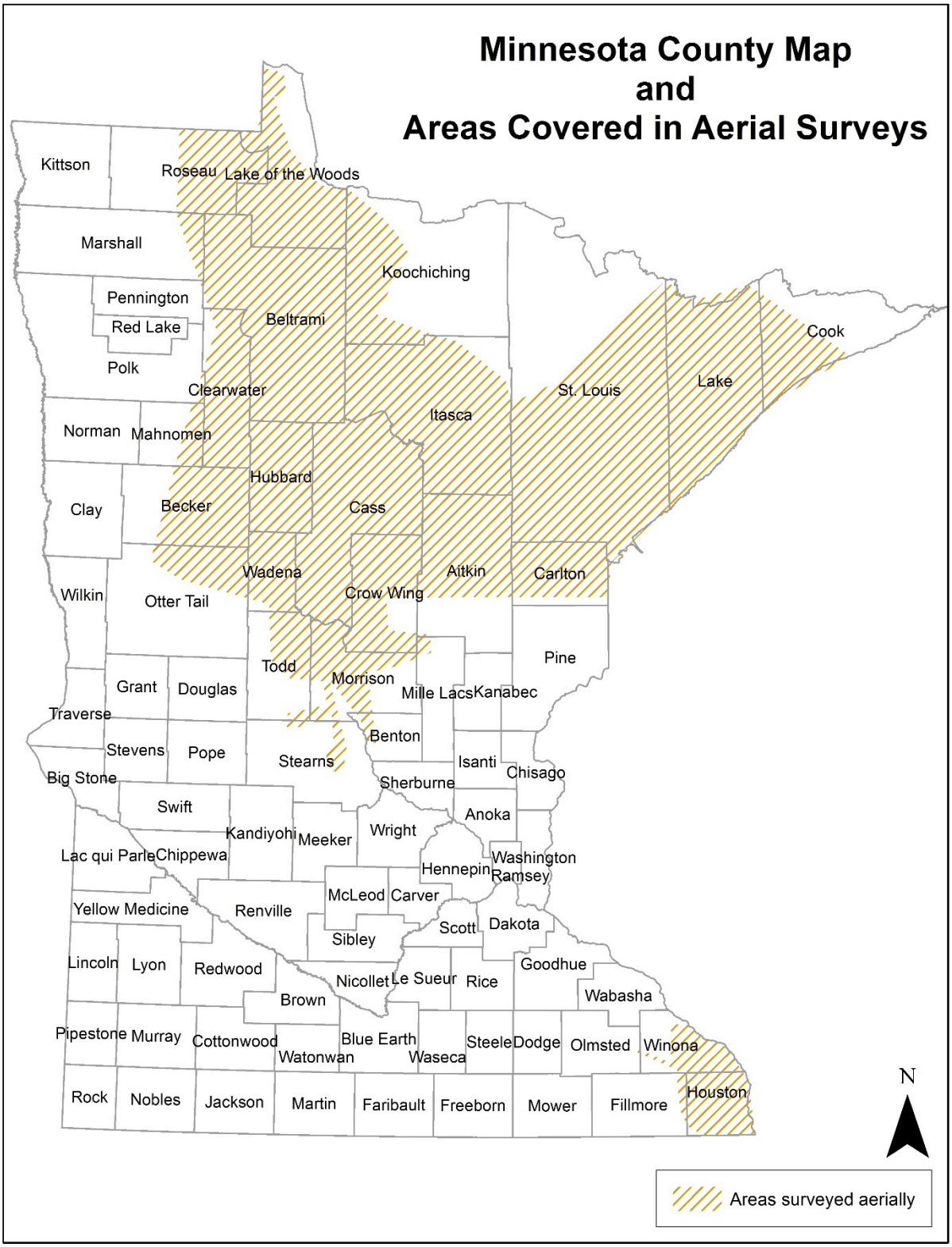
Minnesota County Map
and
Areas Covered in Aerial Surveys
Kittson
Roseau
Lake of the Woods
Marshall
Koochiching
Pennington
Red Lake
Beltrami
Cook
Polk
Clearwater
St. Louis
Lake
Itasca
Norman
Mahnomen
Hubbard
Clay
Becker
Cass
Wadena
Aitkin
Carlton
Wilkin
Otter Tail
Crow Wing
Pine
Todd
Morrison
Grant
Douglas
Mille Lacs
Kanabec
Traverse
Benton
Stevens
Pope
Stearns
Isanti
Chisago
Big Stone
Sherburne
Swift
Anoka
Kandiyohi
Meeker
Wright
Lac qui Parle
Chippewa
Washington
Hennepin
Ramsey
McLeod
Carver
Yellow Medicine
Renville
Scott
Dakota
Sibley
Lincoln
Lyon
Redwood
Goodhue
Nicollet
Le Sueur
Rice
Brown
Wabasha
Pipestone
Murray
Cottonwood
Blue Earth
Steele
Dodge
Olmsted
Winona
Watonwan
Waseca
Rock
Nobles
Jackson
Martin
Faribault
Freeborn
Mower
Fillmore
Houston
N
Areas surveyed aerially

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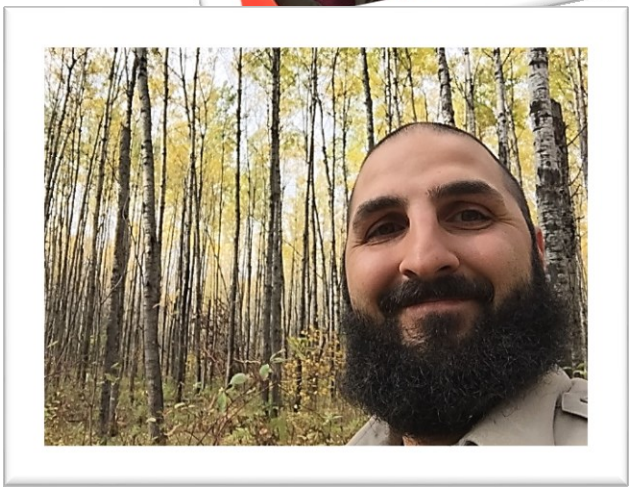
Welcome Mike Parisio and Jess Hartshorn!

We are happy to announce that in June 2016 we added two forest entomologists to the forest health staff, replacing the vacated seats held by long-time forest health specialists Mike and Jana Albers.

Jess Hartshorn, Northeast Region forest health specialist, grew up in Dayton, Ohio. She developed a passion for forest health during her undergraduate studies at Southern Illinois University. She received her MS and PhD in forest entomology at the University of Arkansas. During graduate school, Jess studied the life history and mortality factors of a native woodwasp in preparation for the invasion of a related non-native species, *Sirex noctilio*.



Mike Parisio, Northwest Region forest health specialist, grew up in the Catskill Mountains of upstate New York. After watching emerald ash borer destroy many favorite forested areas in Catskill State Park, he made the decision to attend the SUNY College of Environmental Science and Forestry to study forest entomology, and more specifically, emerald ash borer biological control. Mike gained additional forest health-related experience while working for the New York State Department of Environmental Conservation, the SUNY Research Foundation, and the NYS Office of Parks, Recreation, and Historical Preservation.

Mike and Jess hit the ground running. With experienced guidance from Brian Schwingle, Central Region forest health specialist, both have quickly settled into a field routine that includes responding to requests from DNR foresters, ground-checking aerial survey polygons for accuracy, writing for our newsletters and web pages, and participating in staff insect and disease training.

Our team is once again complete, and as always, we look forward to serving our DNR foresters and the greater forestry community of Minnesota.

Annual Aerial Survey

Since the early 1950s, the Minnesota Department of Natural Resources (MNDNR) aerial survey has been a valuable tool for monitoring forest insects and pathogens across 13 million acres of forest land. Annual surveys are accomplished through the collaboration of MNDNR Forest Health and Resource Assessment Units and the U.S. Forest Service Northeastern Area State and Private Forestry (USFS). MNDNR Forest Health staff plans the scope, timing, and intensity of the surveys, and Resource Assessment staff conducts aerial sketch-mapping, digitizes the data, and produces digital shapefiles. USFS State and Private Forestry conducts aerial sketch-mapping on the national forests, and the combined survey results are incorporated into a national database. The summary table below shows the amount of acres damaged by insects, disease, and other factors.

Comparison of Aerial Survey Results in 2015 and 2016

Damage agent	Acres Affected in 2015	Acres Affected in 2016	Comments
Aspen and birch decline	38,948	15,052	
Bark beetles	3,154	65	Excludes bark beetles of hardwoods and tamarack; the 2016 value is an underestimate but still accurately reflects a declining trend in bark beetle populations.
Birch leafminer	Not detected	932	A single large outbreak was observed on Ottertail Point in Leech Lake (Cass Co.).
Black ash decline	30,483	Not surveyed	
Eastern larch beetle	33,786	71,157	Widespread tamarack damage and mortality continues across the northern regions of Minnesota.
Emerald ash borer	Not Surveyed	3715	Only Winona and Houston counties were surveyed, so this is an underestimate for 2016.

Damage agent	Acres Affected in 2015	Acres Affected in 2016	Comments
Wildfire	7,507	1,557	Some parts of Minnesota that had forest fires in 2016 were not surveyed, so the 2016 value is an underestimate.
Flooding	1,066	5,692	Parts of southern Minnesota that experienced flooding in 2016 were not surveyed, so the 2016 value is an underestimate.
Forest tent caterpillar	65,750	14,798	The 2016 value is an underestimate due to partial coverage of the state.
Hail	Not detected	454	Several severe storm events produced hail large enough to damage trees in northern Minnesota.
Jack pine budworm	5,210	2,392	The 2016 value is likely an underestimate due to storm interference with aerial survey.
Larch casebearer	14,220	15,286	
Northern hardwood decline	4,768	1,214	Defined in 2016 surveys as crown dieback on northern hardwoods or basswood; there was a considerable amount of acreage attributed as mortality to unknown hardwood species, which could be decline but is not included here.
Spruce budworm	105,522	130,514	
Twolined chestnut borer	106	607	The amount of forests affected in 2015 was a significant underestimate due to suboptimal survey timing; almost all of the 2016 acreage was estimated from limited

Damage agent	Acres Affected in 2015	Acres Affected in 2016	Comments
			photograph-based surveys, so it is also an underestimate.
Wind damage	3,232	18,953	Several severe storm events produced widespread damage with winds strong enough to uproot trees and break main stems in 2016.

Insects

Bark beetles of pine and spruce

Bark beetles of conifers other than tamarack were uncommon in 2016. Nearly all of our native bark beetles that attack conifers cause problems during and after a drought, and most parts of Minnesota have experienced adequate precipitation during the past couple of growing seasons, resulting in a decline in bark beetle issues.

In 2016, only 65 acres of damage were attributed to bark beetles in forest health aerial surveys, and only 14 locations (stands or mortality centers) were documented in ground surveys as having problems with conifer bark beetles. One of those ground-based surveys recorded spruce beetle (*Dendroctonus rufipennis*) on white spruce in Becker Co., while the remainder of the detections were mostly *Ips* species in red, jack, and Scots pines. Only four of the 14 ground-based surveys reported bark beetles as the primary cause of symptoms.

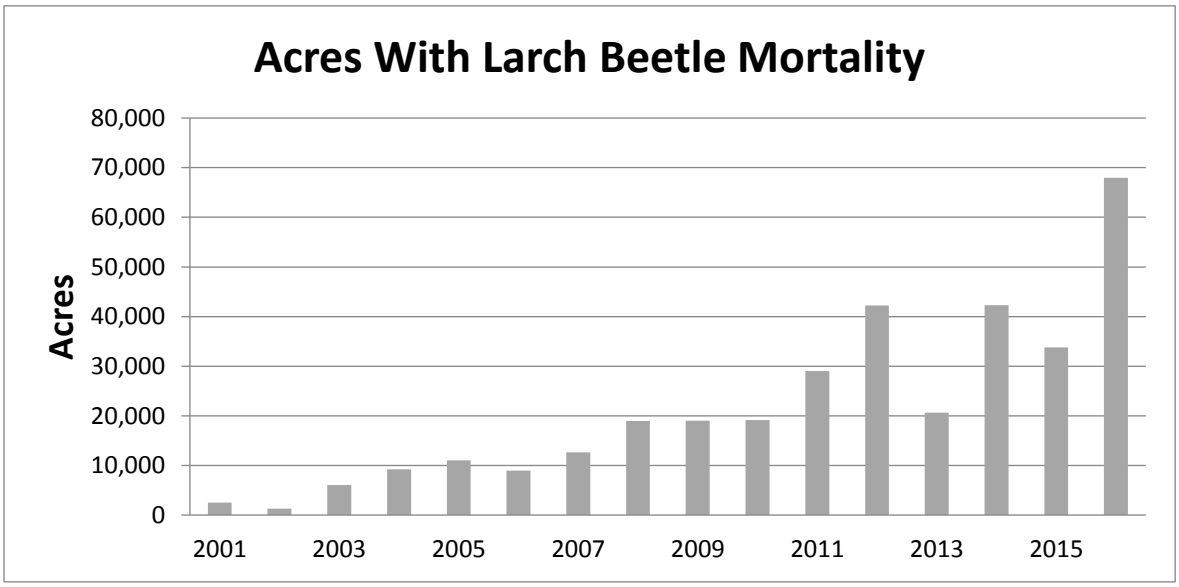
Numerous conifer problems identified in the aerial survey were from unknown causes. Even if we had used polygons attributed with dying or discolored conifers from an unknown cause as a proxy for bark beetle infestation, acreage would have decreased from last year by 54 percent.

