2014

Minnesota Forest Health Report

Minnesota Department of Natural Resources
Division of Forestry, Forest Health Unit

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

Cover photo: Oak dying from two-lined chestnut borer.

Photo credits: Photos are from DNR forest health staff unless indicated otherwise.

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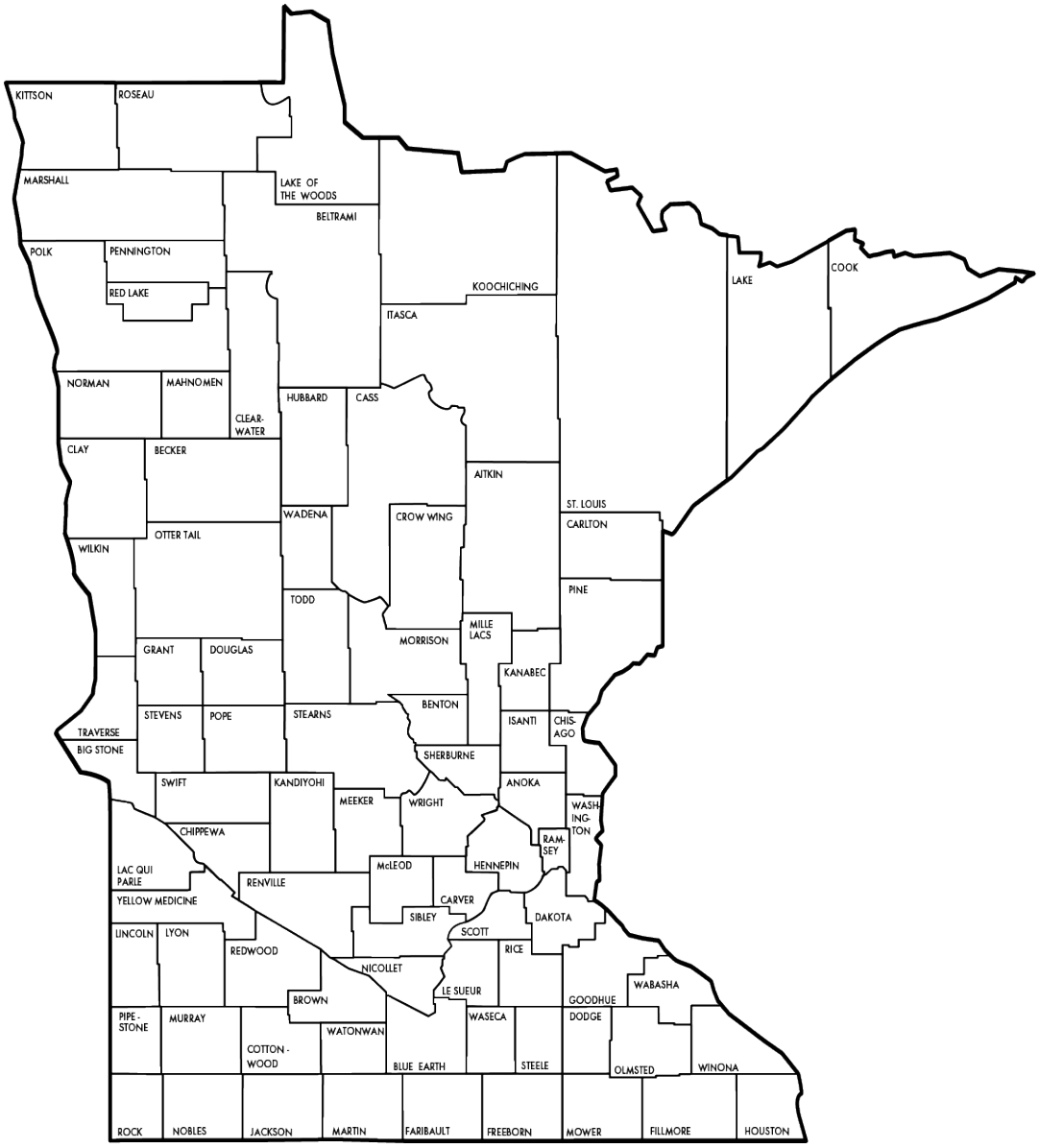

Minnesota County Map

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Minnesota Forest Resources Summary

Minnesota is home to three major ecosystems: prairies in the west, boreal forests in the northeast, and hardwoods running between the two from the Canadian border to the southeastern area of the state. The forests of Minnesota are many and varied.

Changes in the early years of the 21st century pale compared to the dramatic changes of the late 1800s and early 1900s. During that period, nearly half of Minnesota's forest land was converted to agriculture and other land uses in the wake of widespread logging that peaked in 1905. Since then, the state's forests have been a remarkable story of resiliency and recovery. However, demands on forest resources will continue to increase along with biological threats

from native and nonnative diseases, insects and plants. Minnesotans face the challenge of managing forests to make them available for use and enjoyment today as well as in the future.

Minnesota's forests sustain damage from a combination of abiotic stressors and native and nonnative pests. Many of the native pests are recurring and cyclic and play an integral role in the ecology of Minnesota forests. With the increasing effects of climate warming, some native pests are causing more losses in both hardwood and softwood forests.

Historically, invasive insects and pathogens have had a large impact on Minnesota's forest health. Diseases such as white pine blister rust and Dutch elm disease greatly altered the health and makeup of Minnesota's forests in the 20th century. Oak wilt has proven difficult to manage even though we have the tools available to prevent and control this tree killer.

The early detection and treatment of gypsy moth outbreaks and emerald ash borer, both exotics, have slowed the introduction and spread of these two destructive insects in our state. More threats loom in the continuing fight against nonnative diseases such as *Diplodia* shoot blight and nonnative insects such as mountain pine beetle and Douglas-fir beetle. Monitoring forest damage and surveying for insects and pathogens are crucial to predicting the quantity and quality of Minnesota's future forest resources and to devising ways to manage them.

The U.S. Department of Agriculture Forest Service, through its Forest Inventory and Analysis program and in partnership with the Minnesota Department of Natural Resources Division of Forestry, inventoried Minnesota's forest resources in 1935, 1953, 1962, 1977, 1990, 2003, and 2008. Starting in 1999, annual inventories have been conducted in which a portion of field plots is inventoried each year and a full inventory is completed after five years. Minnesota's first full inventory was completed in 2003, covering 1999 to 2003. The second full inventory, completed in 2008, covers 2004 to 2008. With complete re-measurement of annual inventory plots, we are able to produce better estimates of growth, mortality, and removals, and produce detailed reports on ground land use change.

Aerial Survey Results

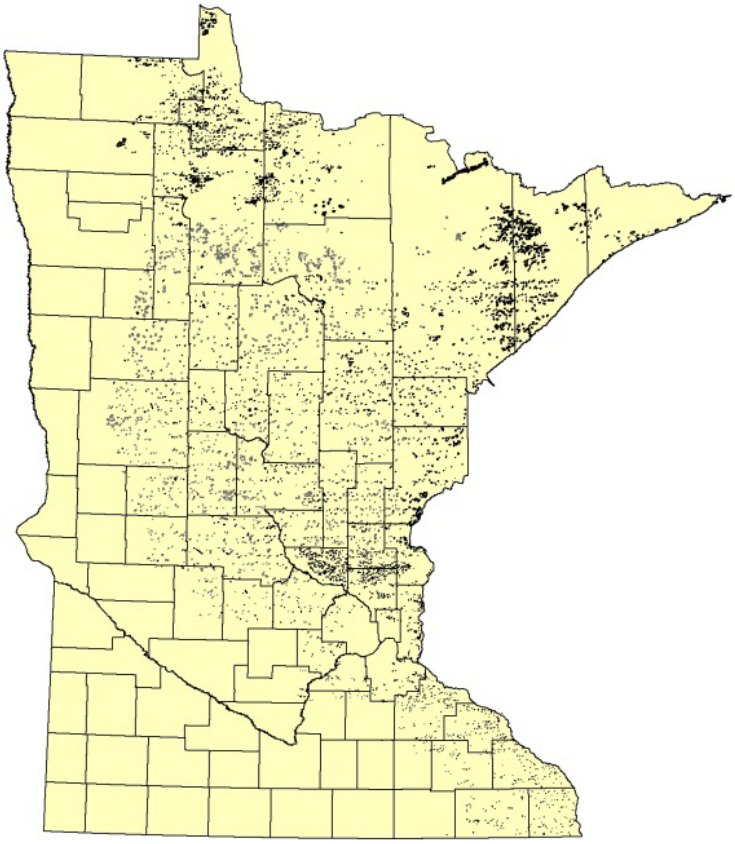
Since the early 1950s, aerial survey has been a valuable tool for monitoring forest insects and pathogens across the 16 million acres of forest land in Minnesota. For the past fifteen years, these annual surveys have been accomplished through the collaboration of the Minnesota Department of Natural Resources (DNR) Forest Health and Resource Assessment Units and the U.S. Forest Service (USFS) Northeastern Area State and Private Forestry (S&PF). The Forest Health staff plans the scope, timing, and intensity of the surveys, trains Resource Assessment staff, provides ground-truthing, analysis, and dissemination of survey data. Resource

Assessment staff conducts aerial sketch-mapping on the state quads, digitizes the data, and produces digital shape files. State and Private Forestry conducts aerial sketch-mapping on the federal quads, does post-flight map rectification, and holds the final review meeting. Aerial survey results are incorporated into the USFS national database since our procedures and products comply with national standards. The summary table below shows the amount of acres of damage caused by various insects, disease, and other factors.

Summary of acres damaged and poplygons by damage agent

Damage agent	# polygons	Acres affected
Aspen leaf-rollers	79	18,019
Bark beetles	0	0
On red pine	31	520
On white spruce	58	1,730
All other conifers	176	2,641
Decline	0	0
Ash	338	38,697
Aspen	611	28,635
Dutch elm disease	813	622
Eastern larch beetle	1,841	42,305
Emerald ash borer	1	16
Fire	1	217
Flooding	100	4,288
Forest tent caterpillar	1,735	155,772
Jack pine budworm	5	354
Larch casebearer	167	14,779
Large aspen tortrix	3	665
Spruce budworm	624	94,199
Two-lined chestnut borer	62	46
Unknown damage agent	110	2,314
Wind damage	83	4,329
Totals	**6,838**	**410,148**

Polygons Mapped in the 2014 Aerial Survey



The above map shows scattered polygons (in black) across Minnesota, representing areas of damage recorded in the aerial survey.

In 2014, the state portion of the survey began on June 19 and was completed on August 14. The federal portion of the survey began on July 8 and was completed on July 19. A map with the portion of the survey by quad shows intended start dates along with actual start and completion dates; see following page.

Thanks to Resource Assessment's sketch-map team Gentry Carlson and Joel Perrington, who accomplished this year's aerial survey and data-processing. Thanks also to Marc Roberts, S&PF, for mapping the federal portion of the survey and to Quinn Chavez, S&PF, for post-flight map rectification and the final review meeting.

2014 Cheat Sheet for Coding Damage Polygons in ArcView

File Names: Store successive shapefile versions as skm06v01.xxx, skm06v02.xxx, etc. in S:\sketchmp\dmg_polys_06

Items coded: Arrange data fields in the following order and format:

Polygon ID: Name of 1:100,000 quad on which polygon is first delineated plus 3-digit number: e.g. LakeItasca025. Numbering starts at 001 in every quadrangle. Once assigned, this ID will not change. Character field, width 25.

ID Number: Only the numerical portion of Polygon ID above. Numeric field, width 3, no decimal.

Damage type code: Use severest type if more than one may apply. Numeric field, width 2, no decimal.

Defoliation (D)	1	Branch breakage (Br)	6
Mortality (M)	2	Stembreak/uproot (St)	7
Discoloration (Dc)	3	Branch flagging (Bf)	8
Dieback (Db)	4	Other damage (0)	10
Topkill (Tk)	5	Old mortality (OM)	11

State severity code: Coding default is L unless otherwise specified. Character field, width 2.

Trace, 5%-25% affected	T	Moderate, 51%-75% affected	M
Light, 26%-50% affected	L	Heavy, > 75% affected	H

Federal severity code: Derived from state severity code. Numeric field, width 2, no decimal.

T, L	1	M, H	2

Pattern code: Coding default is 1 unless otherwise specified. Numeric field, width 2, no decimal.

Where host cover > 50% and damage is:		Where host cover < 50% and damage is:	
Cg = Contiguous	1	C = Continuous	3
P = Patchy	2	Sc = Scattered	4

Agent codes: The following codes are common; see Aerial Survey Handbook for anything else. Coding default = Unknown (90000) where agent is not specified. Numeric field, width 6, no decimal. Based on Aerial survey GIS Handbook Appendix E Revised 11/2007.

Bark beetles (BB)	11000	Dutch elm disease (DED)	24022
Larch beetle (LB)	11010	Fire (F)	30000
Large aspen tortrix (LAT)	12037	Porcupine damage	41006

Spruce budworm (SBW)	12038	Abiotic (A)	50000
Jack pine budworm (JPB)	12041	Flooding (Fl)	50004
Larch casebearer (LCB)	12047	Snow/ice	50011
Forest tent caterpillar (FTC)	12096		
Leaf Rollers	12155		
Emerald ash borer	15087	Wind damage (WD)	50013
Two-lined chestnut borer (TLC)	15005	Winter injury (WI)	50014
Decline (DC)	24008	Herbicide damage (HD)	70001
Oak wilt (OW)	24021	Unknown	90000

Agent Name: Common name of causal agent exactly as given in Handbook. Character field, width 40.

Host code: Following are common; see Handbook for others. Use Hardwoods, Softwoods (conifers) or Both if more than one species is involved. Numeric field, width 4, no decimal.

Host code name	Code	Notes	Host code name	Code
Hardwoods (Hw)	001		Birch	370
Softwoods (Sw)	002		Hickory	400
Both	003		Ash	540
Balsam fir	012		Black ash	543
Tamarack	071		Aspen	746
White spruce	094		Balsam poplar	741
Black spruce	095	(In bogs)	Oaks	800
Jack pine	105		Willow	920
Red pine	125		Basswood	950
White pine	129		Elm	970
Scotch pine	130		Unknown	999
White cedar	241			

Host name: Common name of host exactly as given in Handbook. Character field, width 40.

Acres: Calculate with Theme-Utilities > Calculate Area/Perimeter/Length in DNR Tools. Numeric field, width 16, 2 decimal places. Delete Area, Per feet and Perimeter fields, retain Acres only.

Pest Conditions Report

This report contains pest information from a national list of the major forest insects and diseases that occur within the state and any other pests that cause recordable host damage during the year. Data collected in the aerial survey will be entered into the federal Pest Event Reporter database used to produce the National Forest Insect and Disease Conditions Report.