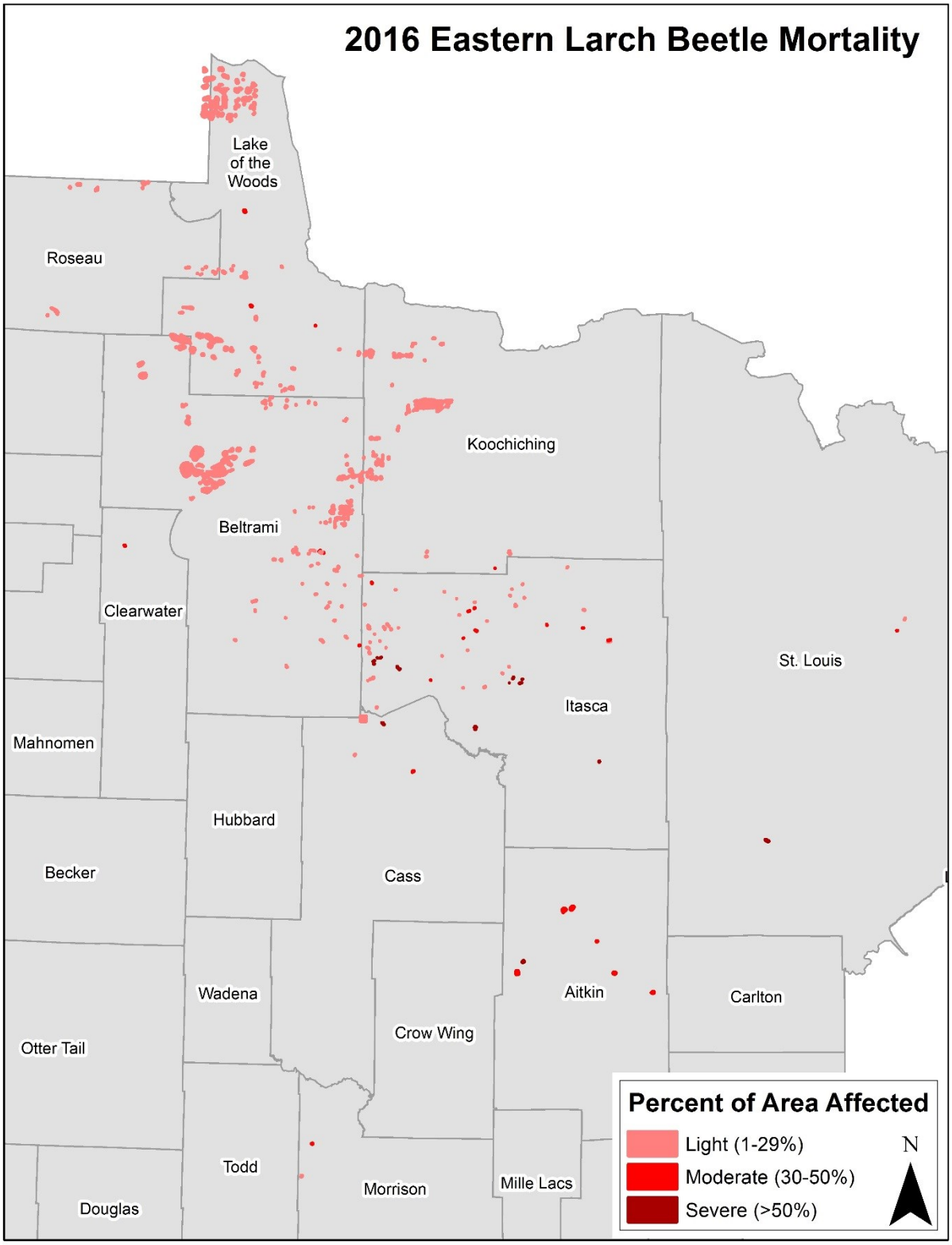
Pines killed by bark beetles

Eastern larch beetle

Widespread tamarack mortality caused by eastern larch beetle (*Dendroctonus simplex*) continued across north-central Minnesota (see map, p. 13). Beltrami, Koochiching, Lake of the Woods, and Roseau counties contained the majority of all impacted areas in 2016, and represented an 88 percent increase over acres mapped as newly-affected in 2015 (27,967). In 2016 there were 50,000 *newly-affected* acres out of 68,000 total acres. The majority of this damage was considered light, however, with less than five percent of all damage mapped as either moderate (30-50 percent affected) or severe (more than 50 percent affected).

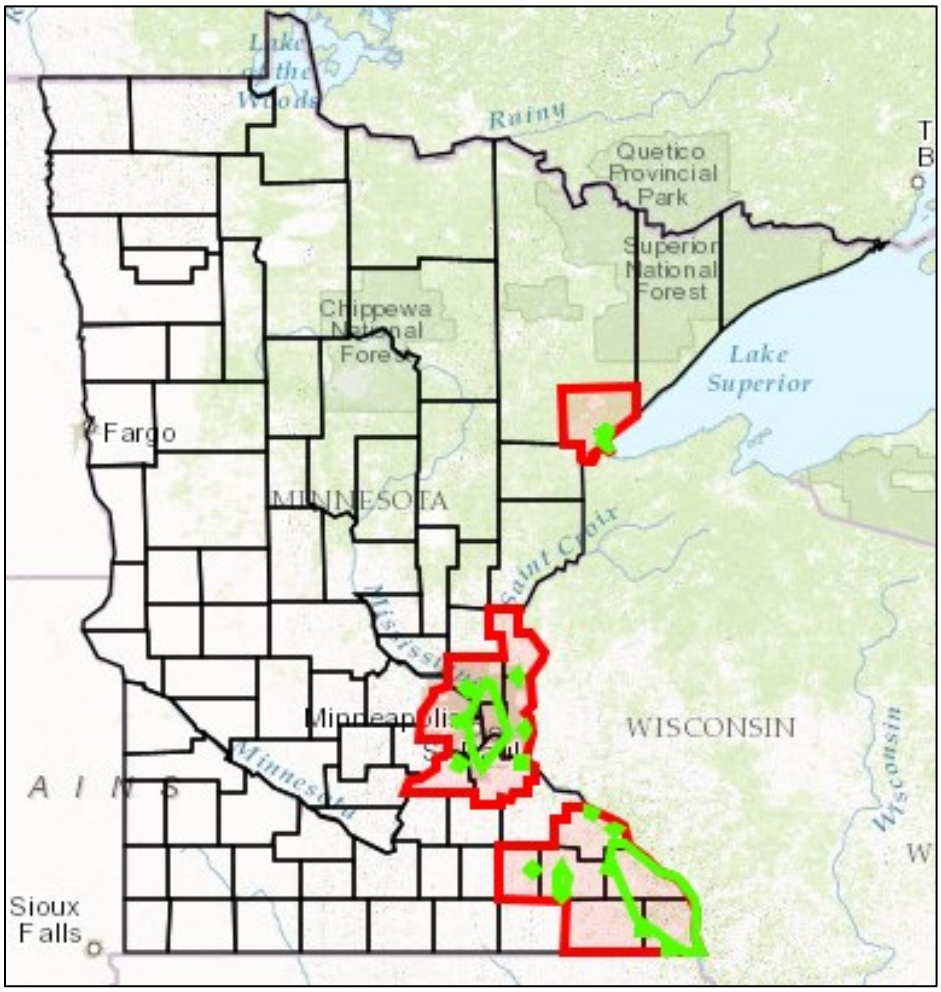
Although the majority of trees observed are not yet severely affected, they are expected to continue to decline in the upcoming years and be gradually killed by eastern larch beetle. Since we began recording eastern larch beetle damage in 2001, an estimated 283,000 acres of tamarack forests have been impacted. Though it will eventually be surpassed by emerald ash borer, eastern larch beetle is currently considered the most damaging forest insect in Minnesota in terms of tree mortality and overall acreage impacted.




2016 Eastern Larch Beetle Mortality
Lake of the Woods
Roseau
Koochiching
Beltrami
Clearwater
St. Louis
Itasca
Mahnomen
Hubbard
Becker
Cass
Wadena
Aitkin
Carlton
Crow Wing
Otter Tail
Todd
Morrison
Mille Lacs
Douglas
Percent of Area Affected
Light (1-29%)
Moderate (30-50%)
Severe (>50%)
N

Emerald ash borer (EAB)

This year only Dodge and Wabasha counties in southeast Minnesota were added to those quarantined for EAB. The following additional counties are under state and federal quarantine: Anoka, Chisago, Dakota, Fillmore, Hennepin, Houston, Olmsted, Ramsey, Scott, Washington, Winona, and Park Point in St. Louis County (see map below). A portion of southeast St. Louis County was added to the Duluth Park Point quarantine when EAB was discovered in greater Duluth this year.



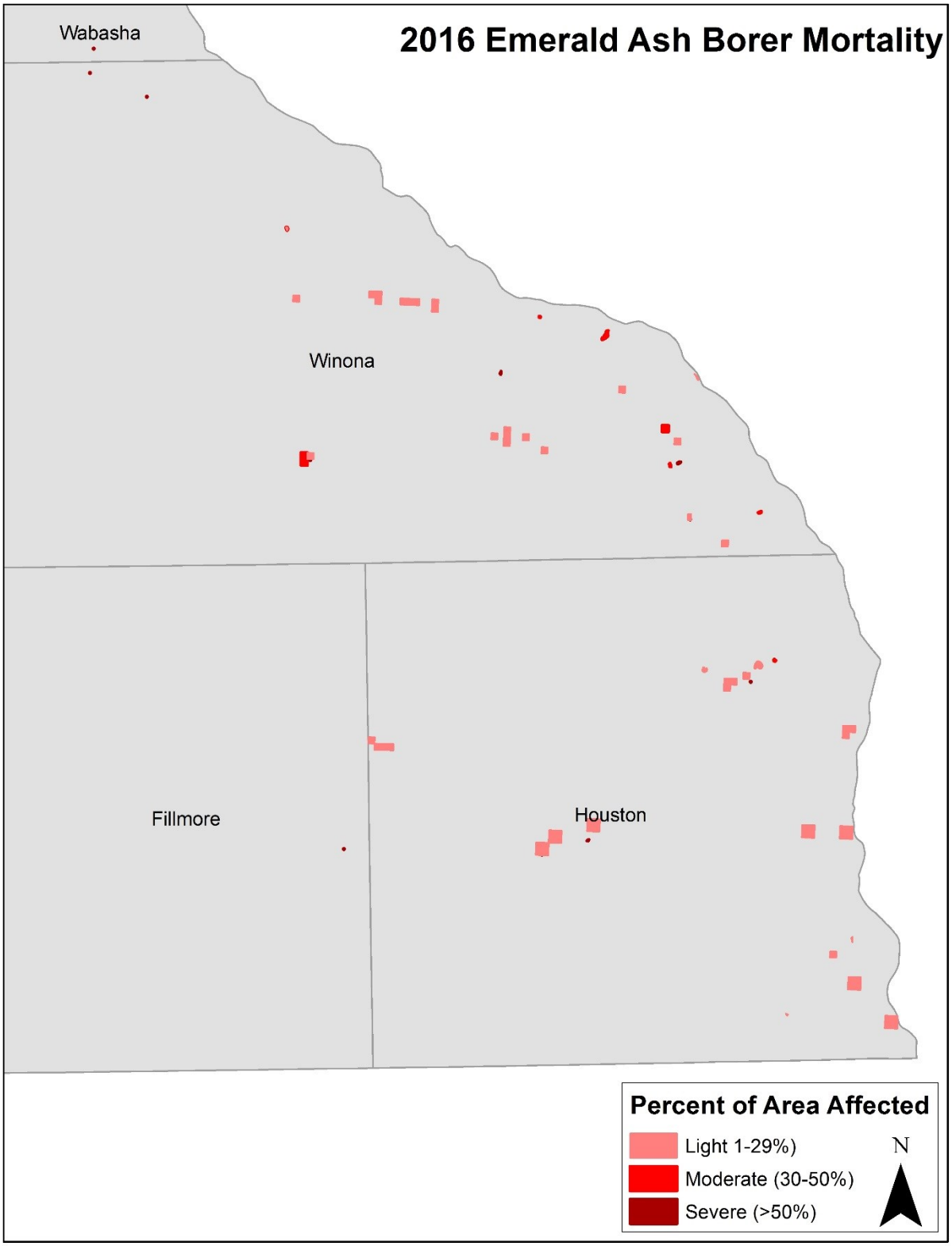
Map of EAB quarantine, from Minnesota Department of Agriculture (MDA), accessed on-line December 2016. Counties outlined in red are federally quarantined. Areas in green are considered generally infested. See MDA's website for an updated quarantine map.

Tetrastichus planipennisi *larvae in EAB gallery*

USDA Animal and Plant Inspection Service deployed EAB traps this year rather than the Minnesota Department of Agriculture (MDA); 1,470 traps were placed. Several positive traps were reported in southeastern Wabasha County, already under quarantine.

During 2016, MDA released 89,501 parasitoid wasps (45,288 *Tetrastichus planipennisi*; 42,600 *Oobius agrili*, and 1,613 *Spathius galinae*) at 12 sites located in the Twin Cities and southeast Minnesota. This was the first year that *S. galinae*, a newly-approved larval parasitoid from the Russian Far East, was released in Minnesota, at three sites along the Mississippi River in the Twin Cities. Brian Schwingle found a clutch of *T. planipennisi*, a larval parasitoid, in an EAB gallery (pictured above) while ground-truthing in southeast Minnesota; the find was more than four miles from the nearest parasitoid release location, evidence that *T. planipennisi* is spreading in the southeast part of the state.

The map on p. 16 depicts ash mortality and crown dieback due to emerald ash borer that was marked in the aerial survey in southeastern Minnesota. Approximately 3715 acres of land was impacted by EAB.


2016 Emerald Ash Borer Mortality
Wabasha
Winona
Fillmore
Houston
Percent of Area Affected
Light 1-29%)
Moderate (30-50%)
Severe (>50%)
N

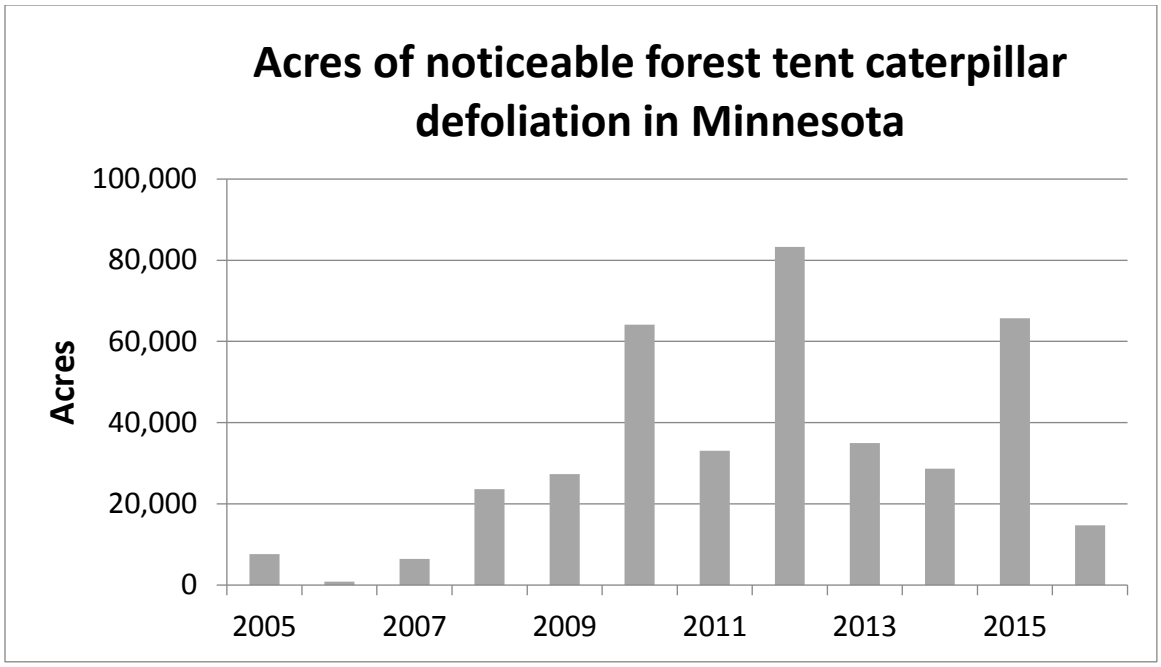
Forest tent caterpillar (FTC)

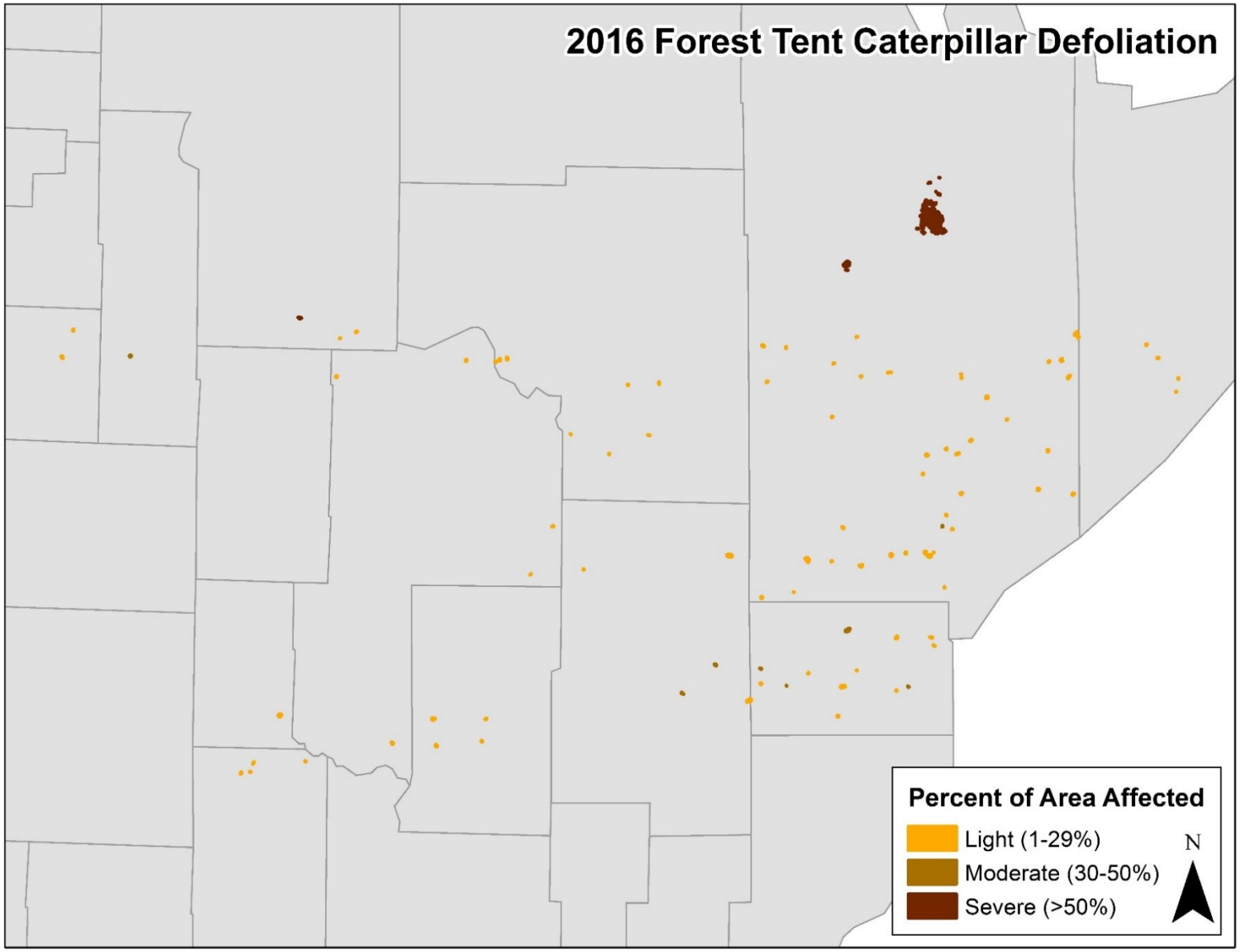
While only 14,725 acres of hardwoods were recorded with forest tent caterpillar defoliation in 2016, defoliation was underestimated because weather conditions postponed aerial surveys. Defoliation was also underestimated because portions of central Minnesota that often sustain defoliation were not surveyed. Most of the areas expected to be impacted by FTC were surveyed in July and August, well after larval feeding and after most defoliated aspens have produced a second flush of leaves. Forest managers should consider regenerating aspen stands that are nearing rotation age if they are in areas that have experienced multiple years of severe FTC defoliation.

In 2012 there was an increase in defoliated acreage compared to the previous six years, and we expected that this increase was leading to an outbreak. In 2013 and 2014, however, the damage decreased. There was a sharp increase in defoliation in 2015, and we again expected that to continue into 2016, but were surprised to find 78 percent less area affected. Because of the late aerial surveys and partial coverage this year, it's not possible to accurately compare surveyed damage to previous years. This also means that reliable predictions for future defoliation events are nearly impossible to make.

While some of the recorded defoliation was light to moderate and in small patches across northeastern Minnesota, two large spots in northern St. Louis County have been severely defoliated year after year and will most likely experience branch dieback and whole tree stress in the future.

Forest tent caterpillars congregating at the base of a quaking aspen tree in Itasca County.

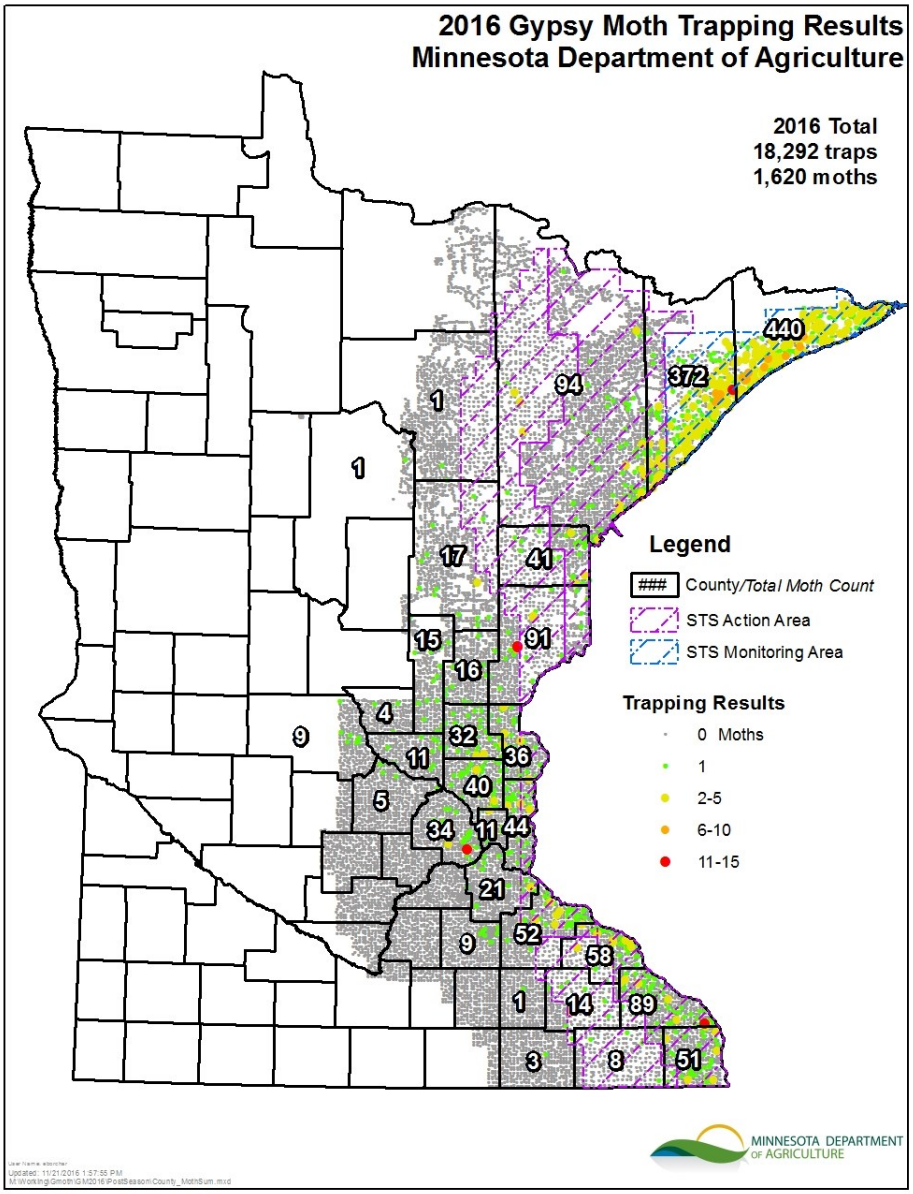

Acres of noticeable forest tent caterpillar defoliation in Minnesota
Acres
100,000
80,000
60,000
40,000
20,000
0
2005
2007
2009
2011
2013
2015


2016 Forest Tent Caterpillar Defoliation
Percent of Area Affected
Light (1-29%)
Moderate (30-50%)
Severe (>50%)
N

Gypsy moth

After an all-time high capture of 71,258 male moths in 2013, Minnesota Department of Agriculture trap catch numbers were significantly reduced to 523 in 2014. This figure began to climb again in 2015 with 1,052 moths. The total increased slightly in 2016, with 1,620 gypsy moths caught in survey traps statewide.

The majority of the finds were in the southeast and northeast corners of the state due to the population moving in from Wisconsin. The Minnesota Department of Agriculture has identified three areas of concern where treatment proposals are likely in 2017 – one in southeast Minnesota, one in the Twin Cities metro area, and one between the Twin Cities and Duluth.

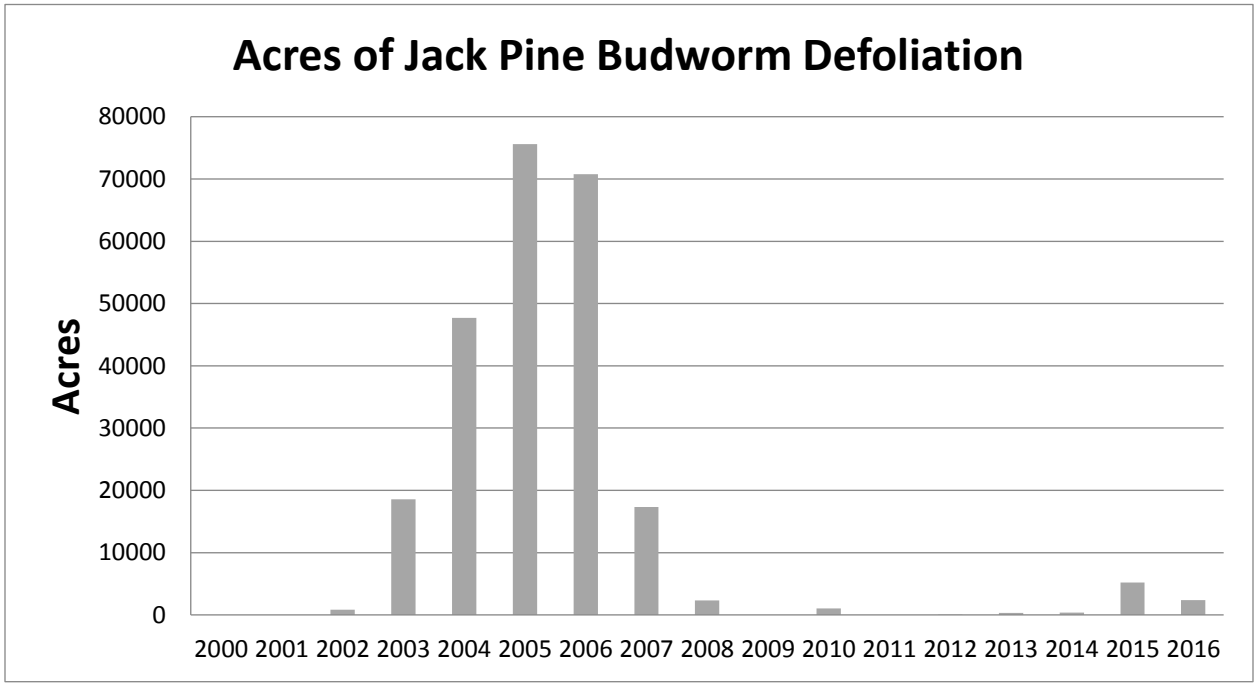


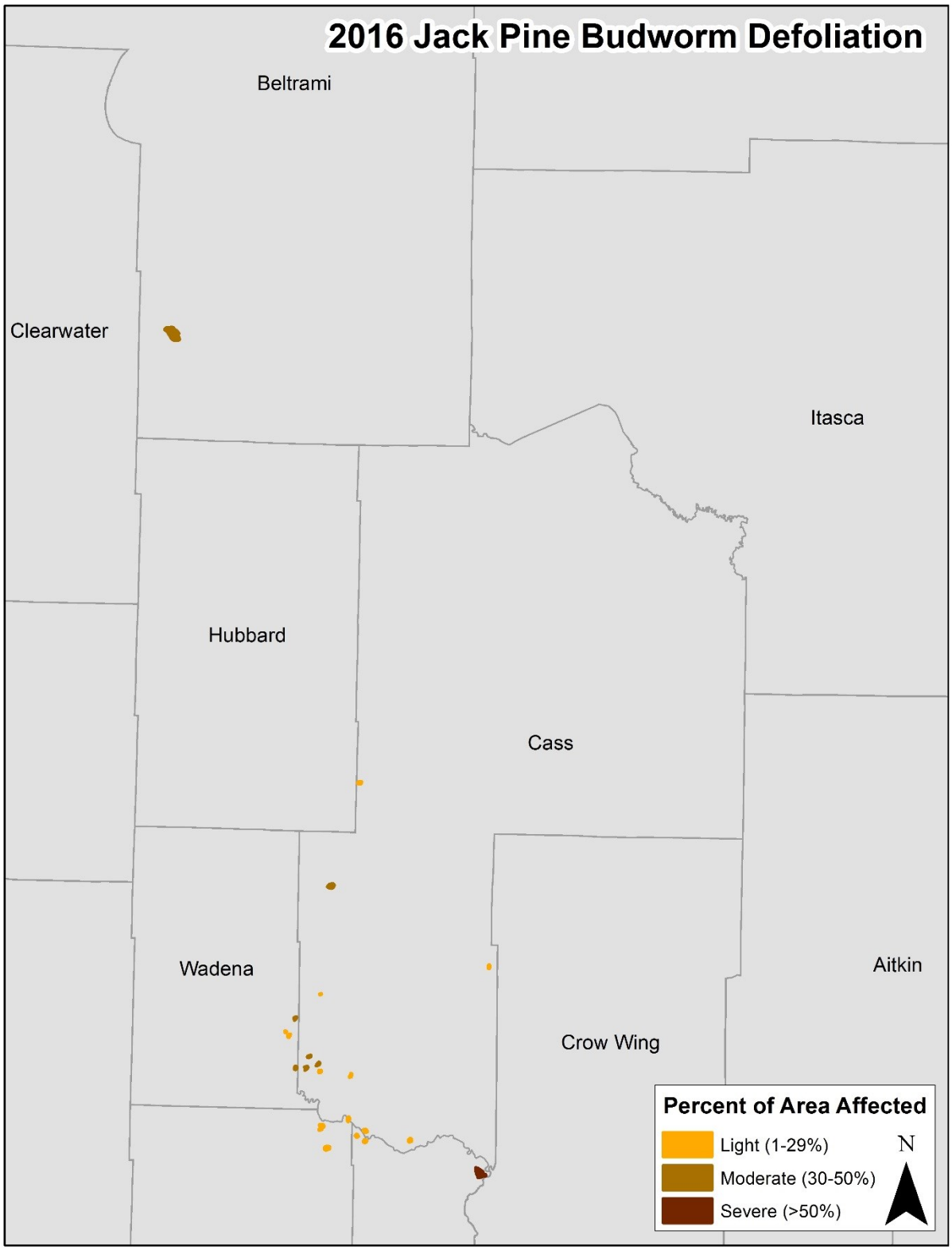
Jack pine budworm

Jack pine budworm (JPBW) defoliation continued in some areas of Minnesota's west-central and northwest counties (see map on p. 22) in 2016. Damage was not as severe as anticipated. The affected area decreased from 5,210 acres in 2015 to 2,392 acres in 2016 and possibly indicates the current outbreak is subsiding. Stands defoliated in 2014 and 2015 showed limited mortality in 2016. Despite the attempt to prioritize JPBW during aerial survey scheduling, several rain events removed JPBW feeding debris from trees and masked much of the visible defoliation damage from the air. For this reason, we will continue to monitor the situation closely next year in the event that the JPBW population is still growing.

Although the acres of damage appear relatively insignificant in 2016, it is important to note that there is much less jack pine on the landscape due to massive salvage operations of mature trees after the last major jack pine budworm outbreak from 2003 to 2008. During the height of this outbreak, as many as 75,591 acres of jack pine forest were defoliated statewide in a single year (2005).