Insects

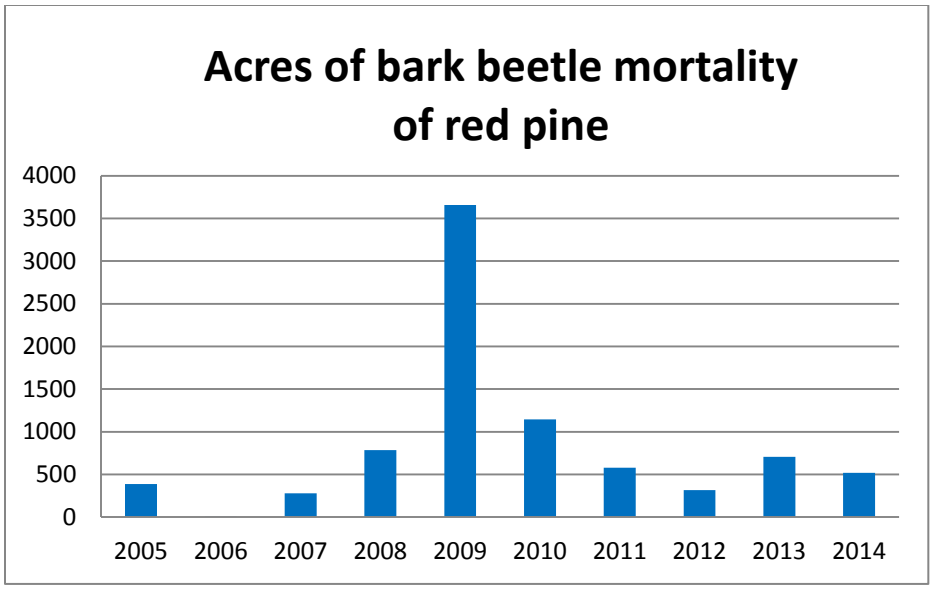
Pine slash left in pine stand after thinning

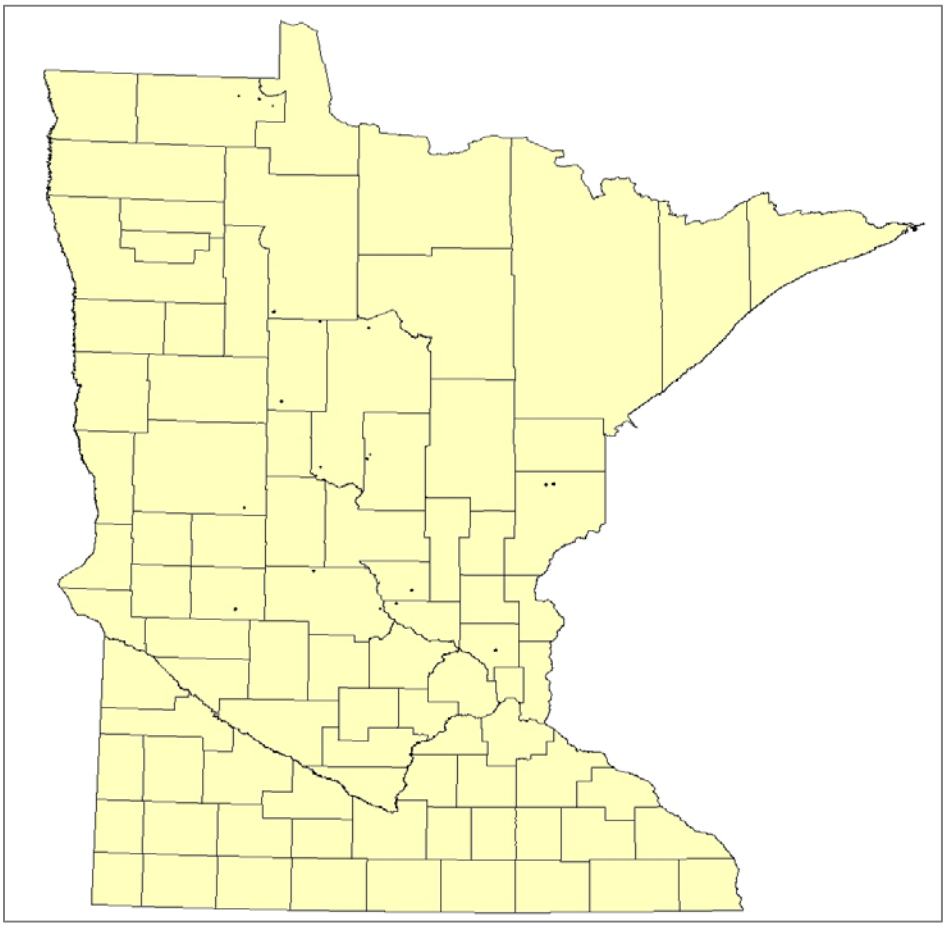
Bark beetles

Ips spp., *Dendroctonus valens*

Hosts	Red, rarely jack and white pines
Setting	Rural forests
Counties	Roseau, Beltrami, Hubbard, Cass, Crow Wing, Ottertail, Pope, Stearns, Benton, Sherburne, Pine, Anoka
Survey methods	Aerial detection
Acres affected	520 acres in 31 polygons
Damage type	Mortality

Mortality decreased from 707 acres in 2013. Spring weather in 2014 was cool and rainy, discouraging bark beetle survival and subsequent pine mortality. See map on next page.


Acres of bark beetle mortality of red pine
4000
3500
3000
2500
2000
1500
1000
500
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014



Larch beetle galleries under bark

Eastern larch beetle

Dendroctonus simplex

Hosts	Tamarack
Setting	Rural forests
Survey methods	Aerial survey
Acres affected	42,305 acres on 1841 polygons
Damage type	Mortality

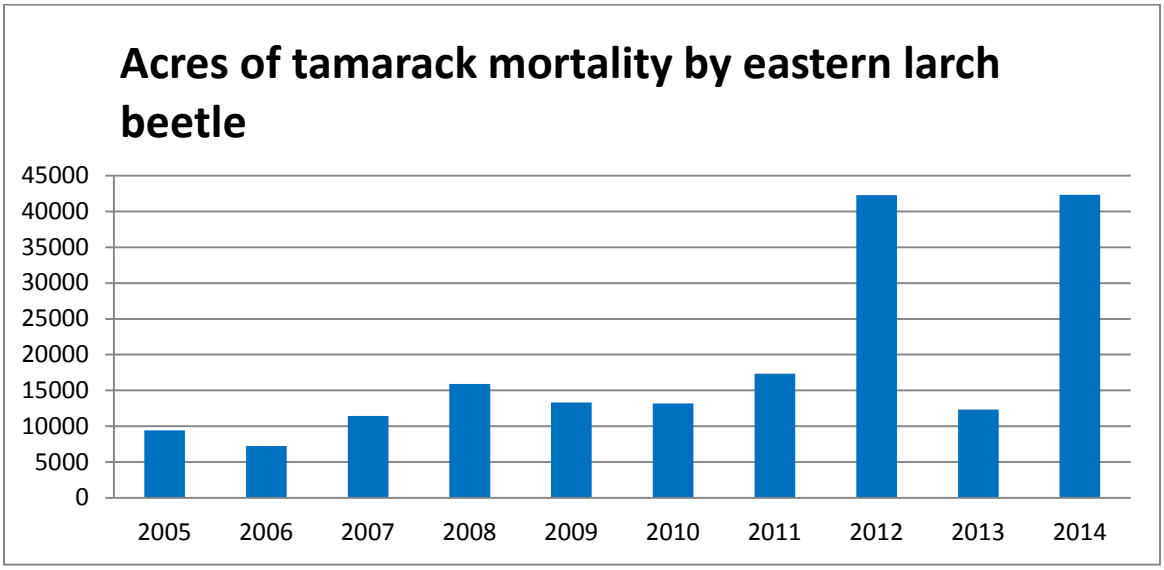
This is the 15th consecutive year since the first recorded outbreak of eastern larch beetle (ELB) in Minnesota. As of this year, 21.5 percent of the tamarack cover type on all ownerships has extensive to complete mortality due to larch beetle attack. See map, charts and photo on following pages.

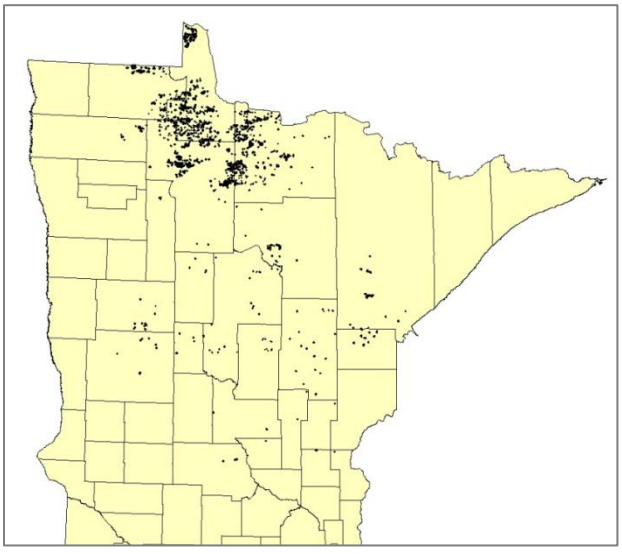
Professor Brian Aukema and graduate student Fraser McKee, researchers at the University of Minnesota, Department of Entomology, have studied many aspects of the insect biology and ecology of this outbreak. Here are some of their published findings:

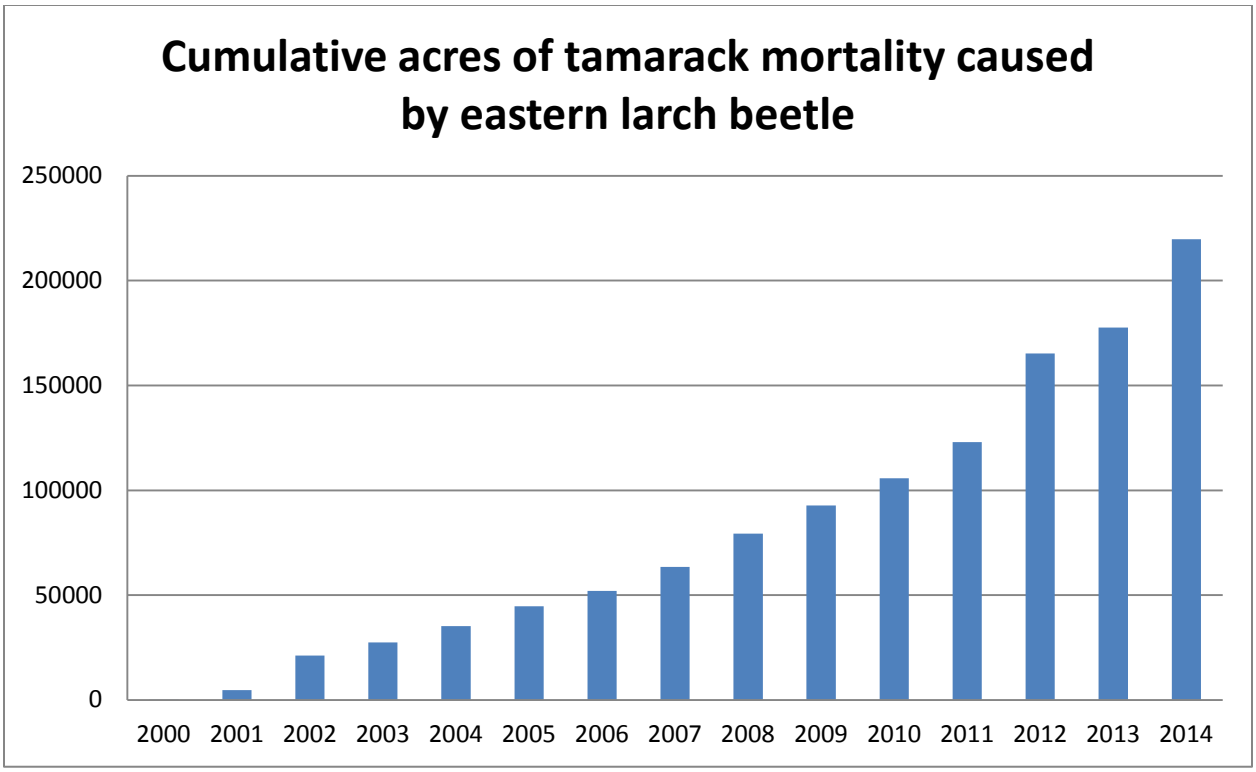
- This outbreak has no known biotic predisposing factor such as extensive defoliation. Trends of recent climate warming, however, are suspected to be a contributing factor.
- Preliminary results show that within the current outbreak there is an increase in the rate of mortality following successive years of drought, with highest mortality occurring in areas with the most severe, prolonged drought.
- Probability of tamarack mortality from ELB was significantly negatively correlated to diameter, crown ratio, stand age, and stand basal area, and positively correlated to height.
- Researchers recorded development and emergence of brood adults:
    - Brood adults began emerging from natal trees in late summer and proceeded to successfully attack, colonize, and establish a new cohort that survived to adulthood in healthy tamaracks.

- This finding indicates a shift in voltinism from one to two generations per year, not previously noted in the literature.
- Multi-voltinism by the by the eastern larch beetle may be one mechanism by which the current outbreak in Minnesota is being sustained.

- Models indicated that tamarack mortality due to ELB increased when:
  - the first frost-free day occurred in late spring the previous year, and
  - the first day less than 10° C occurred in late spring of the current year.
- These patterns likely reflect synchronous emergence of beetles and attack of tamarack with frozen root systems.