Based on eight-year outbreak return intervals for JPBW in north-central Minnesota, the population spike in certain areas during 2015 was not surprising. If the population is truly decreasing in north-central Minnesota, monitoring efforts will begin to focus on northwestern Minnesota (e.g., Roseau and Lake of the Woods counties) where JPBW outbreaks typically occur on a 10-year return interval and are expected to increase within the next few years.

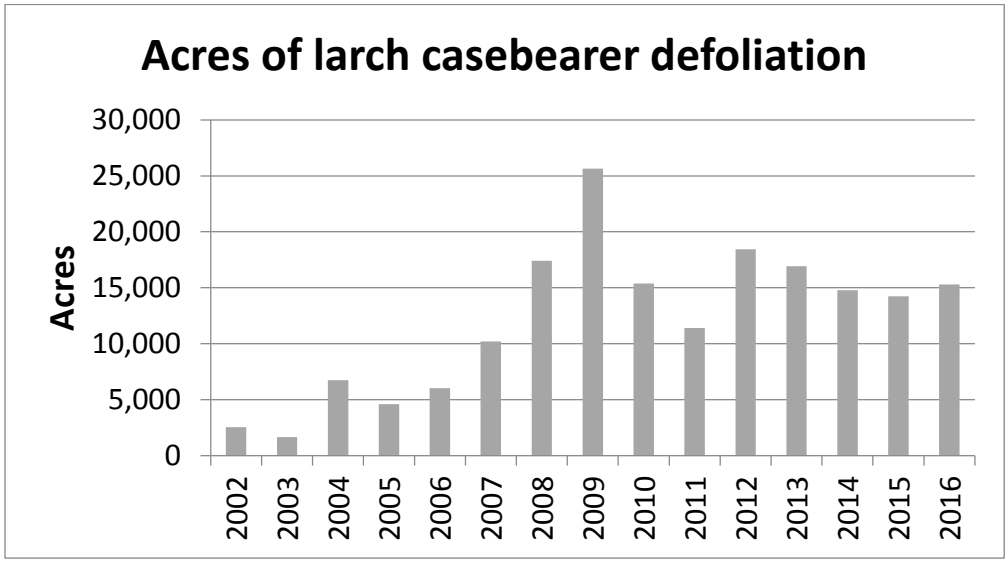


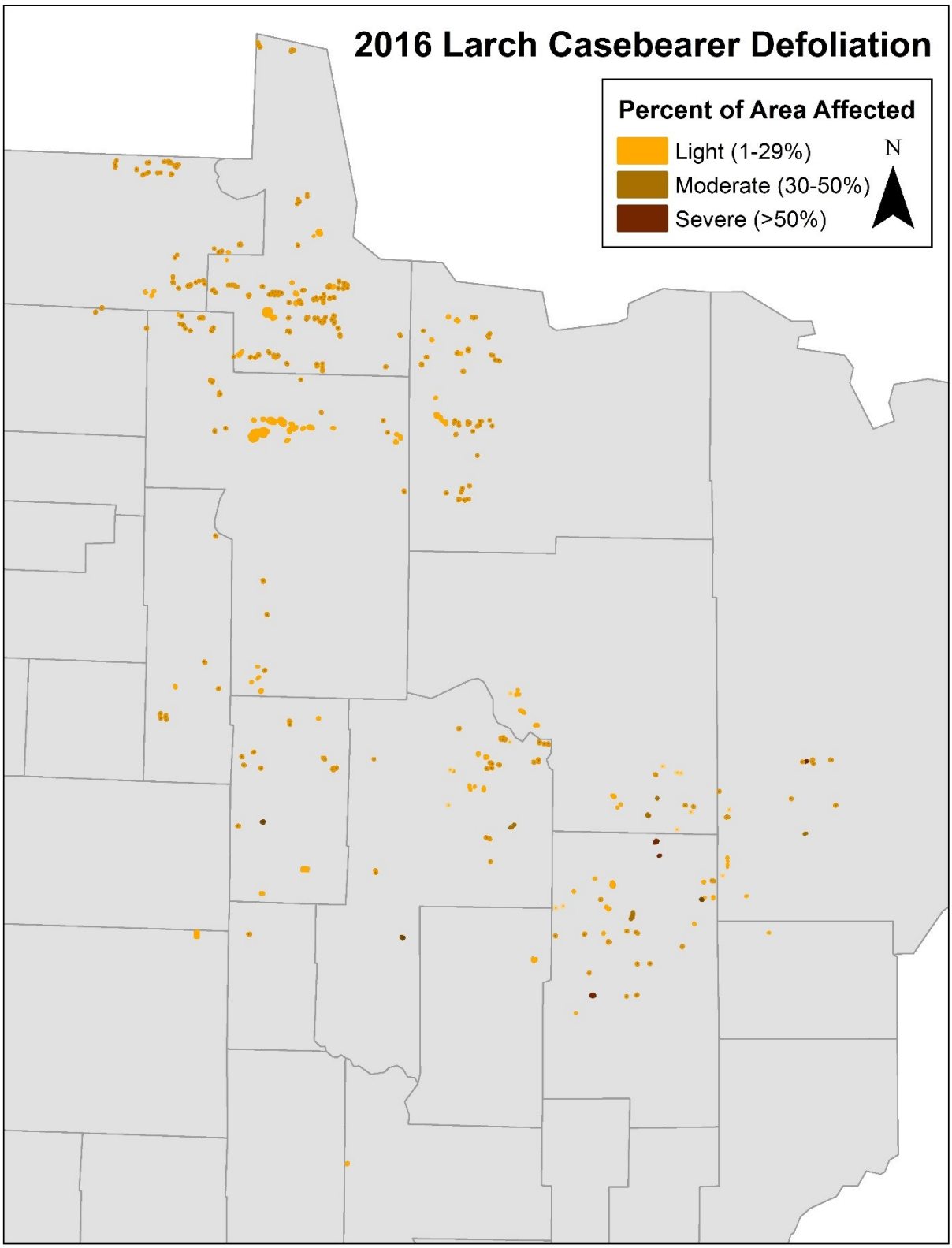

2016 Jack Pine Budworm Defoliation
Beltrami
Clearwater
Itasca
Hubbard
Cass
Wadena
Aitkin
Crow Wing
Percent of Area Affected
Light (1-29%)
Moderate (30-50%)
Severe (>50%)
N

Larch casebearer

Larch casebearer has been causing noticeable defoliation in Minnesota for 16 consecutive years, with affected acreage increasing each year. Defoliation by larch casebearer increased eight percent from 2015 to 2016, and several areas in Aitkin, Beltrami, and St. Louis counties have seen tamarack repeatedly defoliated for the past four to five years. Just over 1,200 acres, about eight percent of the total impacted area (15,286 acres), were defoliated in 2016 and also in 2015. The majority of acres affected in 2016 consisted of small, diffuse patches spanning the north central and Arrowhead regions (see map on page 24).

Tamarack has an advantage over other conifers when it comes to dealing with defoliating insects. Being deciduous, tamarack can produce a second flush of foliage when summer defoliators damage early-season needles. While this process is energy-intensive and stressful, most tamaracks can handle it for a few consecutive years before serious dieback or mortality occurs. Any stands nearing rotation age currently being impacted by larch casebearer or are near active infestations should ideally be set up for a regeneration harvest.

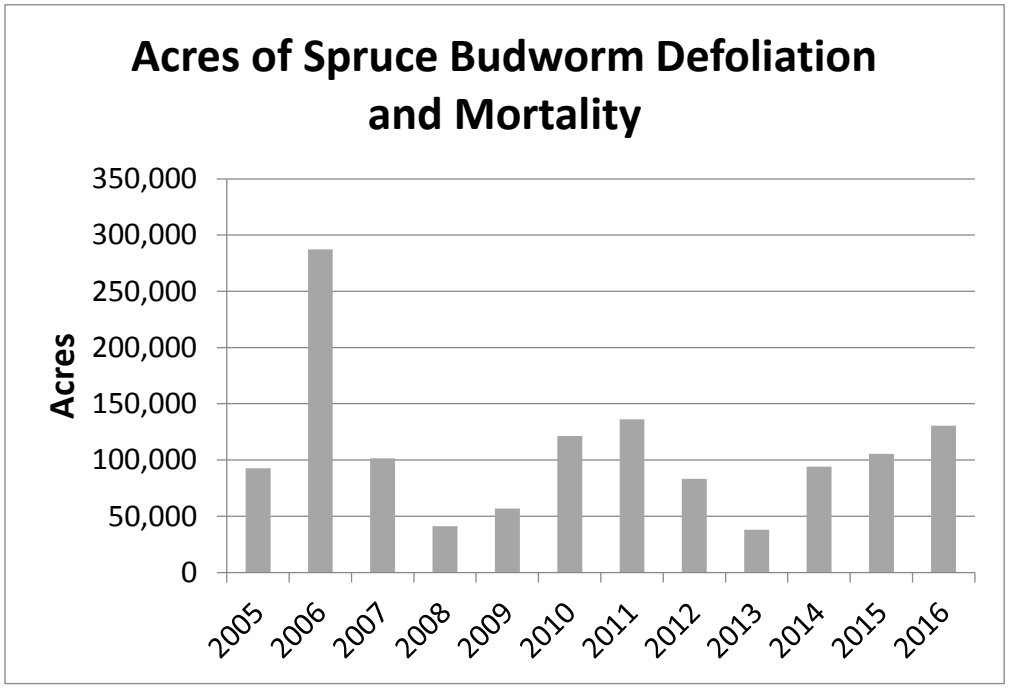


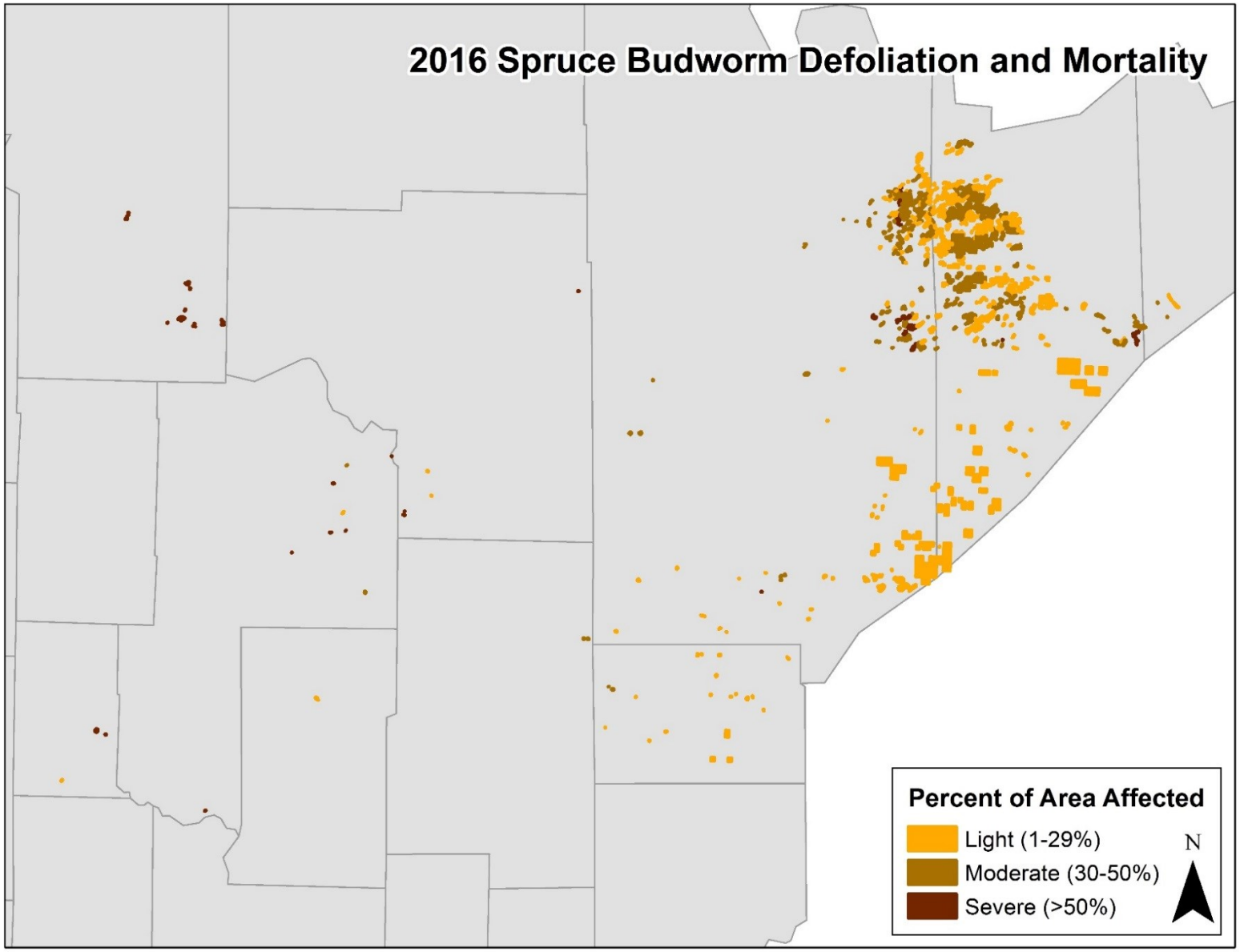

2016 Larch Casebearer Defoliation
Percent of Area Affected
Light (1-29%)
Moderate (30-50%)
Severe (>50%)
N

Spruce budworm

The Minnesota DNR has mapped spruce budworm defoliation and mortality with aerial surveys since 1954. The 2015 survey showed a 10 percent increase in newly damaged areas compared to 2014, and 2016 saw a 24 percent increase in newly damaged areas compared to 2015. More than 97 percent of the 130,514 acres affected by spruce budworm in 2016 was in Lake and St. Louis Counties (map on p. 26), much like in 2015 and 2014. Trees in these areas have experienced moderate to severe defoliation for several consecutive years and will likely have additional defoliation and mortality through 2020.

Outbreaks typically last about eight years, and after five consecutive years of spruce budworm defoliation, mature white spruce and balsam fir begin to die. Managers in the Arrowhead region should expect widespread mortality of spruce-fir stands, if they are not experiencing it already. Due to the predictable nature of spruce budworm defoliation and its effects on balsam fir and white spruce, managers should focus on establishing regeneration harvests before the value of standing timber is lost.




2016 Spruce Budworm Defoliation and Mortality
Percent of Area Affected
Light (1-29%)
Moderate (30-50%)
Severe (>50%)
N

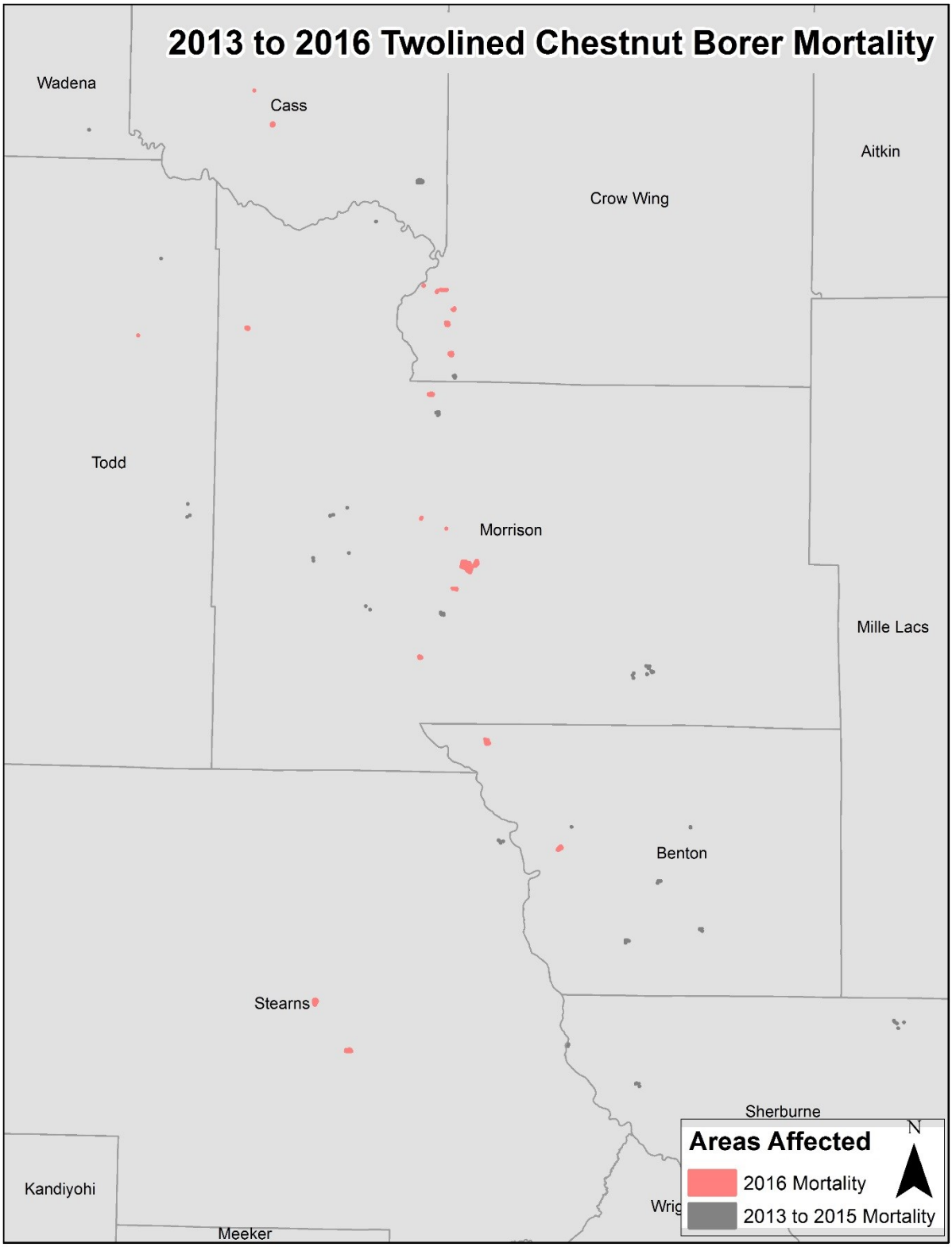
Twolined chestnut borer

Dieback and mortality caused by twolined chestnut borer was distributed widely across Minnesota in 2016, but the area most heavily affected was centered in Morrison County. Aerial and ground surveys in that county recorded 607 acres of damage and mortality; this is likely an underestimate of the total area impacted.

A serious pest of oak, twolined chestnut borer has been active in central Minnesota consistently since 2014. It is likely that the growing-season droughts in 2012 and 2013 promoted attack by this wood-borer.

In an oak wilt early detection project in select areas of central Minnesota, we analyzed 2015 landscape imagery that revealed drought and twolined chestnut borer caused abundant oak mortality before 2016. In most infested stands, mortality exploded from 2014–2015, but most of that mortality, represented in the map on p. 28, was not recorded in previous aerial surveys. Aerial surveys from 2013–2015 recorded only 110 acres affected by twolined chestnut borer in central Minnesota. In contrast, the imagery analysis and subsequent ground-checking revealed 1,010 acres of previously-undocumented twolined chestnut borer infestation. Flight timing and aerial survey protocol do not allow surveyors to efficiently record damage from twolined chestnut borer. We will reconsider how we survey for this pest in the future.

Oak damaged by twolined chestnut borer


2013 to 2016 Twolined Chestnut Borer Mortality
Wadena
Cass
Aitkin
Crow Wing
Todd
Morrison
Mille Lacs
Benton
Stearns
Sherburne
Kandiyohi
Meeker
Areas Affected
2016 Mortality
2013 to 2015 Mortality
N

Diseases

Bur oak blight

Bur oak blight appears to be relatively common on bur oak over much of its range in Minnesota, and can be found in 78 of 87 counties.

Bur oak blight seems to be more common and severe in Kandiyohi, Sherburne, and Stearns counties, although no formal surveys have proven this. To determine the incidence and severity of bur oak blight in one of those areas, a pilot plot was installed in Kandiyohi County. We determined that 15 percent of the 40 surveyed bur oaks had lost more than 40 percent of their leaves by mid-September due to bur oak blight. We will determine in 2017 whether or not this pilot survey will be expanded.

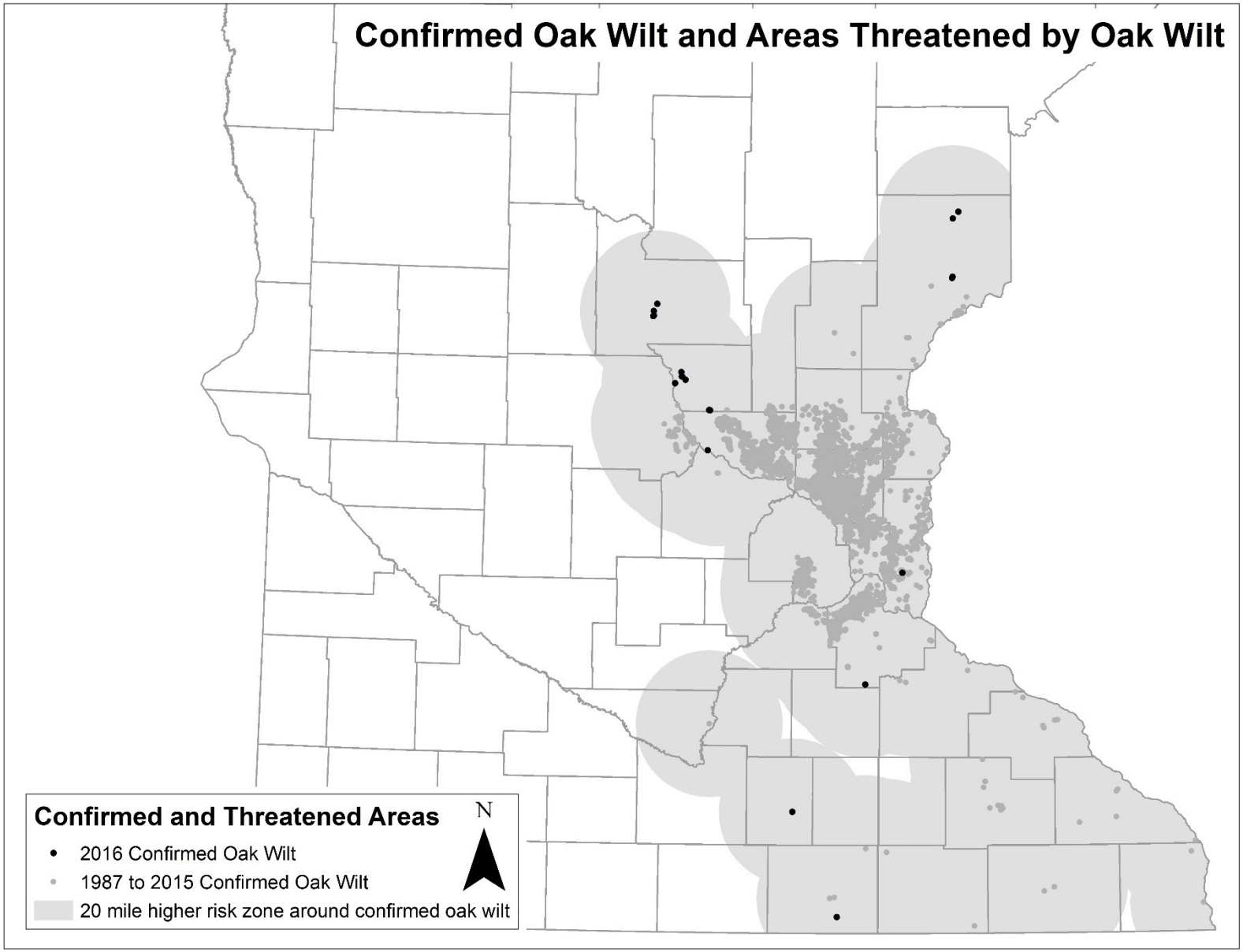
In addition to a lack of information on incidence and severity, the long-term impact of bur oak blight is unknown. To determine its impact, long-term photography plots were established in 2014. Permanent photography plots of individual oaks in Kandiyohi and Sherburne counties showed that bur oak blight severity was similar or slightly lower in 2016 than in 2015 (see figures on p. 30).

An oak in north-central Kandiyohi County has sustained significant leaf loss from bur oak blight for at least three consecutive years. Pictures were taken in mid-September of 2014 (left), 2015 (middle), and 2016 (right).

Oak wilt

Oak wilt is a non-native, fatal disease affecting all oak species in Minnesota. It was first discovered around 1950 in the Twin Cities area and has been spreading by natural means and by movement of infected firewood and logs since then (see map, p. 32).

Oak wilt was confirmed in Waseca County for the first time in 2016 and was confirmed in Morrison and Mower counties for the first time in 2015.


Confirmed Oak Wilt and Areas Threatened by Oak Wilt
Confirmed and Threatened Areas
N
2016 Confirmed Oak Wilt
1987 to 2015 Confirmed Oak Wilt
20 mile higher risk zone around confirmed oak wilt

Oak Wilt Early Detection Projects

Detecting new oak wilt infections at low disease densities is important in order to control its spread as soon as possible. Oak wilt at low disease densities is extremely difficult to identify during our normal aerial surveys because of its limited presence on the landscape relative to other more common forest problems. We wanted to determine if it was possible to detect new oak wilt infections in two different areas of Minnesota not known to have oak wilt using two types of aerial photographs and inexperienced staff to identify oak wilt on the ground.

Color photography over eastern Minnesota

In 2014, 6-inch resolution color photographs were taken over a large area in southern Pine and Mille Lacs counties and Northern Isanti and Chisago counties (see map on p. 35). The area photographed contained a relatively large amount of known oak wilt and a large diversity of tree species. MNDNR Resource Assessment staff screened the photographs twice and identified 1,337 locations as likely oak wilt.

We had an intern with little experience ground-check a portion of the identified oak wilt locations, and he misidentified oak wilt about 55 percent of the time. An experienced photo-interpreter misidentified oak wilt only about six percent of the time, indicating that photo-interpretation by someone with experience is better than ground identification by a novice.

Only three new isolated oak wilt locations were confirmed from the photographic survey. We concluded that the area covered by the survey was too large, contained too much tree diversity and too much oak wilt for early detection, and that only experienced staff should confirm oak wilt locations.

High-resolution color infrared photography over central Minnesota

To improve our ability to detect new oak wilt infection centers, in 2016 we obtained high-resolution color infrared photographs taken of selected areas of nearly pure oak forest with only one oak wilt infection center and significant development (a risk factor for oak wilt introduction). The photographs were centered near Little Falls in Morrison County (see map on p. 35).

This time Resource Assessment provided us with significantly fewer areas identified as potential oak wilt (454), using computer automation. We ground-checked 31 of those areas, resulting in four confirmed oak wilt centers.

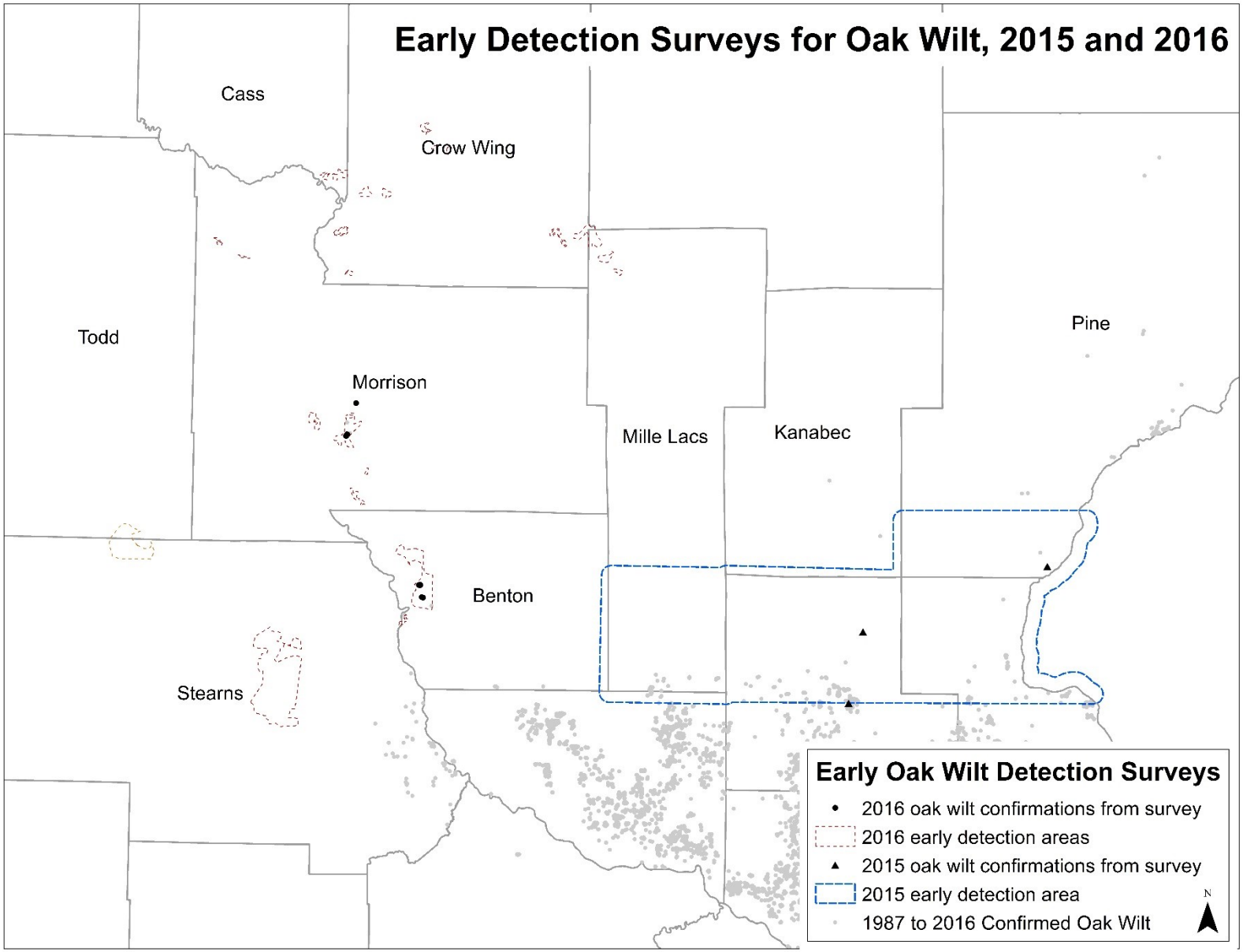
In another comparison of traditional aerial survey to using aerial photographs, Resource Assessment surveyed the targeted areas aerially at 3-mile flight-line spacing. Forty-nine possible locations of oak wilt were identified from this survey; 13 of the 49 were ground-checked and one was confirmed with oak wilt, also detected with computer automation.

Altogether, the traditional aerial survey and photographic survey from 2016 yielded four new oak wilt confirmations. The automated photographic survey detected three more oak wilt pockets than the traditional aerial survey.

Conclusions

Out of all the surveys, we concluded that early detection efforts made in 2016 were more efficient than those in 2015 in terms of confirmed oak wilt centers per area surveyed and per hour of staff time. The 2015 and 2016 surveys resulted in seven new isolated oak wilt locations, but the number of confirmed locations is still not satisfactory given the time invested.