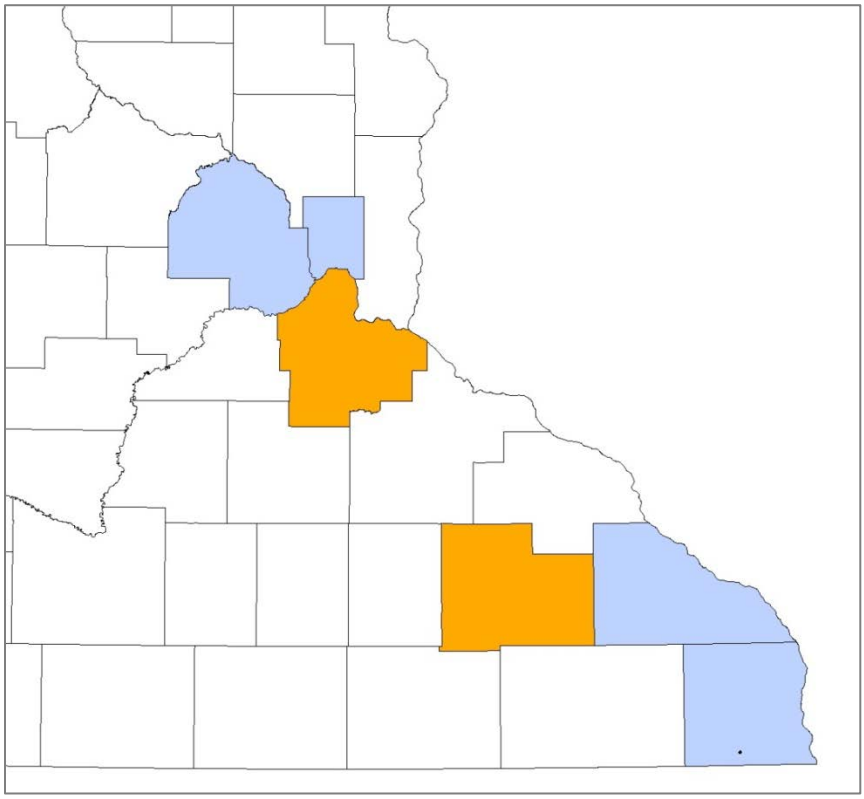
Aerial view of recent (yellow) and old (grey) mortality by larch beetle. Photo, Fraser McKee, Univ. of MN

Emerald ash borer

Agrilus planipennis

Hosts	White, green, and black ash
Setting	Urban and rural forests
Counties	Dakota, Olmsted, Hennepin, Ramsey, Winona, Houston
Survey methods	Ground survey and aerial survey
Acres affected	16 acres in Houston Co. mapped from the air
Damage type	Mortality

Emerald ash borer (EAB) was discovered in two new counties (Olmsted and Dakota) in Minnesota during 2014, bringing the total number of known EAB-infested counties to six. The initial Olmsted County find south of Rochester was made in August after a report of declining ash trees. Shortly after that, another confirmation of EAB was made five miles to the north and just outside Rochester city limits. The initial find in Dakota County occurred in late December and was located across the Mississippi River from another infestation in Hennepin County. These finds resulted in emergency quarantines for EAB in Olmsted and Dakota counties by the Minnesota Department of Agriculture (MDA). After a comment period and public hearing, the emergency quarantines became part of the formal state quarantine for EAB in early January 2015.



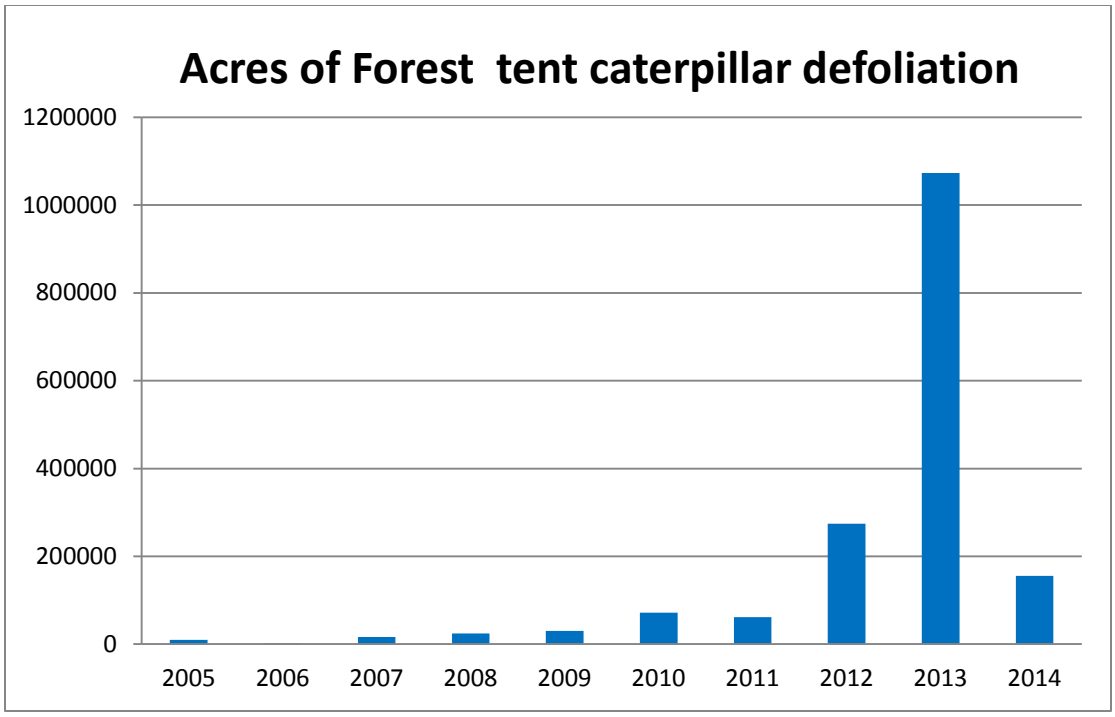
Parasitized FTC pupa inside the cocoon; see dark brown spot on pupa.

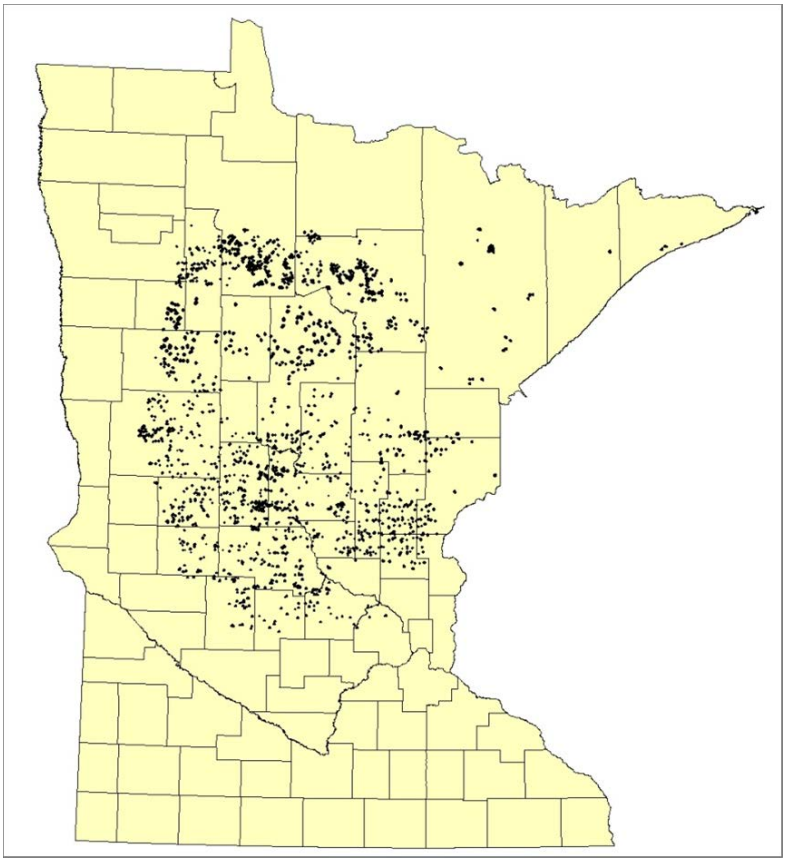
Forest tent caterpillar

Malacosoma disstria

Hosts	Aspen, oak, basswood, birch, willow, tamarack, and other hardwoods
Setting	Rural forests
Counties	Beltrami, Cass, Crow Wing, Wadena, Hubbard, Becker, Ottertail, Mahnomen, Pennington, Clearwater, Grant, Douglas, Pope, Cook, Lake, St. Louis, Itasca, Aitkin, Carlton, Todd, Morrison, Mille Lacs, Kanabec, Pine, Stearns, Benton, Sherburne, Isanti, Chisago, Swift, Kandiyohi, Meeker, Wright
Survey methods	Aerial and ground survey
Acres affected	155,772 acres on 1735 polygons
Damage type	Defoliation was predominantly “very light” (less than 25 percent of canopy impacted).

We were expecting the forest tent caterpillar (FTC) outbreak to peak at two to four million acres of defoliation this year based on past outbreak patterns, but sketch-mappers only mapped 156,000 acres of defoliation. We surmised that FTC populations crashed during larval or pupal development in 2013, as very few egg masses were found during ground survey in preparation for 2014 defoliation predictions.


Acres of Forest tent caterpillar defoliation
1200000
1000000
800000
600000
400000
200000
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

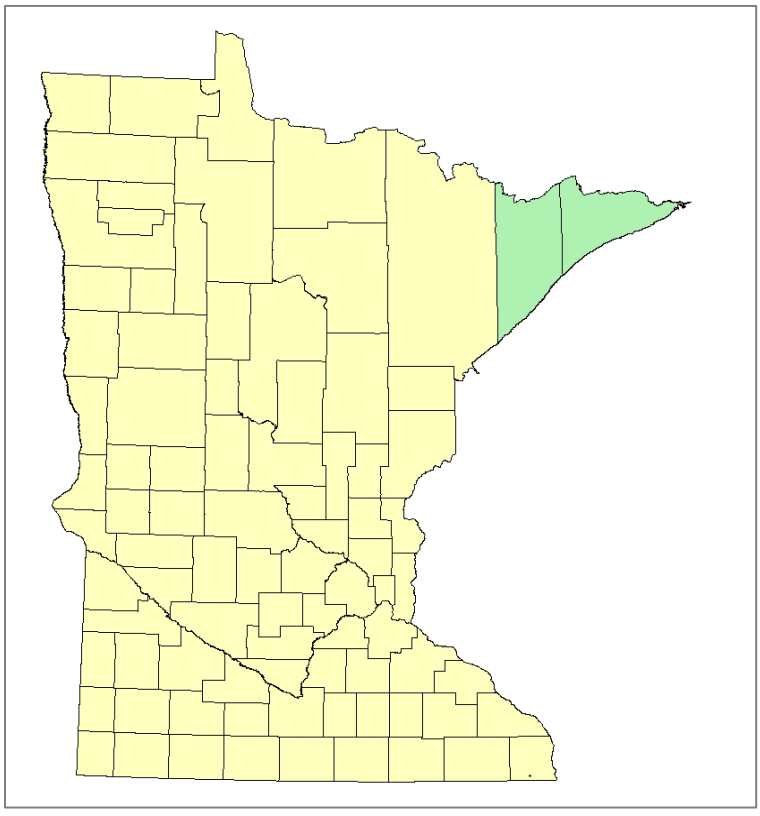


Gypsy moth

Lymantria dispar

Hosts	Oak, aspen and other hardwoods
Setting	Rural and urban forests
Counties	Cook and Lake
Survey methods	Male moth trapping and ground survey
Acres affected	None
Damage type	No defoliation observed

The Minnesota Department of Agriculture instituted the first gypsy moth quarantine on July 1, 2014 in Lake and Cook Counties, based on last year's trap catches, life stages found, and population estimates. Trapping in 2013 produced over 70,000 male moths, nearly three times that of the year with the next highest total. Based on the number of moth catches, alternate life stages found and the recommendations of national Slow-the-Spread program leaders, Cook and Lake Counties were quarantined as of July 2014 (illustrated on map below).

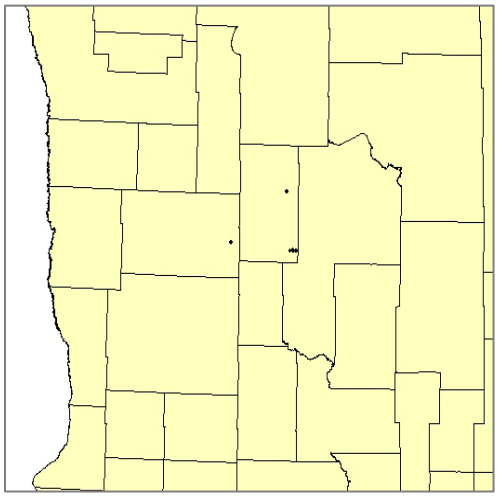


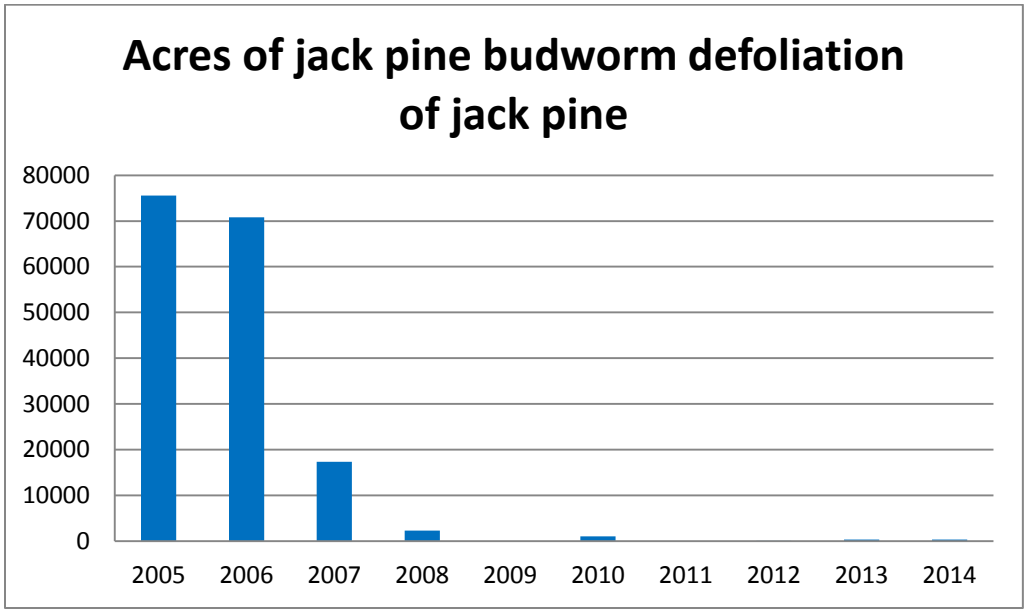
Jack pine budworm

Choristoneura pinus pinus

Hosts	Jack and red pine
Setting	Rural forests
Counties	Hubbard and Ottertail
Survey methods	Aerial survey
Acres affected	354 acres on five polygons
Damage type	Defoliation

We have had very little defoliation caused by jack pine budworm since 2007. This year there were 20 more acres than last year, but two more locations were mapped (map below). This population is expected to build over the next few years, primarily in jack pine.



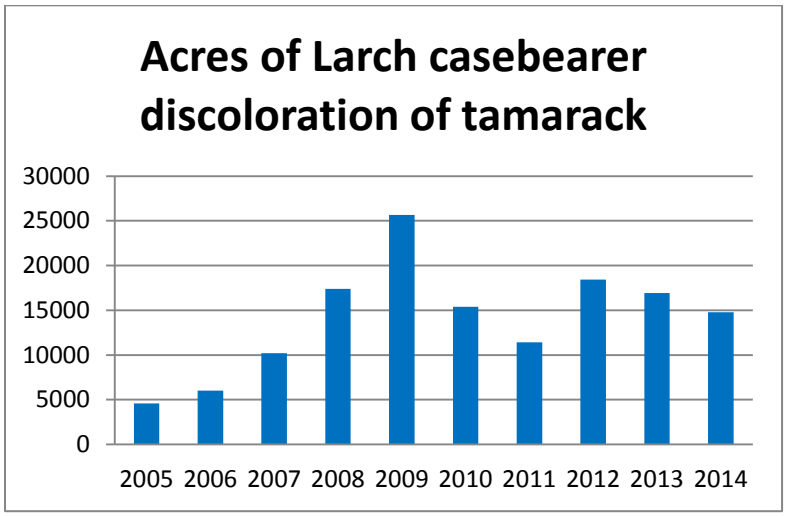


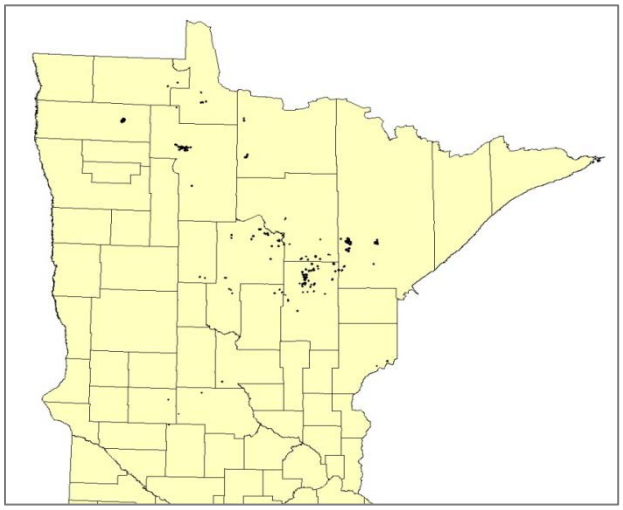
Larch casebearer

Coleophora laricella

Hosts	Tamarack
Setting	Rural forests
Counties	Roseau, Beltrami, Cass, Crow Wing, Hubbard, Becker, Lake of the Woods, Marshall, Clearwater, Pope, Koochiching, St. Louis, Itasca, Aitkin, Pine, Morrison, Stearns, Kandiyohi
Survey methods	Aerial survey
Acres affected	14,779 acres on 145 polygons
Damage type	Discoloration

Casebearer feeding activity on tamarack foliage caused the needles to discolor. Acreage in 2014 was down 2000 acres compared to last year but there are 20 more stands with damage.





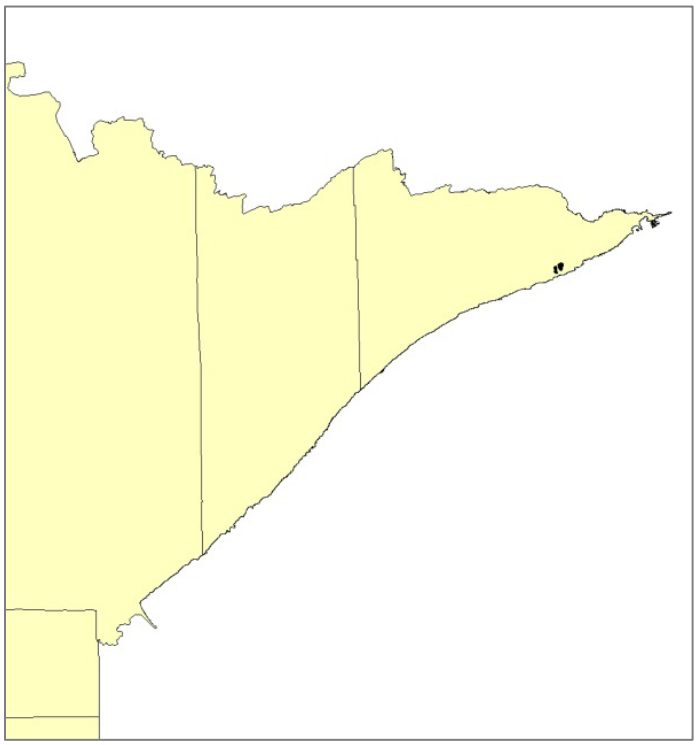
Large aspen tortrix

Choristoneura conflictana

Hosts	Aspen
Setting	Rural forests
Counties	Cook
Survey methods	Aerial and ground survey
Acres affected	2,552 acres on five polygons
Damage type	Defoliation

Large aspen tortrix is an early season defoliator of trembling aspen. Small areas of defoliation were observed in Lake County in 2012 and 2013. In 2014, 665 acres of defoliation were mapped in Cook County.

Large outbreaks of large aspen tortrix have occurred in northeastern Minnesota in the past. One million acres were defoliated in 1969 in an outbreak that lasted from 1969 through 1972. The last recorded outbreak in NE Minnesota was in 1999 when 336,000 acres of defoliation were mapped primarily along the north shore of Lake Superior.



Spruce budworm

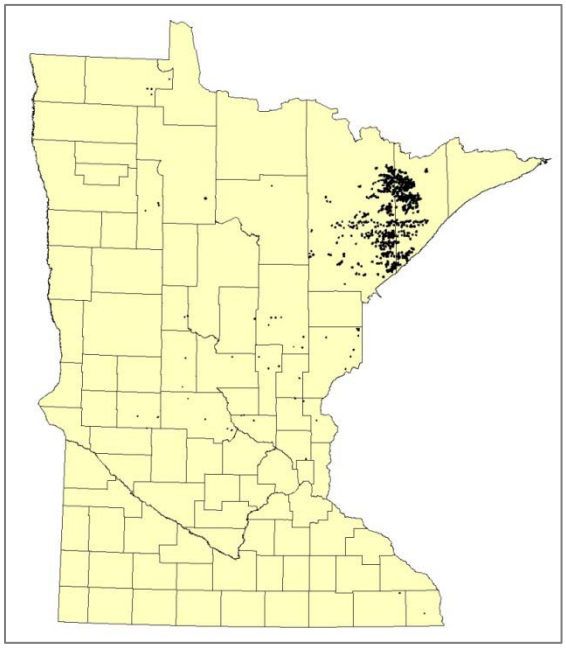
Choristoneura fumiferana

Hosts	Balsam fir and white spruce
Setting	Rural forests
Counties	Roseau, Beltrami, Clearwater, Hubbard, Becker, Wadena, Crow Wing, Pope, Lake, St. Louis, Itasca, Aitkin, Pine, Chisago, Isanti, Mille Lacs, Kanabec, Sherburne, Stearns, Todd, Swift
Survey methods	Aerial survey
Acres affected	94,199 acres on 624 polygons
Damage type	Defoliation. No mortality was mapped this year.

A continuous population of spruce budworm has occurred in northeastern Minnesota since 1954. Acres of defoliation increased to 94,199 acres in 2014, up from 38,029 acres in 2013 (map below). There was a significant shift in the area defoliated to the east and south this year. We expect spruce budworm defoliation to occur in this location for many years, causing extensive mortality of balsam fir.

Small acreages of defoliation began near Two Harbors in Lake County and in extreme southeastern St. Louis County in 2010 and defoliation has increased since. Heavy defoliation occurred this year in Cloquet Valley State Forest. The last outbreak in this state forest occurred from 1974 through 1986. Defoliation also occurred this year in Finland State Forest. The last outbreak there occurred from 1969 through 1986. It has been roughly 28 years since these areas last experienced defoliation by spruce budworm.

Spruce budworm defoliation and mortality was centered around Lake Vermillion in northern St. Louis County from 2002 through 2013, and although no defoliation occurred around Lake Vermillion this year, balsam fir mortality continues.

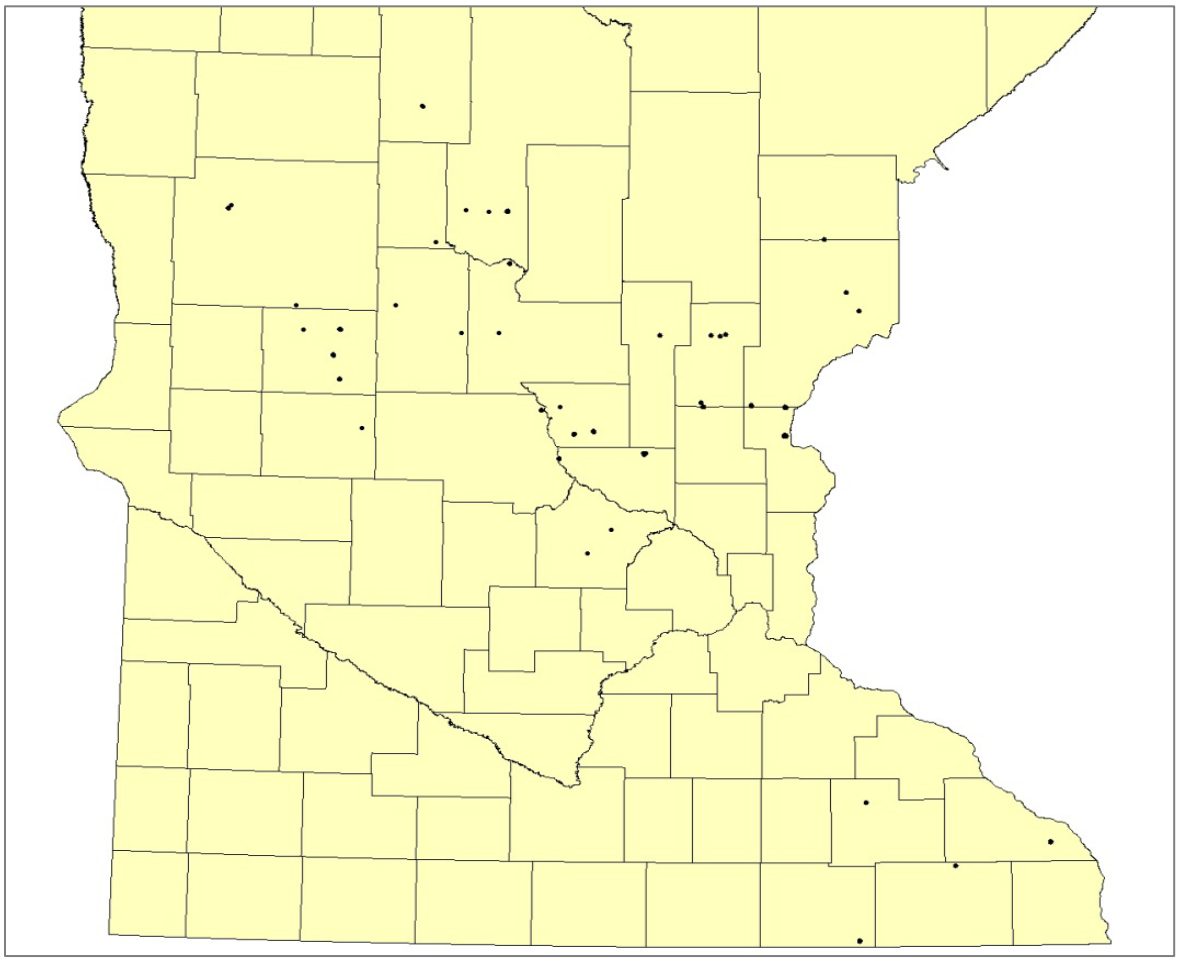


Two-lined chestnut borer

Agrilus bilineatus

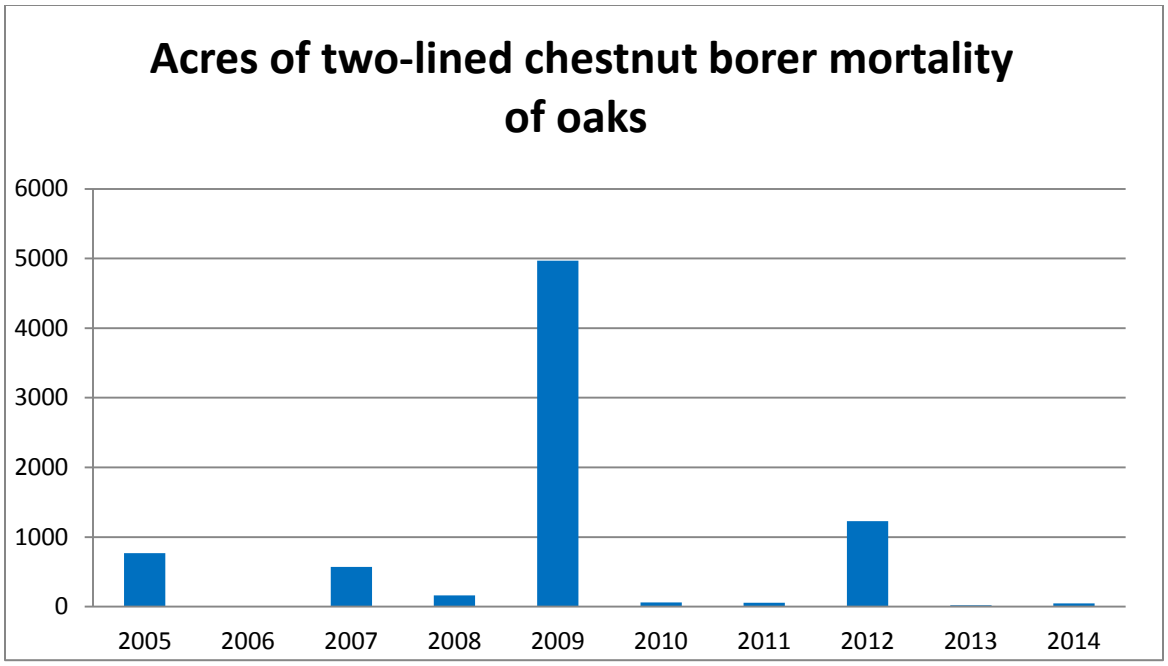
Hosts	Oaks
Setting	Rural forests
Counties	Hubbard, Becker, Cass, Ottertail, Douglas, Pope, Carlton, Todd, Morrison, Mille Lacs, Kanabec, Pine, Benton, Isanti, Chisago, Benton, Wright, Stearns, Olmsted, Winona, Mower, Fillmore, Houston.
Survey methods	Aerial survey
Acres affected	46 acres on 62 polygons.
Damage type	Mortality

Two-lined chestnut borer attacks and kills oaks stressed by drought, defoliation, or root damage. Compared to last year, both the acreage of mortality and the number of polygons doubled and the number of affected counties more than doubled (see map below).