From the surveys in 2015 and 2016, we determined that for early oak wilt detection, it is important to target small areas to survey, use experienced photograph interpreters and ground observers, and conduct the aerial survey at higher flight-line densities.


Early Detection Surveys for Oak Wilt, 2015 and 2016
Cass
Crow Wing
Todd
Morrison
Mille Lacs
Kanabec
Pine
Benton
Stearns
Early Oak Wilt Detection Surveys
2016 oak wilt confirmations from survey
2016 early detection areas
2015 oak wilt confirmations from survey
2015 early detection area
1987 to 2016 Confirmed Oak Wilt
N

Heterobasidion root disease

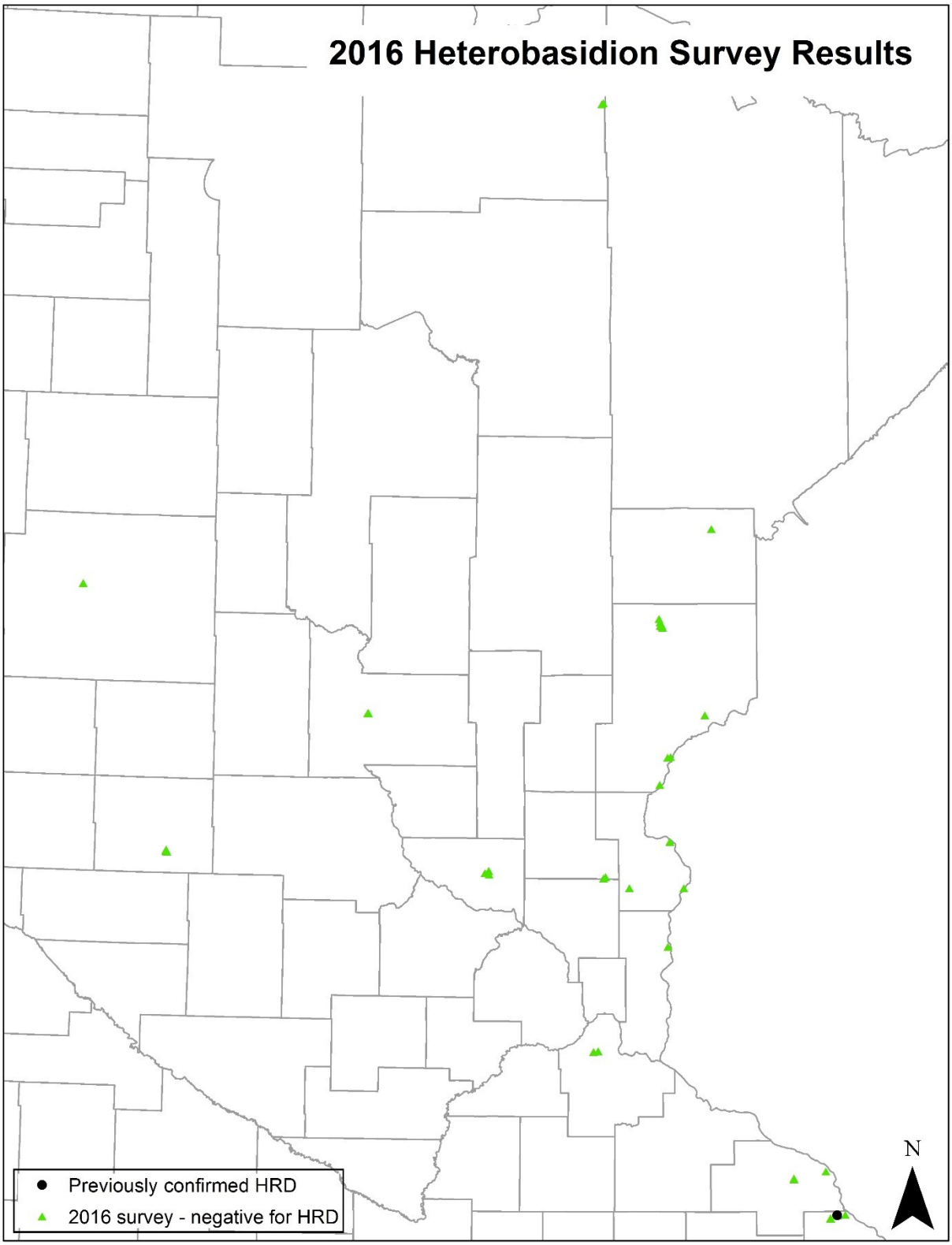
Heterobasidion root disease (HRD, formerly called *Annosum*) was first confirmed in Minnesota in 2014. It is a potentially serious and persistent disease in pine plantations. The MNDNR and University of Minnesota (University) surveyed for this disease intensively in 2016 over a large part of Minnesota. MNDNR collected samples from about 50 mortality centers across 13 counties to analyze for the presence of *Heterobasidion*; the University also sampled additional mortality centers on their own. University staff used polymerase chain reaction technique to detect *Heterobasidion* from samples collected by MNDNR. No additional confirmed locations of the disease were found.

We do know from spore-trapping surveys at five locations in Goodhue, Wabasha, and Winona counties that *Heterobasidion* asexual spores were present in the air during an August, September, and October 2015 trapping period. Spores were not captured during a trapping period in November. The survey was part of a joint project in 2015 with the Michigan Department of Natural Resources, the University of Wisconsin-Madison, and MNDNR. The method of the survey was as follows: At each location, 10 freshly-cut cross-sections of red pine were laid on the ground in pine plantations. The surfaces of these tree "cookies" were treated with fungicide prior to distributing to ensure they contained no living fungus. The tree cookies were collected after 24 hours and incubated in a lab to monitor for *Heterobasidion's* asexual fruiting body. Tree cookies were prepared and analyzed by University of Wisconsin-Madison personnel.

Based on the 2015 spore-trapping results, we advise that small, private, conifer plantation owners in southeast Minnesota protect their conifers from HRD when they thin plantations or yard trees. They can protect remaining conifers by felling trees during extended frozen conditions or by immediately applying an approved fungicide to freshly cut stumps. Currently the only registered fungicide used to prevent HRD in Minnesota is Cellu-Treat®. The negative survey results in November do not suggest spores are not in the air at that time of year. Dry and windy weather during that day probably discouraged spore release from local fruiting bodies.

The state plans to eradicate the infection by clear-cutting and up-rooting the stumps in the infected plantation in Winona County in 2017, since no surveys in 2015 or 2016 resulted in additional HRD mortality center confirmations (see map, p. 38).

Heterobasidion conk at the center left of a red pine stump base.


2016 Heterobasidion Survey Results
Previously confirmed HRD
2016 survey - negative for HRD
N

Diplodia

Diplodia shoot blight of pines (*Diplodia sapinea*) continues to be prolific on the landscape across much of Minnesota, though there has been no formal attempt to quantify landscape-level damage. In 2016, trees in the MNDNR State Forest Nursery experienced significant problems from *Diplodia* shoot blight and collar rot.

One unfortunate result of the excessively wet weather during spring and summer 2016 was increased activity by several pathogens across the state. Prolonged periods of wet weather accompanied by storms with strong winds proved favorable for the spread of spores, and seemed to aggravate *Diplodia* issues at the State Forest Nursery. This resulted in shoot blight and latent infection rates severe enough to result in culling certain seedling cohorts. This was a regional issue not limited to Minnesota, however, as there were reports of similar situations in neighboring Lake States.

We will monitor *Diplodia* levels in the State Forest Nursery in the upcoming years, and incidence should return to normal background levels provided the abnormally wet weather in 2016 does not become a trend.

Diplodia *shoot blight on red pines seedlings in culled 2016 crop*

Pine-oak and pine-pine gall rusts

Pine-oak and pine-pine gall rusts are concerns primarily for jack pine in Minnesota. These rusts are fungal pathogens that infect needles or succulent stems and eventually form galls. If galls form on trunks of young trees, they frequently result in tree death from stem failure (Figure 1). Galls formed on trunks no more than one foot from the ground (Figure 2) either come from infection at the nursery or in the field soon after tree-planting.

MNDNR forest health specialists surveyed 11 state-owned jack pine plantings in Morrison, Pine, and Koochiching counties, where the State Forest Nursery was the source of the planting stock. Plantations ranged from 1 to 12 years since planting. The goal of this effort was to understand the incidence of trunk infections that either came from the nursery or from another source shortly after out-planting. Galls on trunks within one foot of the ground were tallied on 30 seedlings per stand. We found that an average of about 25 percent of the jack pine sampled had trunk galls. Incidence of trunk galls ranged from 0 to 90 percent among these plantations.

In the future, forest health and nursery staff will determine if preventative actions against pine-oak and pine-pine gall rusts at our state nursery are worthwhile.

Figure 1. Galls on trunks from pine-oak gall rust promote trunk failure and tree death.

Figure 2. The orange gall below the pen will likely kill this jack pine seedling. It is just above the ground-line, which means this seedling was infected at the nursery or infected soon after planting.

Wet conditions lead to widespread spruce needle rust

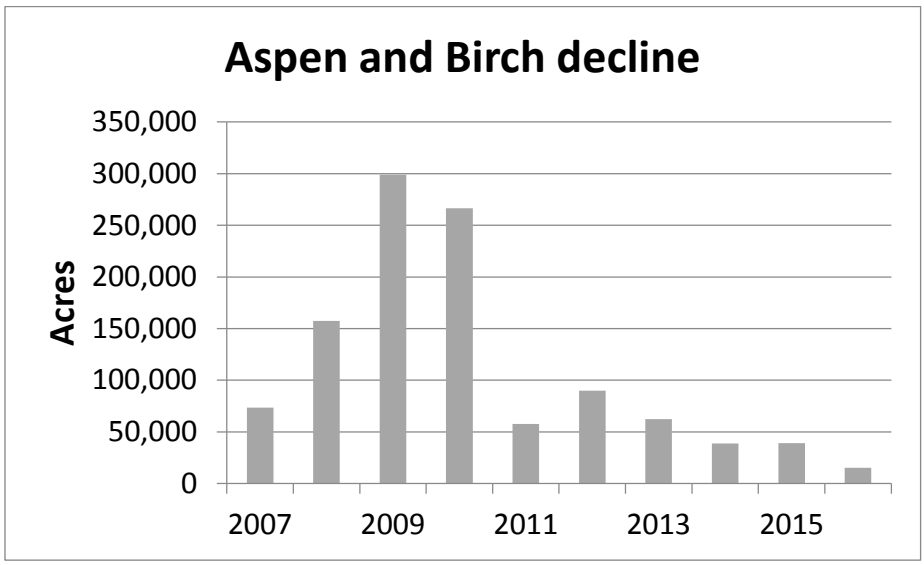
The exceptionally wet spring and summer led to widespread spruce needle rust around August and September in northeastern Minnesota. Areas that sell black spruce tops for winter decoration noticed significant decline in tree quality from this disease. At least ten species of spruce needle rust (*Chrysomyxa*) cause similar symptoms in spruce, and their relative distribution and abundance in Minnesota is not clear. In July and August, needles on Colorado blue, white, black, and occasionally Norway spruce develop noticeable orange pustules (see figure below). In August and September the infected needles fall off, giving a thin, bare appearance to the tree. Different species of *Chrysomyxa* require different alternate hosts; however, removal of the alternate hosts rarely controls the problem. However, needle rusts are typically aesthetic issues and do not require treatment. Registered fungicides are available if the problem persists and begins to significantly damage the tree.

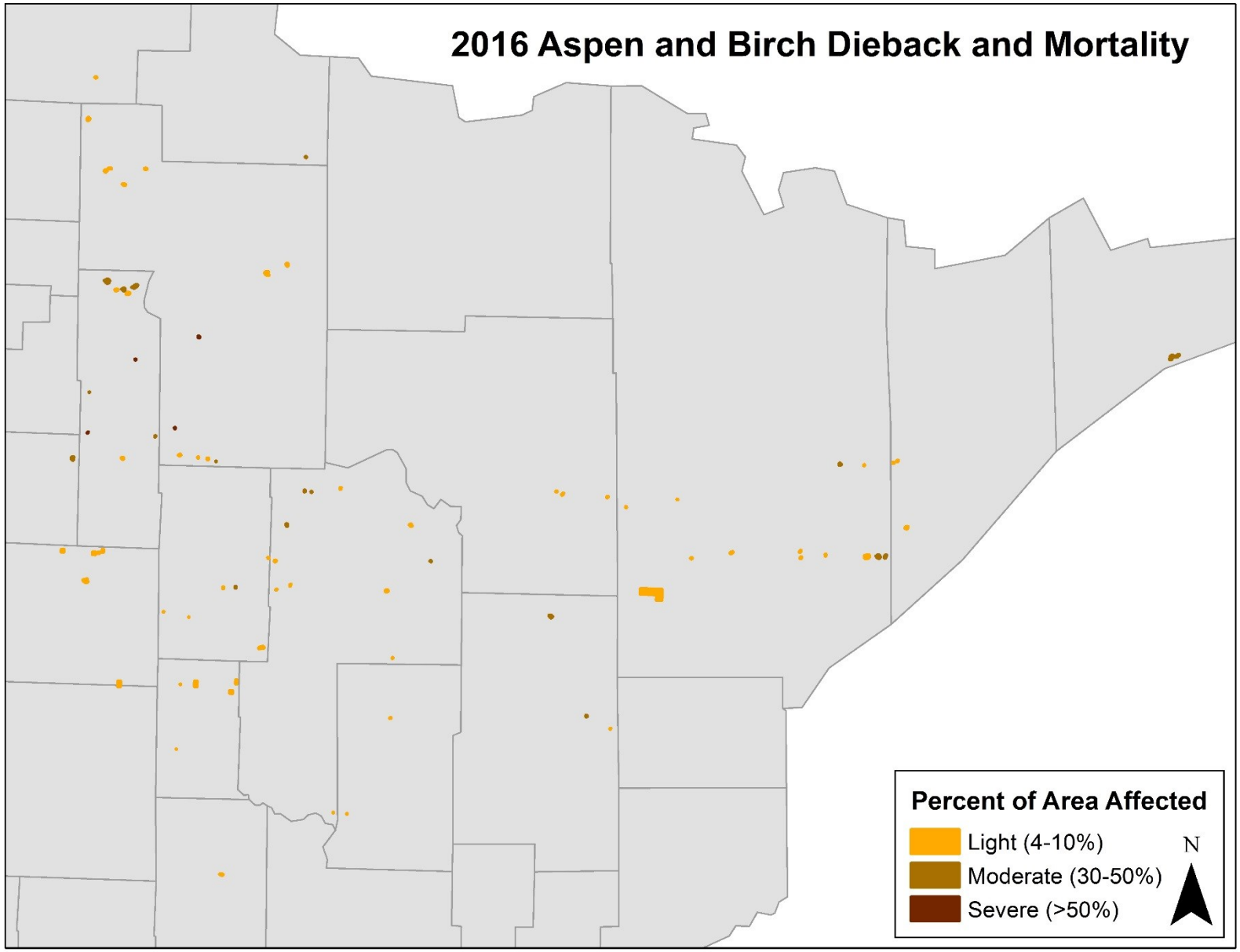
Yellow and orange needles with rust fruiting bodies growing from infected needles.

Environmental Stress Agents

Aspen and birch decline

Decline of aspen and paper birch is characterized by stunted leaves, dying twigs and limbs, and dead trees, and has been a consistent sight across the Minnesota landscape for years. A combination of factors including drought, secondary insect pests, cohort senescence, and unfavorable site conditions typically cause the decline. After a sharp increase in affected acres in 2009, noticeable decline of aspen and birch has dropped year-by-year, and 2016 was no exception. In 2015, almost 39,000 acres of aspen and birch were in a state of decline; declining acres dropped by 60 percent to just over 15,000 in 2016. Part of the reduction in aspen and birch decline is because forests are recovering from drought; the other reason is that many of the declining stands were harvested.