TLCB attacks in upper crown and the resulting partial mortality

TLCB-killed red oak during a drought


Acres of two-lined chestnut borer mortality of oaks
6000
5000
4000
3000
2000
1000
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

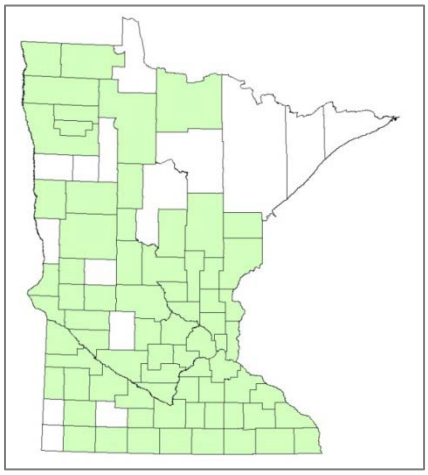
Diseases

Bur oak killed by bur oak blight

Bur oak blight

Tubakia iowensis

Host	Bur oak
Setting	Rural and urban forests
Counties	*New county records*: Dodge, Benton, Todd, Wadena, Yellow Medicine, Lincoln, Lyon, Murray, Nobles, Jackson, Watonwan, Martin, Chippewa, Pine, Traverse, Stevens, Grant, Carlton, Swift, Clay, Red Lake, Kittson, Roseau, Aitkin, Crow Wing, Koochiching.
Survey methods	Ground surveys to ascertain presence of pathogen
Acres affected	Unknown
Damage type	Leaf discoloration and defoliation; twig dieback



Bur oak blight (BOB) was commonly seen in Minnesota again in 2014. Twenty-six new counties were added to the list of counties known to have BOB (map above shows counties with BOB in green).

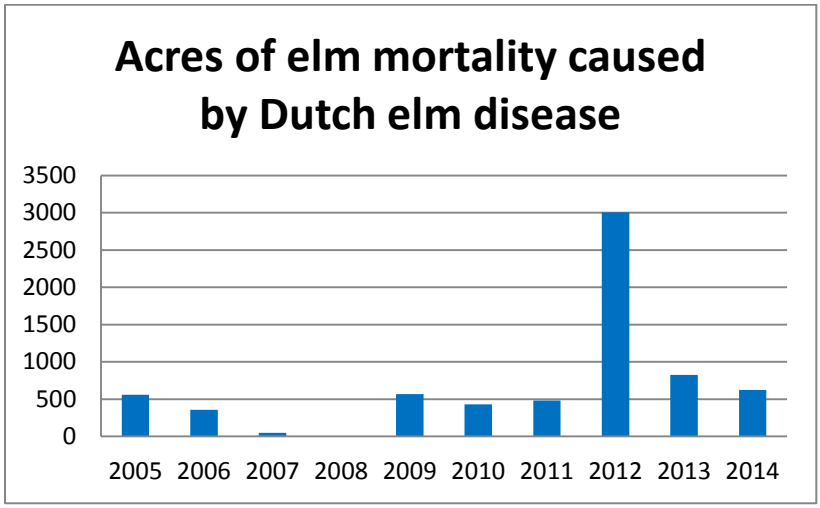
Conditions in April and May during leaf emergence were wetter than the 30-year average over much of bur oak's range in Minnesota, which has been the case each spring since 2011. These moist conditions favor leaf infection by the fungal pathogen that causes BOB, so the occurrence of BOB was expected. Areas of central Minnesota had noticeably higher BOB incidence and severity than other parts of the state, such as southeastern Minnesota.

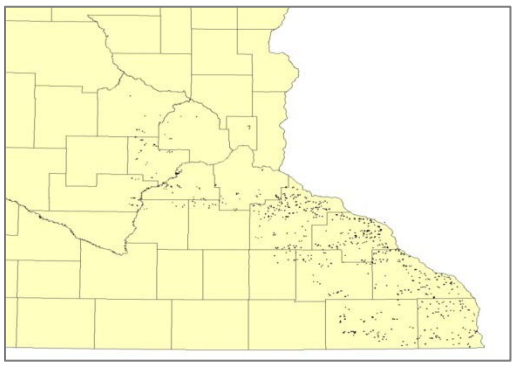
Dutch elm disease

Ophiostoma ulmi

Hosts	American and red elms
Setting	Rural forests
Counties	Wright, Hennepin, Ramsey, Carver, Sibley, Scott, Dakota, Le Sueur, Rice, Goodhue, Wabasha, Dodge, Olmsted, Winona, Fillmore, Houston.
Survey methods	Aerial survey
Acres affected	622 acres in 813 polygons
Damage type	Discoloration and mortality

Acreage affected is down by 200 acres and the incidence is down by 26 percent compared to 2013.



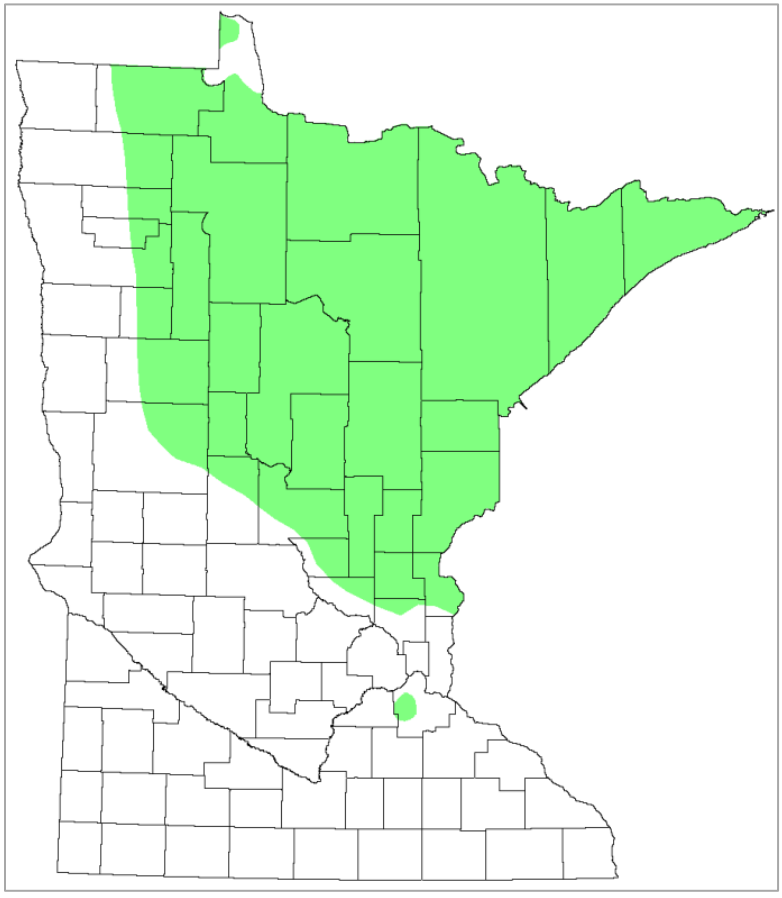


Eastern dwarf mistletoe

Arceuthobium pusillum

Hosts	Black spruce; rarely, white spruce and tamarack
Setting	Rural forests
Counties	Beltrami, Cass, Crow Wing, Wadena, Hubbard, Becker, Ottertail, Lake of the Woods, Roseau, Mahnomen, Marshall, Pennington, Red Lake, Clearwater, Cook, Lake, St. Louis, Itasca, Aitkin, Carlton, Todd, Morrison, Mille Lacs, Kanabec, Pine, Benton, Sherburne, Isanti, Chisago, Anoka, Dakota
Survey methods	Ground observations
Acres affected	Unknown. Literature suggests 11-55 percent of cover type is infested.
Damage type	Mortality

Eastern dwarf mistletoe is a native disease and is always fatal. The primary host is black spruce and there are approximately 1,551,000 acres of black spruce in the state. Losses are not spread equally over the forest. Infections occur in un-merchantable stands and along stand edges where it has been active for decades or centuries and in new infection centers that are roughly circular. Losses are estimated to be less than 2 percent of the cover type area each year.



Heterobasidion root disease

Heterobasidion irregulare

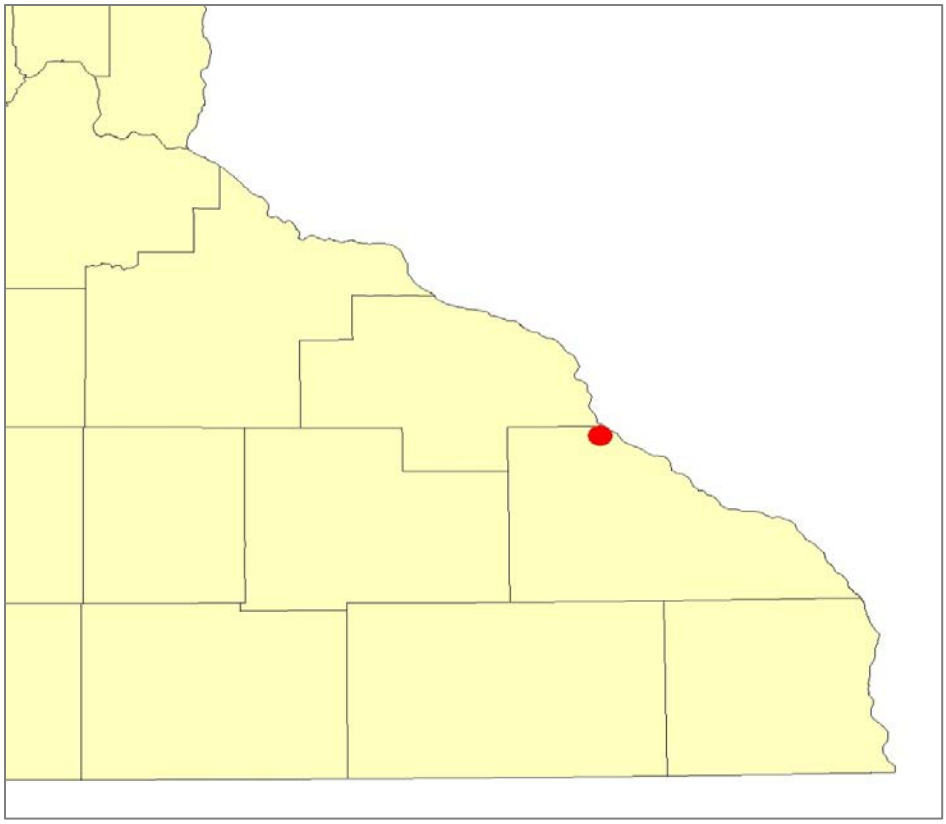
Hosts	Pine, balsam fir, eastern red cedar and other trees and shrubs
Setting	Pine plantations
Counties	Winona
Survey methods	Ground survey
Acres affected	1/10 acre in a red pine plantation
Damage type	Decreased canopy vigor and mortality

Dr. Robert Blanchette, University of Minnesota forest pathologist, made the first confirmed discovery of *Heterobasidion* root disease (HRD) in Minnesota in mid-November 2014. Blanchette's lab isolated the fungus from a dead red pine root in northern Winona County on state land, two miles southwest of Minneiska (indicated by a red dot on map below). They confirmed the identity of the fungus through culturing, DNA sequencing, and fruiting body identification. The nearest known confirmed HRD site to this site is roughly 28 miles northeast in Trempealeau County, Wisconsin.

HRD has killed four neighboring pines at the Winona Co. site, and approximately 10 other adjacent red pines have crowns with reduced vigor. The infection likely occurred during the previous thinning in December, 2003. Weather conditions during that month were unusually warm (highs commonly reached 40°F) with no snow cover. Such conditions make infection by *Heterobasidion* likely if spores are present. The spore source is unknown, but surveys in 2015 by DNR and University personnel will determine if other HRD infections occur in southeast Minnesota. Spores may have come from nearby infected trees, from the Trempealeau County location, or from contaminated logging equipment.

This is the third detection of Heterobasidion species in the state, but it is the first official confirmation of disease. Two *Heterobasidion* conks (i.e. shelf fungi) were collected from conifers in Itasca State Park in 1970 and 1979, but the species identity has not been confirmed to date by DNA sequencing.

Heterobasidion conks on old cut stump



Oak wilt

Ceratocystis fagacearum

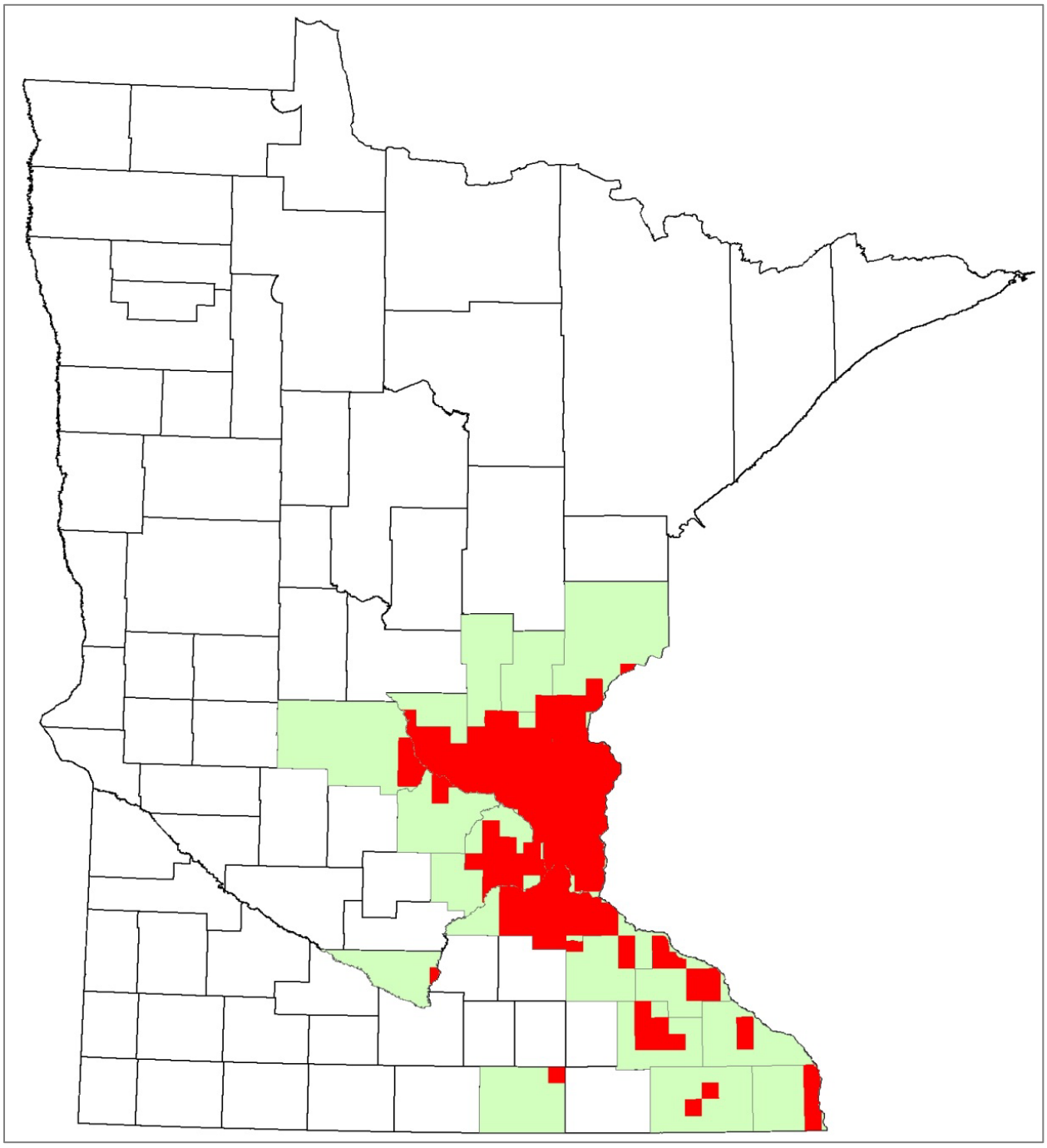
Hosts	Oaks
Setting	Rural and urban forests
Counties	Mille Lacs, Kanabec, Pine, Stearns, Benton, Sherburne, Isanti, Chisago, Wright, Hennepin, Anoka, Ramsey, Washington, Carver, Scott, Dakota, Goodhue, Wabasha, Olmsted, Winona, Houston, Fillmore, Freeborn, Nicollet
Survey methods	Ground surveys and University of Minnesota Plant Disease Cinic results
Acres affected	Not determined
Damage type	Mortality