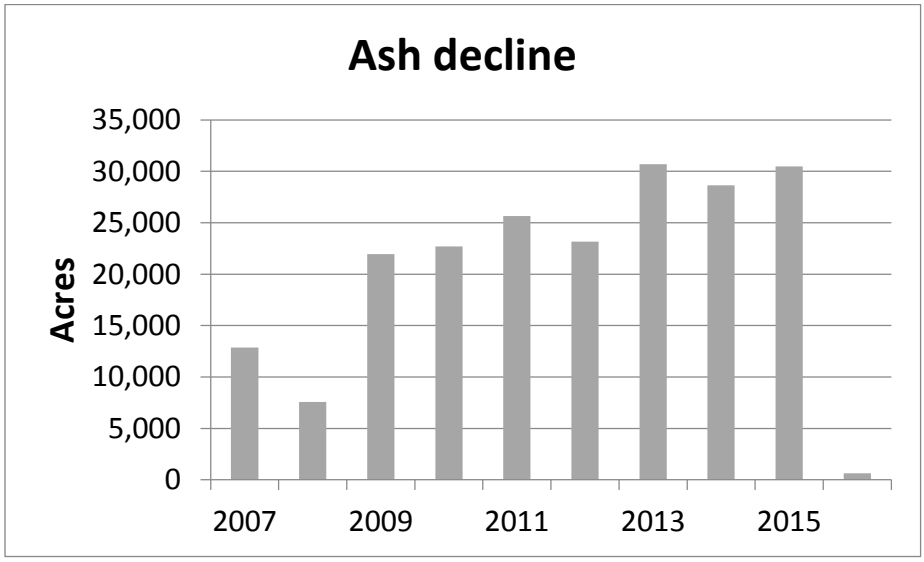


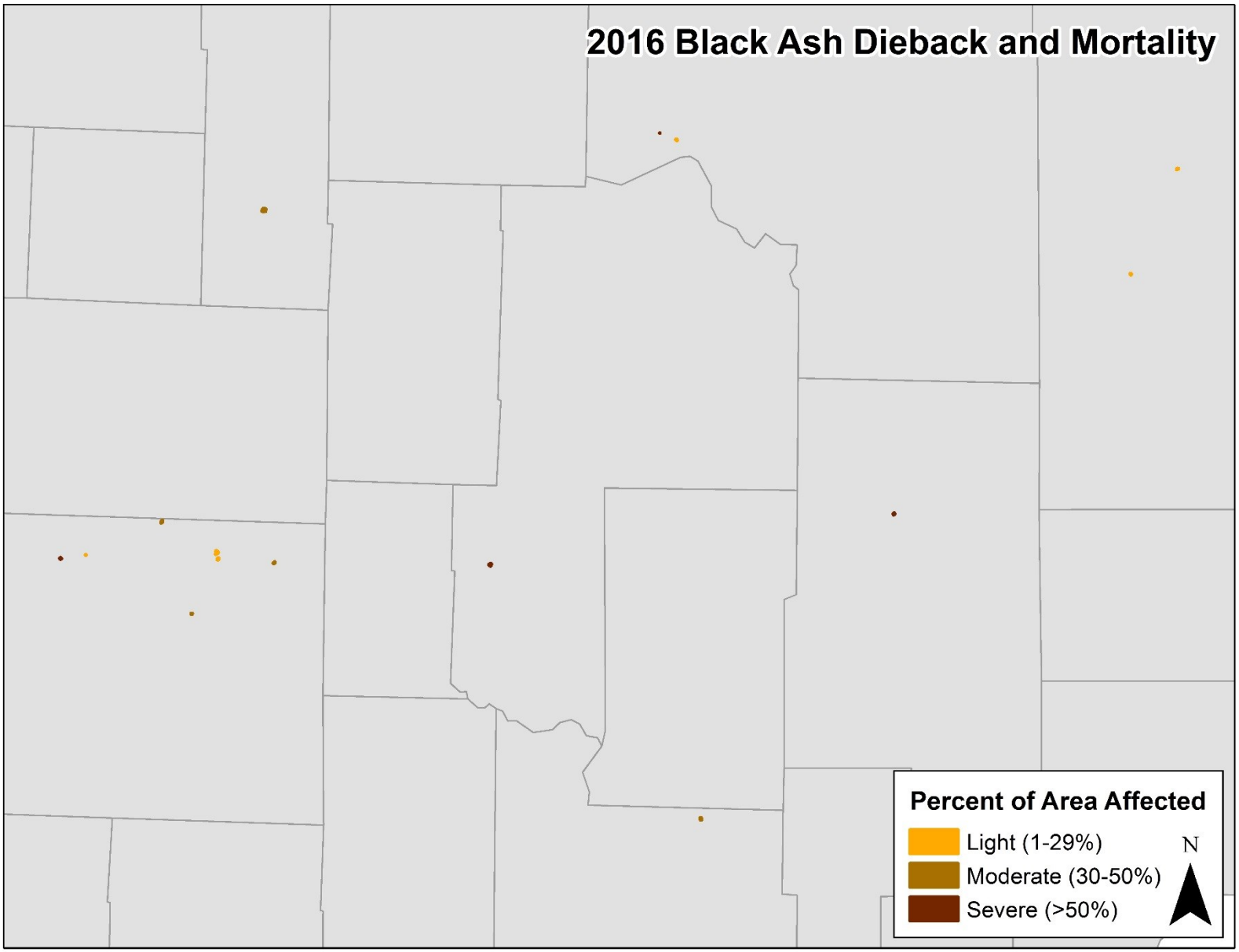

2016 Aspen and Birch Dieback and Mortality
Percent of Area Affected
Light (4-10%)
Moderate (30-50%)
Severe (>50%)
N

Black ash decline

Similar to aspen and birch decline, symptoms of black ash decline are stunted leaves, branch dieback, epicormic sprouts, and mortality, and is a condition commonly encountered in Minnesota ash forests. Only 616 acres of black ash decline were reported this year compared to 20,000-30,000 impacted acres reported annually for the past several years. This fact doesn't indicate an actual decrease in acres of decline; rather, new survey software limitations as well as a smaller area surveyed resulted in missed and unreported black ash dieback and mortality. We plan to address the software limitations to document the present black ash decline on the landscape in 2017.

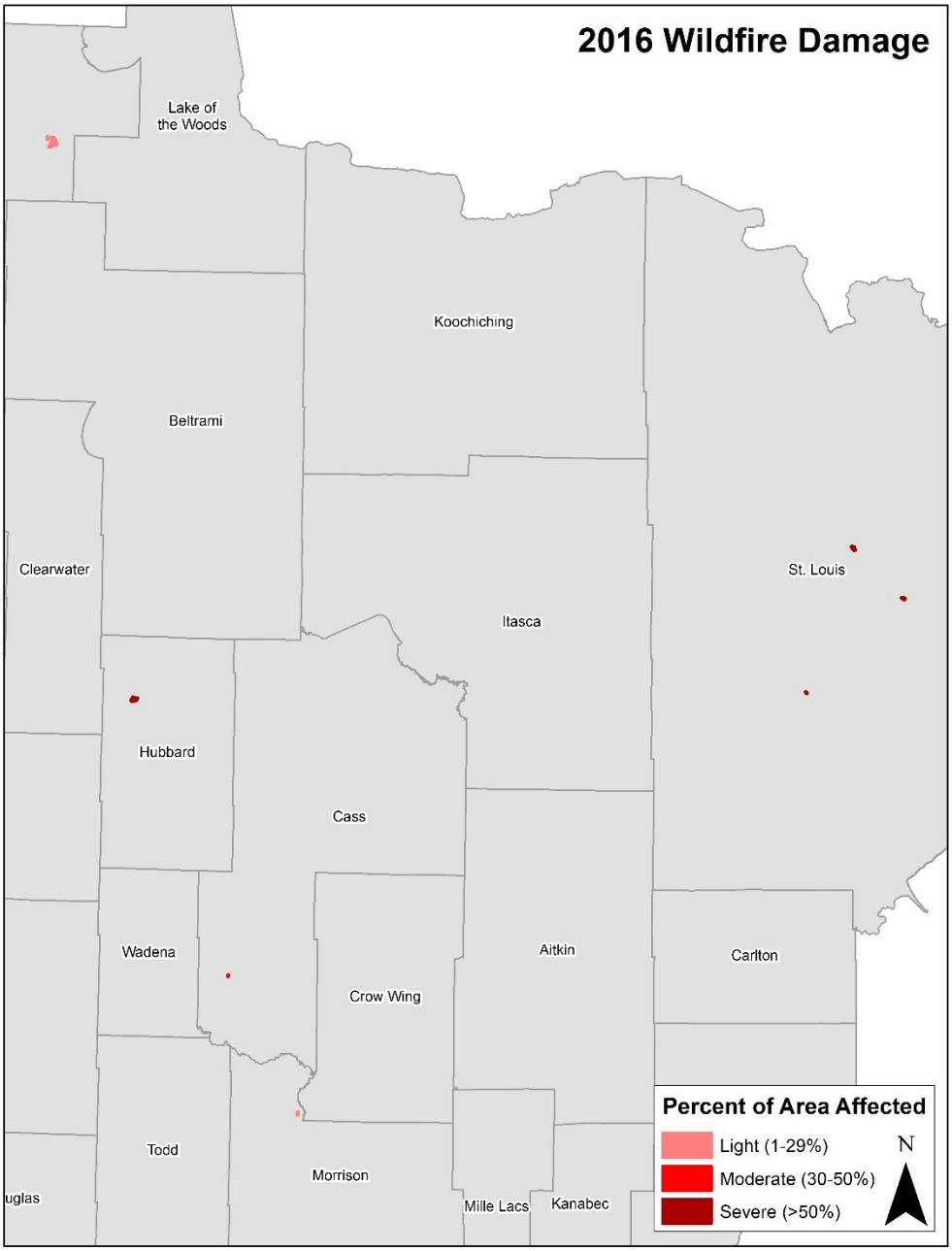
The presence of black ash decline in northern Minnesota forests will make early detection of emerald ash borer (EAB) exceedingly difficult, if not impossible. Not only do symptoms of black ash decline mimic EAB infestation, masking the presence of actual infestations, but black ash stands are often in standing water with limited or no access. Only after several years of EAB infestation will we be able to detect it by aerial survey.




2016 Black Ash Dieback and Mortality
Percent of Area Affected
Light (1-29%)
Moderate (30-50%)
Severe (>50%)
N

Wildfire

Aerial surveyors mapped 1,557 of the 2,017 forested acres affected by wildfire reported in Minnesota in 2016. There was a discrepancy between acres *reported* and acres *mapped* due to timing of fires and limited aerial survey coverage. Many of the larger wildfire areas were salvaged, but damaged trees on the perimeter of wildfire boundaries and outside salvage boundaries (especially in conifer stands) represent a potential food source for bark beetles and other wood-boring insects in 2017.

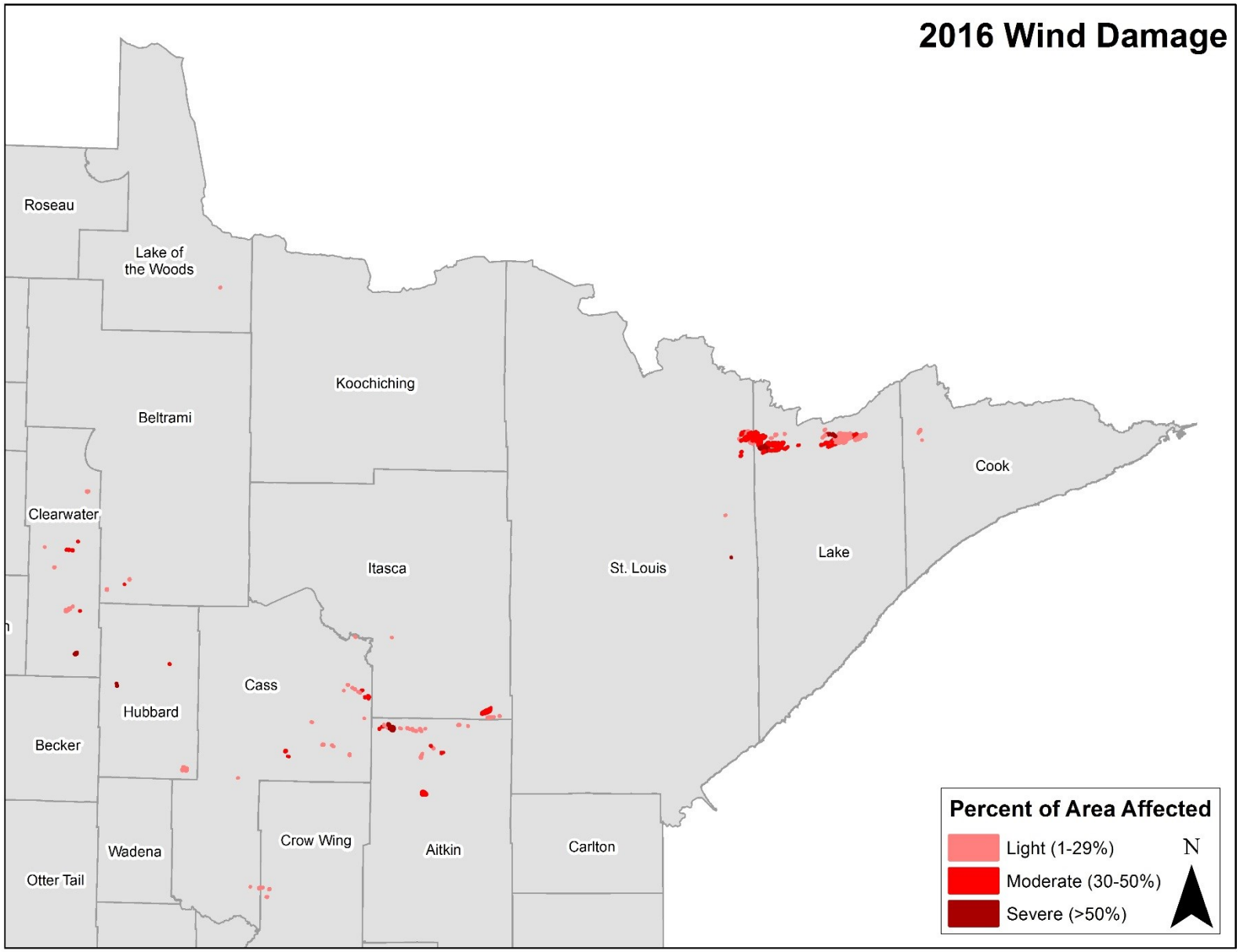


Wind

Minnesota experienced several major storm events with extreme winds in 2016. The most notable events occurred on June 19, July 19-20, and July 20-21. Aerial survey detected 18,953 acres of visible wind damage. The July 20-21 storm was perhaps the most severe and produced winds in excess of 50-60 MPH across most of northern Minnesota, although winds upwards of 80 MPH were reported in certain areas. Damage to trees ranged from relatively minor branch flagging or breakage to main stem breakage and uprooting. Blowdown damage in the north-central part of the state was widespread and scattered, stretching from Clearwater Co. to northern Aitkin Co. The most highly-impacted areas were located in northern portions of the Superior National Forest and within the Boundary Waters Canoe Area Wilderness, totaling around 13,000 acres. Another notable damage area included iconic mature forests in Itasca State Park.