Oak wilt symptoms were noticeably more abundant on *bur* oak in 2014 than in previous years. Aerial surveyors identified over 1,900 oaks in general that showed active symptoms of oak wilt, comparable to previous years. Freeborn and Nicollet counties were confirmed to have oak wilt for the first time by the University of Minnesota Plant Disease Clinic. Oak wilt is widespread and relatively abundant in Anoka, Chisago, Dakota, Hennepin, Isanti, Olmsted, Ramsey, Sherburne, and Washington counties.

The northernmost known oak wilt-infected area is in St. Croix State Park in Pine County. Oak wilt is a severe threat to surrounding forests there due to species composition and flat terrain. State park staff in 2014 attempted eradication of several oak wilt infection centers in their campground.

The DNR's forest health unit plans to improve early detection efforts of oak wilt at its northern geographical edge in 2015 with the use of high-resolution aerial photographs and ground investigations. In order to target the leading geographical edge of oak wilt, a finer resolution map of disease distribution was made in 2014. The red townships on the map below contain a confirmed oak wilt tree or pocket. These confirmations were made by DNR personnel or program partners from 1987 through 2006. Due to staff changes and shortages, no oak wilt locations were confirmed between 2007 and 2013. Starting in 2014, tracking and confirming oak wilt locations resumed by DNR regional forest health staff and the University of Minnesota Plant Disease Clinic.

Counties (green) and townships (red) on the map below indicate confirmed oak wilt based on ground checks and lab confirmations (does not include aerial surveys).

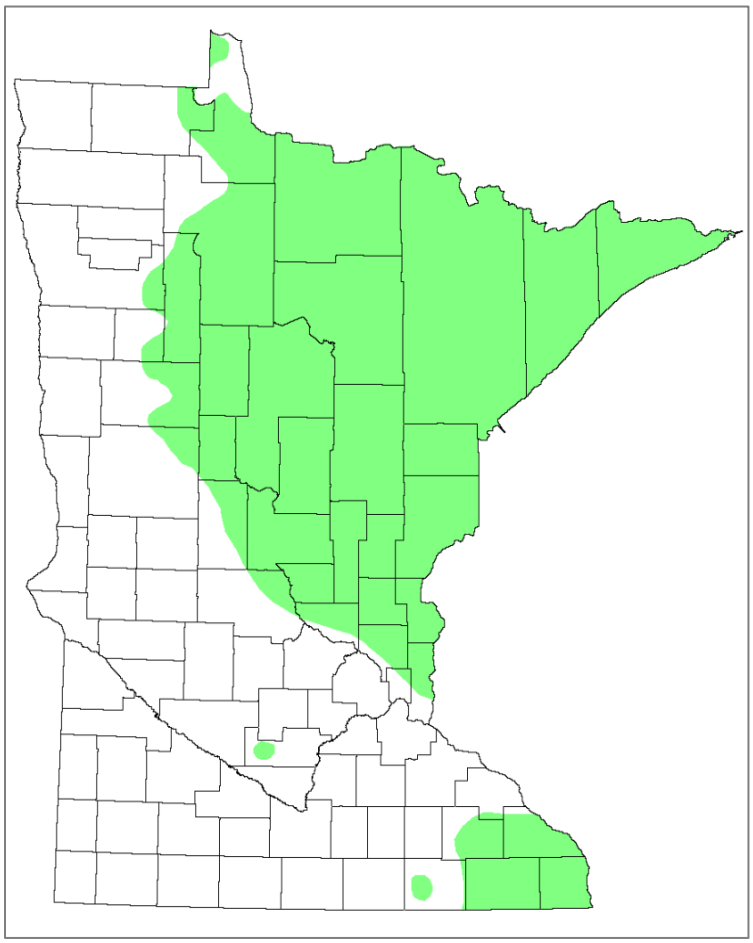


White pine blister rust

Cronartium ribicola

Hosts	White pine
Setting	Rural forests
Counties	Beltrami, Cass, Crow Wing, Wadena, Hubbard, Becker, Ottertail, Lake of the Woods, Roseau, Mahnomen, Marshall, Clearwater, Cook, Lake, St. Louis, Itasca, Aitkin, Carlton, Todd, Morrison, Mille Lacs, Kanabec, Pine, Stearns, Benton, Sherburne, Isanti, Chisago, Anoka, Ramsey, Washington, Sibley, Wabasha, Olmsted, Winona, Mower, Fillmore, Houston
Survey methods	Ground survey
Acres affected	Unknown
Damage type	Decline, dieback and mortality

An introduced, invasive species, this fungus has disrupted and in many places crippled natural and artificial regeneration of white pine and caused top-kill in mature white pines since the 1930s. If climate change predictions are correct, less white pine blister rust could be expected all across Minnesota in the future. The map below shows the range of white pine and white pine blister rust in Minnesota.

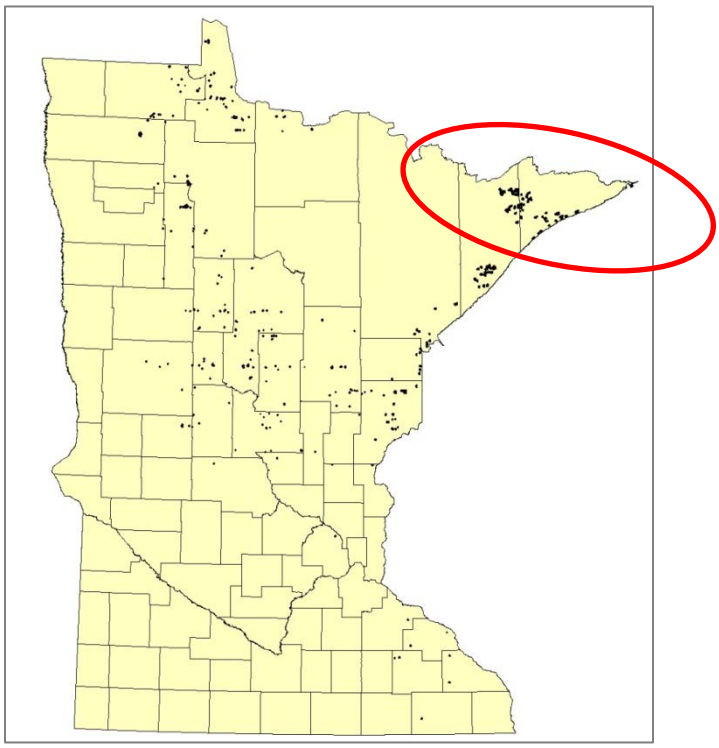


Environmental Stress Agents

Aspen decline

Hosts	Trembling and bigtooth aspen
Setting	Rural forests
Counties	Beltrami, Cass, Crow Wing, Wadena, Hubbard, Becker, Ottertail, Lake of the Woods, Roseau, Mahnomen, Marshall, Polk, Pennington, Clearwater, Douglas, Koochiching, Cook, Lake, St. Louis, Aitkin, Carlton, Todd, Morrison, Kanabec, Pine, Stearns, Benton, Mille Lacs, Kanabec, Chisago, Hennepin, Goodhue, Wabasha, Olmsted, Winona, Fillmore.
Survey methods	Aerial survey
Acres affected	38,697 ac on 338 polygons
Damage type	Crown decline, dieback, and mortality. Decline in aspen crowns is reversible with abundant rainfall. Decline ranges from small leaves and discoloration, dieback and top-kill to eventual mortality.

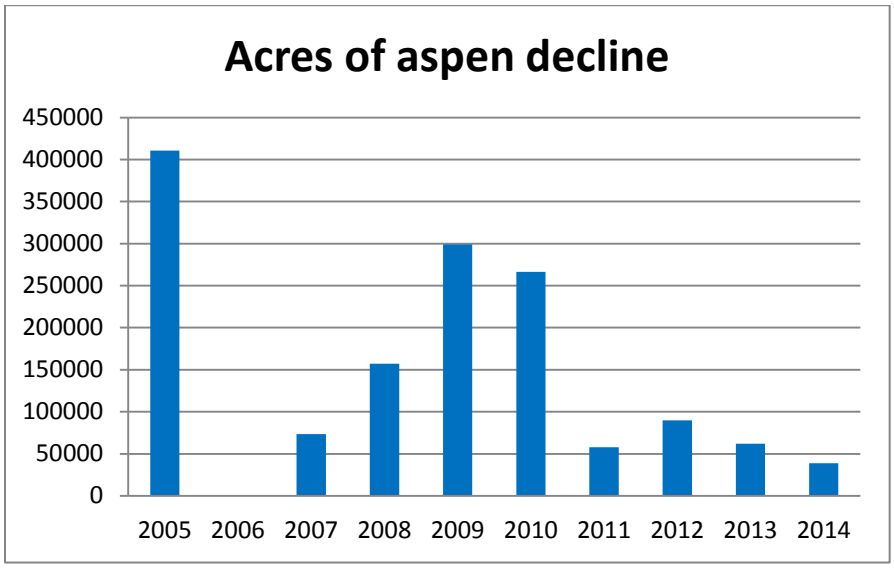
We have mapped and studied aspen decline since 2004. Less aspen decline was mapped in 2014 than in the two previous years. Acreage mapped by the aerial survey peaked at just over 400,000 acres in 2005. The main area of concern is within the red oval on the map below. There are a number of reasons for the decrease in acreage in recent years. The first is that the area has received more precipitation. Surviving trees showing symptoms of decline such as small leaves, thin crowns, or off-color foliage are showing fewer symptoms with the return of better moisture conditions.



Aspen that has died due to decline fall down quickly after dying (see photos below). As a result, many of the dead trees are no longer standing and are not visible from the air. We now see many surviving trees as well as the understory and regeneration on the sites. Many of the stands no longer have obvious symptoms of aspen decline. While we're mapping fewer acres, it does not change the amount of tree mortality and growth loss that has already occurred.

The causes of the decline are several. Trees in the northeastern portion of the state suffered three to four years of heavy forest tent caterpillar defoliation and experienced severe drought in the early 2000s. This area is on the Canadian shield and many of the sites have very shallow soils over bedrock. Unless they receive a steady supply of moisture throughout the growing season, trees are stressed by drought very quickly. The stress of defoliation and drought combined made the trees susceptible to attack by bronze poplar borer and Armillaria root disease.

The polygons in the other parts of the state have been less studied and the reason for them being mapped is less clear and it's likely there are a number of different causes. In some locations, aerial sketch-mappers indicated pockets of trees killed by Hypoxylon canker, not aspen decline.



2008 photo of dead aspen on Otter Lake Road in Cook County

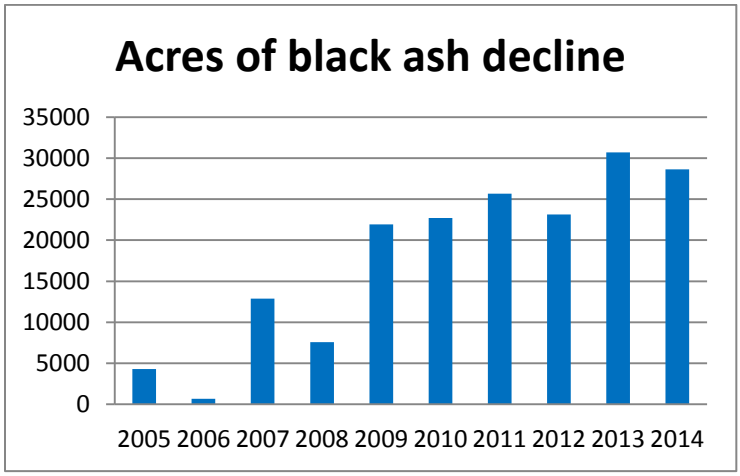
Above two photos are of the same spot as top photo; taken in 2013

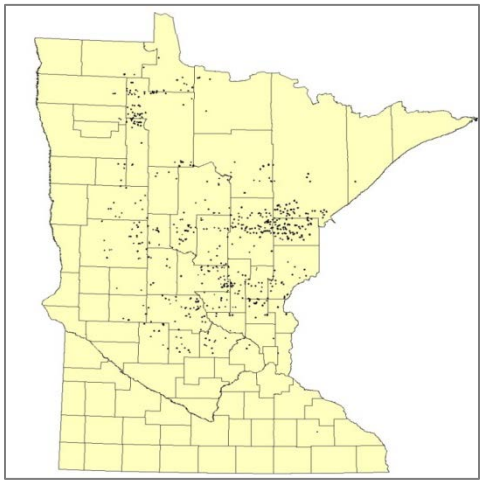
Black ash decline

Physiological problem

Hosts	Black ash
Setting	Rural forests
Counties	Beltrami, Cass, Crow Wing, Wadena, Hubbard, Becker, Ottertail, Lake of the Woods, Polk, Mahnomen, Marshall, Pennington, Clearwater, Douglas, Pope, Lake, St. Louis, Koochiching, Itasca, Aitkin, Carlton, Todd, Morrison, Mille Lacs, Kanabec, Pine, Stearns, Benton, Sherburne, Isanti, Chisago, Kandiyohi, Meeker, Wright, Hennepin, Anoka, Washington, Olmsted.
Survey methods	Aerial survey
Acres affected	28,635 acres on 611 polygons
Damage type	Decline in ash crowns is reversible with the return of favorable growing conditions on the site. Decline ranges from small leaves and discoloration through dieback and top kill to eventual mortality.

Acreage decreased slightly, but number of sites decreased by over 100 compared to last year. The trend is stabilizing around 25,000 acres per year.

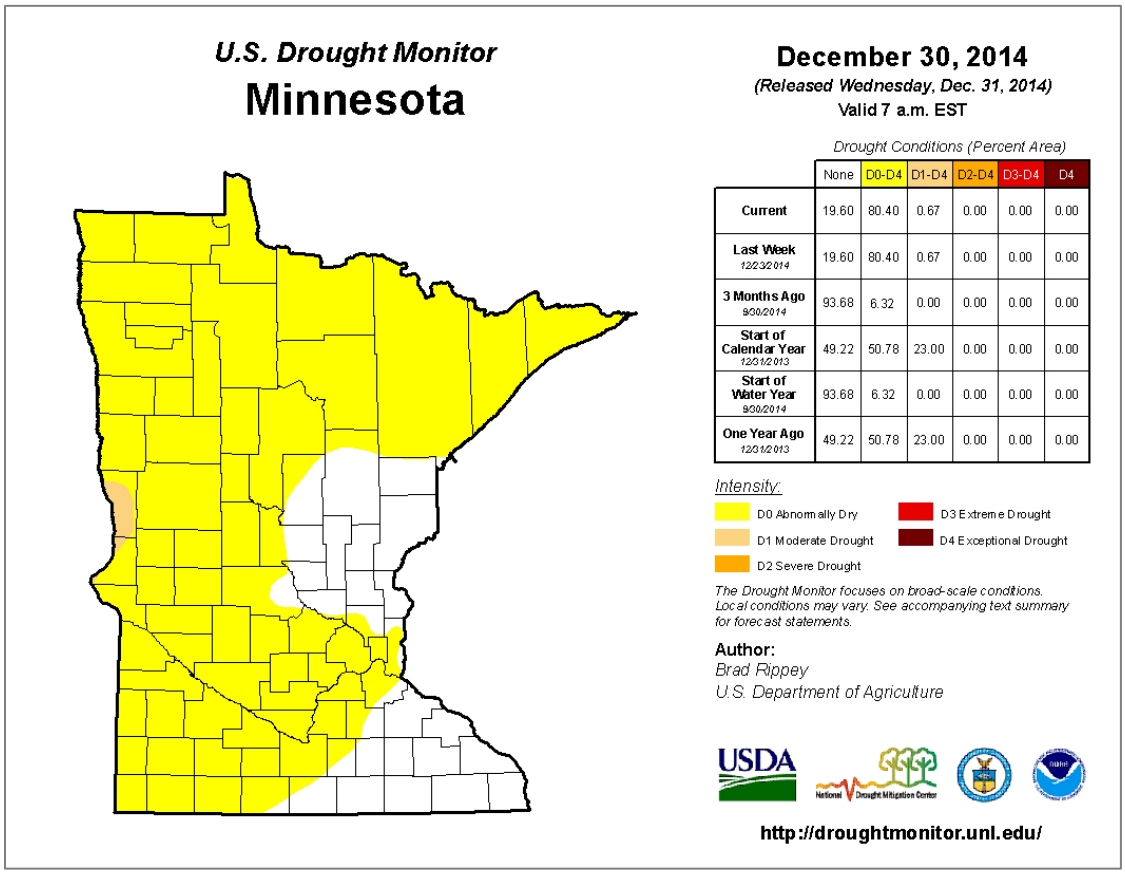


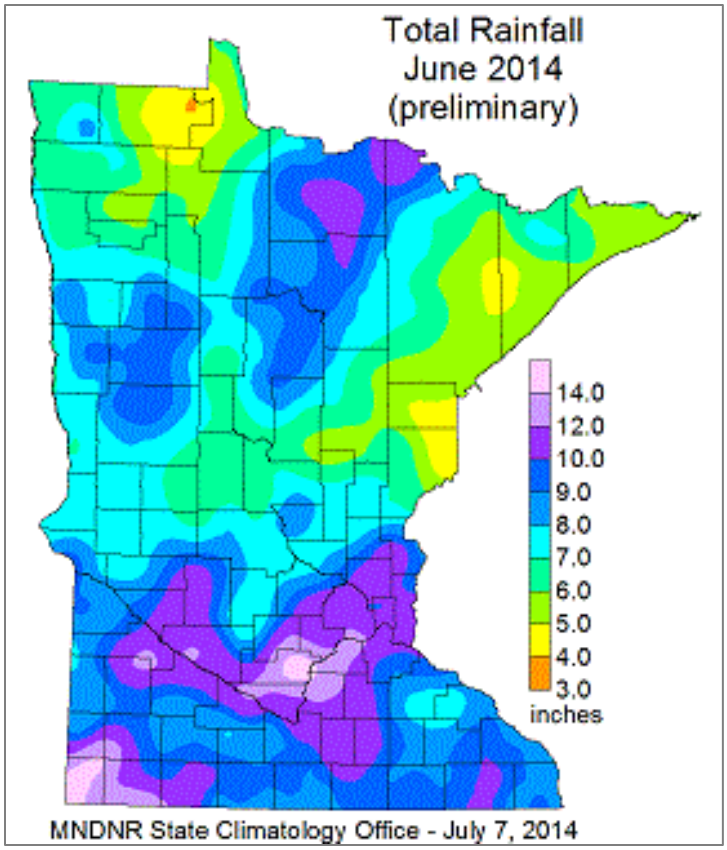


Drought

Hosts	All tree species
Setting	Rural and urban forests
Counties	Beltrami, Cass, Crow Wing, Wadena, Hubbard, Becker, Ottertail, Mahnomen, Pennington, Red Lake, Clearwater, Grant, Douglas, Stevens, Pope Cook, Lake, St. Louis, Itasca, Aitkin, Todd, Morrison, Stearns, Benton, Sherburne, Swift, Kandiyohi, Meeker, Wright, Hennepin, Anoka, Ramsey, Dodge, Washington, McLeod, Carver, Scott, Dakota, Le Sueur, Rice, Goodhue, Wabasha, Dodge, Olmsted, Winona, Fillmore, Houston
Survey methods	Ground survey
Acres affected	Statewide
Damage type	Decline, dieback and mortality

A cool wet spring was again followed by dry weather during the summer and fall months. The intensity of the drought in forested areas was much diminished compared to last year.



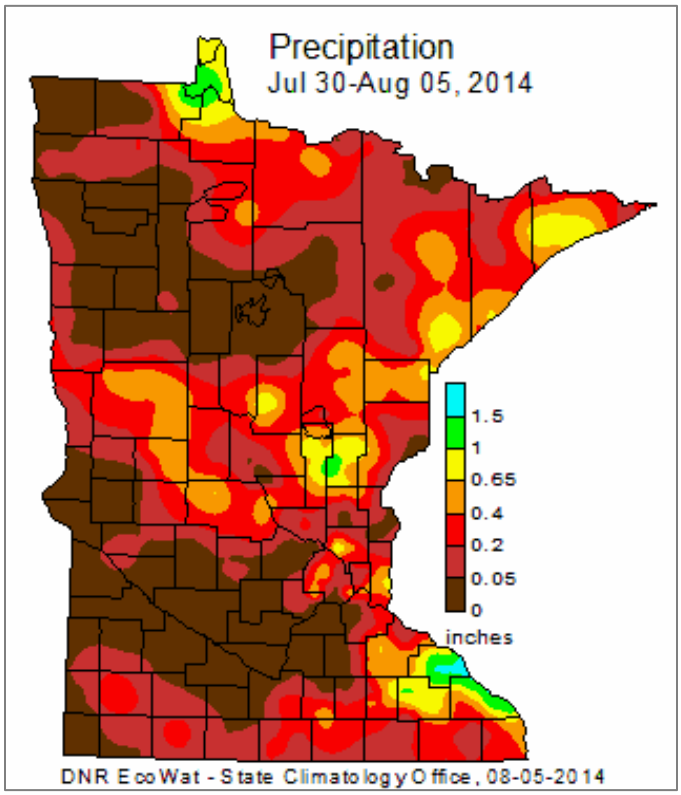


Record-setting Rainfall

June 2014 was Minnesota's wettest June, and wettest month, of the modern record. The state-averaged monthly rainfall total for June 2014 in Minnesota was 8.03 inches, well over the previous record of 7.32 inches set in July 1897 and again in June 1914.

The state-averaged monthly rainfall record was established because of the broad geographic extent of heavy rainfall events. Individual station monthly rainfall records in June were set from Luverne on the Iowa border to International Falls on the Canadian border. June rainfall totals across large sections of the state ranked above the 95th percentile (one year in twenty) when compared with the historical record. Some of these totals triple the historical rainfall average for the month of June.

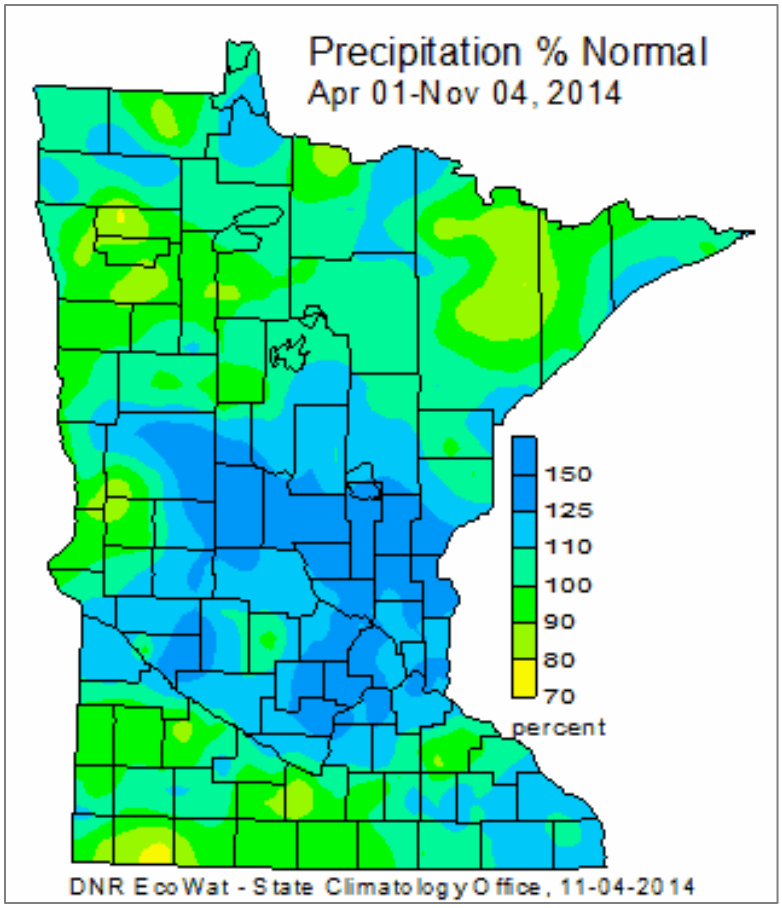
The impacts of the heavy June rainfall were apparent: flooded farm fields and delayed fieldwork, flooded basements, mudslides and flooded roads leading to transportation disruptions, and negative consequences for outdoor activities including construction and outdoor recreation. The spillway connected to a dam at Blue Mounds State Park washed out on June 15 and drained Lower Mound Lake.



Late Summer Drought

The summer of 2014 started with an extremely wet June. Then the last eight weeks were dry; in fact, from June 25 to August 26 most of central and southern Minnesota was from two to six inches short of normal.

As of August 28, the Drought Monitor showed that part of south central Minnesota and a small area of southeast Minnesota was categorized as "Abnormally Dry." So why was the drought slow to return to Minnesota? There are two main reasons. One is that this summer dry period came on the heels of the wettest June on record for the state, and secondly it hadn't been too warm. The preliminary statewide average temperature departure for July 2014 was the same as the Twin Cities at 2.3° below normal. August had a pattern of near normal temperatures, with a lack of extreme heat. Through August 28 in the Twin Cities, there were only two days of 90° F or more. By August 28, 2013 there were 15 days of 90° F or above. Putting this period in a historical context, the total rainfall historical rank showed that parts of southwest and south central Minnesota had one of the driest June 25 to August 26 periods on record.