Although a great deal of salvage harvest was performed where possible, trees weakened or compromised by wind damage and unable to be salvaged in 2016 will be of some concern in the coming years. These trees will be more likely to succumb to environmental stressors such as drought, and depending on the species, can be predisposed to insect attack. As we are currently witnessing, drought and wind-damaged oaks reported in southern Cass Co. during 2015 are currently under attack by large populations of two-lined chestnut borer.

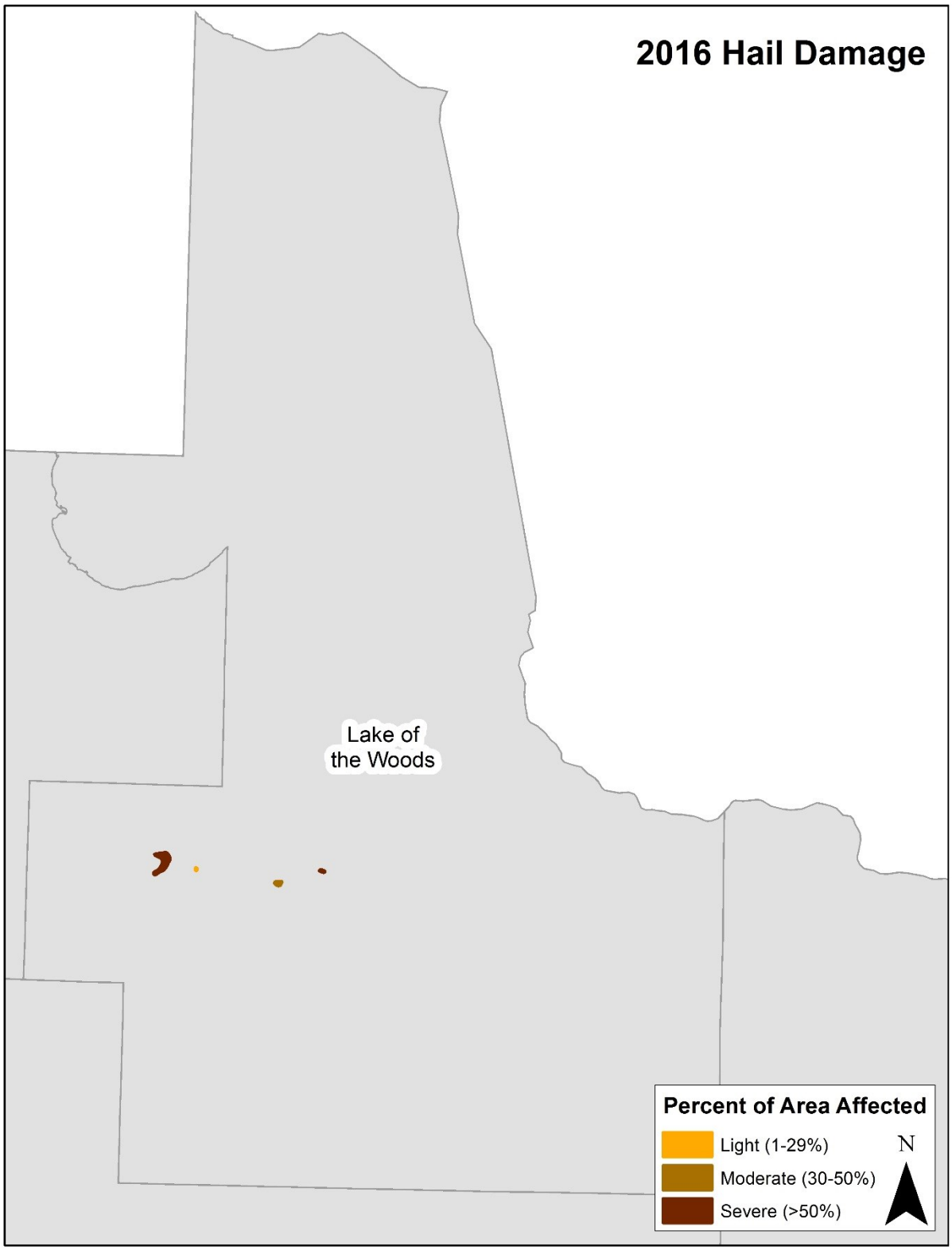
Wind-damaged jack pines following a 2016 wind storm in Clearwater County


2016 Wind Damage
Roseau
Lake of the Woods
Koochiching
Beltrami
Clearwater
Itasca
St. Louis
Lake
Cook
Cass
Hubbard
Becker
Wadena
Crow Wing
Aitkin
Carlton
Otter Tail
Percent of Area Affected
Light (1-29%)
Moderate (30-50%)
Severe (>50%)
N

Hail damage

In addition to strong winds, a major storm event on June 19 produced 1- to 4-inch hailstones that resulted in an extensive swath of damage extending from areas east of Wannaska (Roseau Co.) eastward to areas southwest of Baudette (Lake of the Woods Co.). In total, about 454 acres of hail damage were observed. Large areas of concentrated damage were detectable in the Beltrami Island State Forest (Lake of the Woods Co.) during aerial survey. This included about 75 acres of mature red pine plantation. Pre-salvage has been organized in certain areas where heavily damaged trees are not expected to recover and substantial mortality is anticipated in 2017. Extreme, unpredictable weather events will remain an important aspect of forest health monitoring, as the frequency of severe storm events seems to be increasing.

Hail damage on mature red pines in Beltrami Island State Forest.


2016 Hail Damage
Lake of
the Woods
Percent of Area Affected
Light (1-29%)
Moderate (30-50%)
Severe (>50%)
N

Flooding

Aerial surveyors mapped 5,692 acres of forests affected by flooding and high water in 2016. This is an underestimate of the total acres affected, since several flood events that damaged riparian forests in southern Minnesota were outside our survey (refer to survey map on p. 5). For example, Steele County declared a state of emergency from a flood event in September; Willmar in Kandiyohi County was severely flooded in August. The flooding damage we mapped is a 434 percent increase over that mapped in 2015.

In general, broad-leafed trees adapted to growing in river floodplains can tolerate being flooded for at least a month and sometimes much longer during the middle and later parts of the growing season. They can tolerate even more flooding during their dormant period. Conifers in yards that sustained flooding for several days in 2016, such as pine, fir, and white spruce, may turn yellow and die in 2017 or 2018. Upland broad-leafed trees that were flooded for several days, such as black oak, may slowly decline over the next few years.

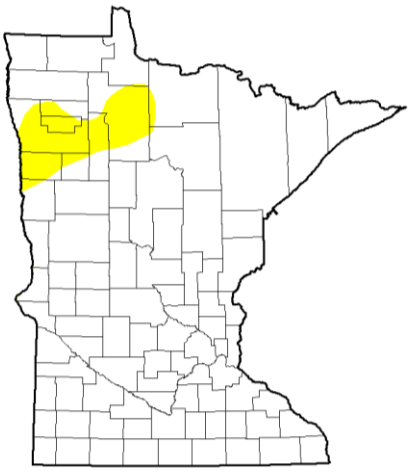
Drought

In December 2015 (see map on following page, left), dry conditions were reported in a small portion of northwestern Minnesota; by the end of April, 2016, the U. S. Drought Monitor reported that portions of northwest and west central Minnesota were still *"abnormally dry*." No other areas in Minnesota were reported to be in a dryness category at that point.

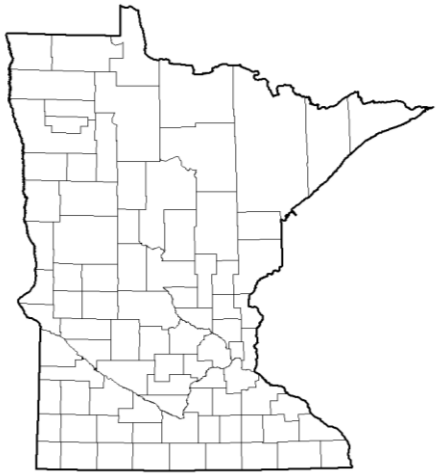
Moisture conditions changed in July, which was wet and stormy for many sections of Minnesota. According to the U. S. Drought Monitor, "Precipitation totals in July were well above normal across central, parts of northern and south central Minnesota. The rest of the state was close to normal. Central Minnesota was the wettest with Mora in Kanabec County seeing 10.02 inches of rain and Brainerd in Crow Wing County seeing 11.65 inches of rain for the month. Normal July precipitation for these areas is about four inches. The last two weeks of July were relatively dry in some southwest Minnesota counties, with some locations seeing a half an inch or less." Notably, the largest summer flood since the June 2012 event in northeast Minnesota struck some of the same areas on July 11-12, 2016. This year Pine County was hit especially hard. Another heavy rain event occurred on July 23, with torrential rains falling over central and southeast Minnesota.

Seasonal precipitation totals (April 1 through August 2) ranked near or above the historical median over much of Minnesota, with a few pockets in north central and southwest Minnesota lagging behind.

The U. S. Drought Monitor map released on December 27, 2016 (map below right) depicts the entire state free of any drought designation. Minnesota has been completely free of any drought designation for nearly three months, beginning on September 6.



December 22, 2015



December 27, 2016

Climate information comes from the HydroClim Minnesota newsletter published by the DNR State Climatology office. Maps are taken from US Drought Monitor from December 22, 2015 and December 27, 2016.

Late frost wreaks havoc on young buds

Overnight on May 14-15, the entire Great Lakes region experienced record low temperatures (see Figure 1 below), resulting in significant damage to young shoots of both conifers and hardwoods. Forest health specialists received several questions from concerned homeowners, Christmas tree farmers, and other private land managers about wilting, purple shoots on spruce trees (Figure 2) and browned oak (Figure 3) and walnut shoots. Symptoms spanned the entire state. While late frosts can kill new shoots resulting in a year of thin crowns, the damage did not result in walnut mortality that was feared in southeast Minnesota.

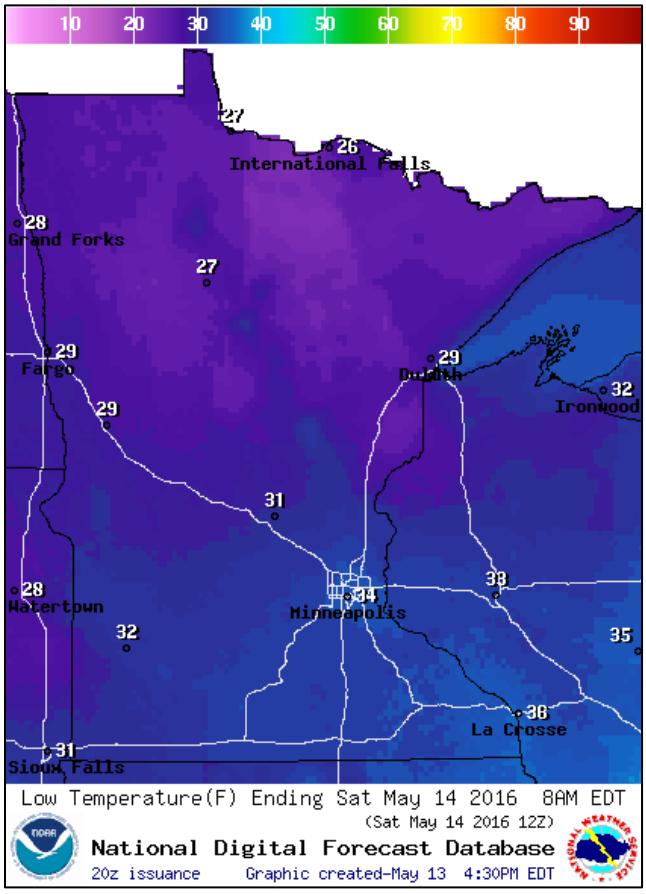


Figure 1. National Weather Service map of Minnesota showing a freeze warning for May 14-15, 2016.

Figure 2. Late spring frost damage to expanding spruce shoots. Photo by Wisconsin DNR.

Figure 3. Brown leaves damaged by a late spring frost. New pink leaves are emerging after the damage. Photo by Wisconsin DNR.

Phenology of tree pests and tree health events in 2016

Date	Pest or Event	Pest Stage or Cause	County
04/29/2016	Eastern tent caterpillar	First- or second-instar larvae	Pine
05/01/2016	Oak wilt	Spore pad	Dakota
05/16/2016	*Ips* species	Egg-laying	Kanabec
05/16–05/19/2016	Sudden ash leaflet drop	late frost and anthracnose	Dakota, Fillmore
05/24/2016	Linden looper	Caterpillar 1.1 inches long	Ramsey
05/25/2016	Jack pine budworm	Second or third instars	Crow Wing, Cass, Todd, Morrison
05/25/2016	Eastern tent caterpillar	Caterpillar ½- inch long	Cass
05/26/2016	Cedar-apple rust	Telial horns on junipers	Goodhue, Sherburne
05/31/2016	Forest tent caterpillar	Caterpillars 1-1/4 inches long	Itasca
06/08/2016	Whitespotted sawyer	Adult	Wright
06/8/2016	Giant ichneumon wasp	Adults on dying sugar maple	Wright
06/17/2016	Forest tent caterpillar	Caterpillars 2 inches long	Morrison, Pine

Date	Pest or Event	Pest Stage or Cause	County
06/18/2016	Forest tent caterpillar	Late instars and pupae	Itasca
07/07/2016	Spruce budworm	Adult moths	St. Louis
07/08/2016	Jack pine budworm	Adult moths	Beltrami
08/03/2016	Cottony ash psyllid	Nymphs on black ash	Dakota

Other Accomplishments

New specifications in timber appraisal guidelines for state lands

The Forest Health Program created timber sale specifications for oak wilt and Heterobasidion root disease prevention in 2016. These specifications provide guidance to MNDNR foresters on tree disease prevention and increase consistency in timber sale permit language for loggers working on state lands.

The specification to prevent oak wilt is as follows: “Oak wilt is within 20 miles and poses a threat. No sale operations allowed from April 15-July 15 (in the Laurentian mixed forest province) or April 1-July 15 (in the Eastern broadleaf forest province) due to oak wilt concerns, unless with written permission from State.” Forest Health updates a map on the MNDNR website to indicate if oak wilt is within 20 miles of a given location in the state.

The specification to prevent Heterobasidion is as follows: “Pine is an important future component of this stand. Heterobasidion root disease (HRD) is within 1 mile and poses a threat to the site. To minimize losses from HRD, conduct felling of trees during frozen ground conditions only.” As of December 2016, this specification is not relevant to any state lands, but it serves as a placeholder in case we do confirm HRD close to land where pine will be managed in the future. This specification does not include recommendations from Forest Health regarding preventing Heterobasidion with approved fungicides, since the DNR cannot write a timber sale permit and mandate pesticide application on that permit. All of Forest Health’s recommendations for managing HRD can be seen on the MNDNR website.

News articles

Diplodia sapinea on Red Pine Seedlings at the State Forest Nursery. *Roots* (DNR Forestry internal newsletter), November to December 2016 issue.

Time to stop pruning oaks, April 5, 2016. Retrieved 01/03/2017 from DNR news article.

Tamarack under Duress. *The Market Place*, Spring 2016 issue. Retrieved 01/03/2017 from DNR news article.

New DNR Forest Health Internet Outreach Material

Diplodia-related Problems on Pines for Woodland Managers, October 2016: Forest health website

Journal Articles

Crocker, S.J.; Liknes, G.C.; McKee, F.R.; Albers, J.S.; Aukema, B.H. 2016. Stand-level factors associated with resurging mortality from eastern larch beetle (*Dendroctonus simplex* LeConte). Forest Ecology and Management, Volume 375, 1 September 2016, pp 27-34