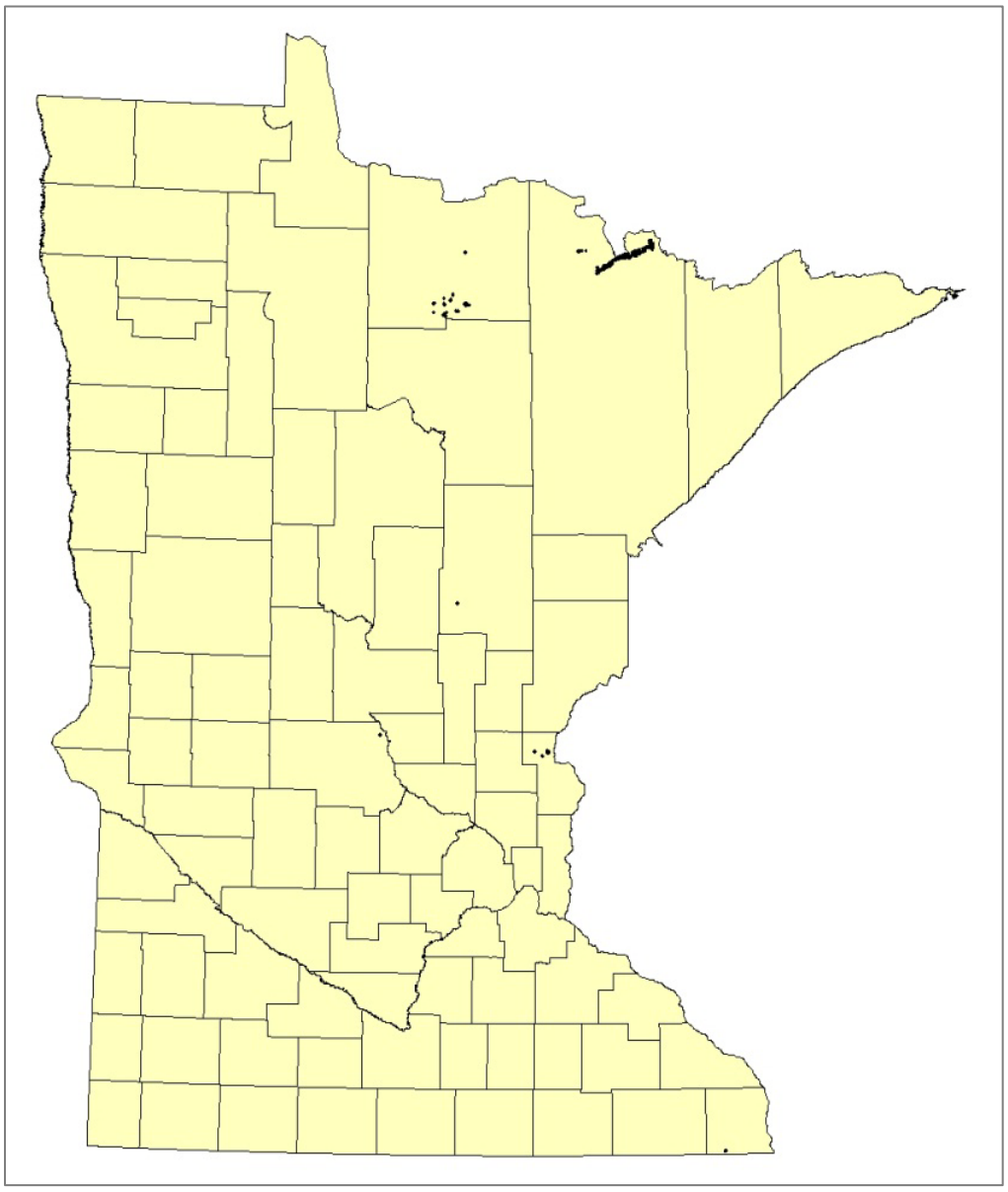
Percent of Normal Precipitation for the 2014 Growing Season

Despite a dry July-through-October period, seasonal precipitation totals since April 1 remained above historical averages nearly everywhere in Minnesota. For large portions of the state, season-to-date precipitation totals ranked above the 75th percentile when compared with the historical database for the April-through-October time period. Below-normal rainfall during the late summer and autumn slowed the record-setting pace established earlier in the growing season.

Wind damage

Hosts	All tree species
Setting	Rural and urban forests
Counties	Koochiching, St. Louis, Aitkin, Stearns, Chisago, Houston.
Survey methods	Aerial survey
Acres affected	4329 acres on 83 polygons
Damage type	Wind-throw, uprooting and stem breakage

Similar damage to standing timber compared to last year.



Forest Tent Caterpillar Egg Mass Survey, Winter 2013-2014

County	Section, township, range	Egg masses/tree
St. Louis	S33-T52N-R13W	0
St. Louis	S8-T52N-R12W	0
St. Louis	S34-T51N-R13W	0
St. Louis	S12-T50N-R14W	0
St. Louis	S16-T48N-R15W	0
St. Louis	S19-T57N-R20W	0
St. Louis	S8-T57N-R20W	0
St. Louis	S16-T61N-R16W	10
St. Louis	S25-T58N-R20W	0
St. Louis	S33-T60N-R16W	0
Lake	S4-T52N-R11W	0
Carlton	S7-T48N-R16W	0
Carlton	S13-T48N-R16W	0
Carlton	S30-T49N-R16W	0
Itasca	S5-T54N-R25W	0
Itasca	S33-T55N-R25W	1.5
Itasca	S29-T55N-R25W	0
Itasca	S29-T55N-R25W	0
Itasca	S29-T55N-R25	0
Itasca	S19-T55N-R25W	0
Itasca	S21-T55-R26W	0
Itasca	S27-T55N-R26W	0
Itasca	S24-R56N-R24W	0
Itasca	S7-T56N-R22W	0
Itasca	S25-T57N-R20W	0
Aitkin	S12-T43N-R24W	0
Aitkin	S3-T47N-R26W	0
Mille Lacs	S27-43N-R25W	1
Mille Lacs	S2-T42N-R25W	0
Mille Lacs	S6-T43N-R27	0

St Louis Co.	10 Average DBH=1.8	Heavy
Itasca Co.	1.5 Average DBH=2.1	Light
Mille Lacs	1 Average DBH =2.1	Light

In 2013, FTC defoliated 1,073,000 acres. For unknown reasons, these caterpillars did not result in moths laying many egg masses that year, and in the winter of 2013-2014 egg masses were found at only three out of 30 locations surveyed. In 2014, FTC defoliated only 155,700 acres. The parasitic flesh fly (*Sarcophaga aldrichi*), also called the friendly fly, was very abundant in both 2012 and 2013, and likely played a role in reducing the number of moths in July of 2013.

Forest tent caterpillar pupal parasitism survey, July 2013

County	Section, Township, Range	Percent parasitized FTC pupae
Itasca	S5-T54N-R25W	82
Cass	S36-T141N-R25W	60
Aitkin	S36-T49N-R26W	96
Aitkin	S34-T48N-R25W	80
Aitkin	S24-T50N-R24W	No cocoons
Aitkin	S5-T51N-R23W	Not enough cocoons for survey
Itasca	S36-T56N-R23W	88
Carlton	S3-T48N-R20W	72
St. Louis	S16-T61N-R16W	84

Jack pine budworm: Early larvae survey, June 10, 2014

Township	Number of larvae in male cone clusters	Number of larvae in vegetative shoots	Notes on cone crop	Predicted defoliation
Hubbard Co. Hendrickson	000000,0,000,000, none	000000,000000,000000, 000000,000000	Poor crop. Only 13 male cones in sample	None
White Oak	000000,000000,100000, 000000,000000	000000,000000,000000, 000000,000000	Abundant cones, but small size	None
Badoura (East)	0000,none,none,111100, 110000	000000,000000,100000, 000000,000000	Good cone crop, average size cones	Very Light
Badoura	000000,none,000000, 100000,000000	000000,000000,000000, 000000,000000	Poor crop, ave size cone clusters	None
Badoura (near entrance)	100000,110000,000000, 000000,none	000000,100000,000000, 100000,000000	Ave crop, ave size cone clusters	Very light
Cass Co. Ansel	111100,100000,100000, 110000,000000	100000, 00000,000000, 000000,000000	Ave to poor cone crop, ave size cone	Very light
Wadena Co. Huntersville	000,100000,none, 000000,none	000000,000000,000000, 000000,000000	Poor crop, small size cone clusters	None
Cnty 153 off Cnty 18	000000,none, none, 0000,00	000000,000000,000000, 000000,000000	Poor crop, small size cone clusters	None

Phenology 2014

Date	Event	County
Winter 2013-2014	Very cold winter; 18 weeks where temperature went below 0°F at least once; from last week in November 2013 through the last week of March 2014. The lowest official temperature for Grand Rapids was -32°F.	Itasca
4/14	Cold, wet spring. Small lakes are open near Staples. No snow cover. Pussy willows blooming. Aspen buds are green and expanding (1%).	Morrison
4/14	Small and large lakes still ice covered near Emily. In wooded areas about 25% snow cover remains. No evidence of aspen bud expansion.	Crow Wing
4/21	Leech Lake completely ice covered. Trembling aspen clones breaking floral buds (1%). Spring peepers singing in ponds. Mourning cloak butterflies observed.	Cass
5/ 5	Trembling aspen male catkins in full bloom; no green leaves showing. Pussy willows shedding pollen, birch and alder catkins are out.	Pine
5/23	Most aspen clones have green leaves; from small buds to 1"long leaves. Red maple flowers have fallen near Grand Rapids. Red elder shoots expanding, leaves 4"long. Blooming: marsh marigolds and blood root.	Itasca
5/23	Paper birch have catkins. Tamarack needles not fully extended. Big tooth aspen has not broken bud. Some Balm of Gilead with leaves >2" long. Blooming: large-flowered bellwort.	Cass and Beltrami
6/ 2	Jack pine shedding pollen. Big-tooth aspen have catkins. Blooming: anemone, chokecherry, winged polygala, blueberry; *Trillium* are fading.	Carlton and Pine
6/2	Forest tent caterpillars 1" long	Itasca
6/3	Jack pine shedding pollen, spruce budworm larvae ¼" long, larch casebearer visible. White pine blister rust aeciospores being produced.	Northern St. Louis
6/4	Wild strawberries and marsh marigolds in bloom.	Lake
6/ 7	Blooming: bastard toadflax, Canada mayflower, shooting stars, star flowers.	Itasca
6/ 9	Aspen leafroller active along Hwy 200 east of Remer.	Cass
6/10	Jack pine needle rust is fruiting east of Badoura Nursery; incidence is very, very low.	Hubbard
6/17	Cedar-apple rust fruiting	Winona
6/18	Oak wilt spore mats forming	Wabasha
6/16	FTC larvae 1 ½" long	Itasca
6/20	Spruce budworm larvae up to ¾" long, about 5% have pupated.	Southern St. Louis
6/25	Chicken of the Woods (Sulfur Shelf) fruiting	Morrison
6/25	Forest tent caterpillar larvae and pupae	Morrison
6/26	Linden looper causing general crown defoliation on red oak west of Baxter along Gull R. Some places widespread; others in pockets.	Cass
6/27	Spruce budworm 15% pupated	Southern St. Louis
6/30	FTC forming cocoons	Itasca
7/7	Spruce budworm moths mostly emerged. A few large aspen tortrix pupal cases.	Southern St. Louis
7/9	Twolined chestnut borer adults	Wabasha
7/20	FTC moth flight in Grand Rapids lasted from July 20 through July 24.	Itasca
8/15	Fall webworm larvae	Wabasha

Date	Event	County
8/19	Chicken of the Woods (sulfur shelf) fruiting	Pine
10/6	Armillaria's honey mushrooms	Houston

Noteworthy phenomena in 2014

Host	Symptoms	Impacted Area	Cause	Range	Notes
Ash	Sparse crowns	Central and southern MN	Heavy Seed Crop in 2013	Growing season	
Bur oak	Leaf blight; leaf drop	Severe symptoms in central MN	Bur oak blight	Summer to fall	
Bur oak; white oak	Twig abscission (cladoptosis)	Common in southern Minnesota	Likely cause: abiotic	Summer	Early twig shed occasionally happens in some oak species and remains unexplained.
Multiple species	Leaf distortion and tatters	Southeast and south-central Minnesota; northeast IA; southwest WI	Row crop herbicide drift	May to early June	Herbicide damage concerns and reports were not uncommon in 2014. At least one was confirmed by Minnesota Department of Agriculture to be associated with acetochlor residue.
Oaks	Wilt	Central and southern Minnesota	Oak wilt pathogen	Spring through fall	Oak wilt was more common in 2014 than usual. It was common on bur oaks and was the most commonly reported problem, by far, reported to the forest health regional specialist in St. Paul.
Oaks and river birches	Interveinal chlorosis	Metro area and southeast Minnesota	Likely cause: heavy spring rains promoting iron deficiency	Summer	

Forest Health Program Special Projects

Commissioner's Initiative: Adaptive Forest Management Plans

Region 1 Jack Pine Project
Harvey Tjader, Project Leader

1. Project objectives
    a. Test whether retention of a live seed source will improve natural regeneration of jack pine in FDc communities
    b. Retain a robust native plant community
    c. Learning how to coordinate with others on a project design and get it initiated

2. Project design and work completed - selected jack pine stands that were about 35-40 years old and whose Native Plant Communities were classified as FDc23 or FDc24
    a. Oshawa (Backus Area)
        i. Strip clearcuts in 9/2011
        ii. Regen plots in 6/2013 showed few if any jack pine
        iii. Species/area plot in 9/2013 showed a net increase in species richness (75-92 +23%) and 180 jack pine/ac; a very droughty period
        iv. Regen plots in 11/2014 showed 1000 jp/ac and 47% stocking; fewer jp as you move east, corresponding perhaps to fewer jp seed trees in the reserve strips
        v. *Diplodia* testing indicates 2014 latent infection levels at 38%. No shoot blight.
    b. Badoura (Park Rapids Area)
        i. Strip clearcut and small patches cut in 10/2011
        ii. Regen plots in 6/2013 showed no jp
        iii. Species/area plot in 9/2013 showed a net decrease in species richness (63-52 -17%) and ~30 jp/ac
        iv. Regen plots in 11/2014 showed 200 jp/ac and 40% stocked; fewer trees in wider portions of the harvest area
        v. Needs *Diplodia* test when regeneration is ready
    c. Nimrod (Park Rapids Area)
        i. Strip clearcut in 10/2011
        ii. Regen plots in 6/2013 showed no jp
        iii. Species/area plot in 9/2013 showed a significant increase in species richness (75-110 +47%) with 24 live jp/ac and 88 dead jp/ac
        iv. Regen plots in 11/2014 showed 71 jp/ac and 14% stocking; some areas within the site are very wet and some parts of the reserve strips have few jp seed trees
        v. Needs *Diplodia* test when regeneration is ready
    d. Menahga WMA (Park Rapids Area)
        i. Small patches cut in fall 2011

ii. Regen plots in 6/2013 showed few jp
iii. Species area plot in 9/2013 showed a net increase in species richness (65-79 +21%) and 180 jp/ac on the plot
iv. *Diplodia* test in 2014 indicates latent infection levels at 31%. No shoot blight.
v. regen survey to be done in spring 2015

e. Welsh Lake (Bemidji Area)
i. Strip clearcuts harvested in 10/2010, reserve strips were narrow, no jp left on the western edge
ii. Regen plots in 11/2011 showed 1363 jp/ac and 73% stocking
iii. Regen plots in 6/2013 showed 1000 jp/ac
iv. Species/area plot in 8/2013 showed a significant increase in species richness (89-105 +18%)
v. *Diplodia* test in 2013 indicates latent infection levels at 21%. No shoot blight.

f. Roy Lake (Bemidji Area)
i. Strip clearcuts harvested in 9/2012
ii. Species/area plot in 9/2013 showed a significant increase in species richness (77-101 +31), including 18 tallied weed species
iii. Needs *Diplodia* test when regeneration is ready
iv. Regen survey to be done in spring 2015

3. Science lessons learned so far
a. grasses (Kentucky bluegrass, Canada bluejoint) seem significant in suppressing early pine regeneration
b. fewer pine seedlings seem to correspond to fewer seed trees in reserve strips and to wider openings
c. seedbed treatment is probably a key factor for some sites (FDc24)
d. followup release treatment will be needed on some of the successful sites

4. Are project objectives being met?
a. we've learned that we need more interaction with the field foresters to get a project design implemented effectively
b. we're learning what to look for during a pretreatment visit in order to predict natural regeneration problems/successes

5. How scalable are the results?
a. They should be applicable throughout the FDc region, ranging from Bemidji to Brainerd.

6. How can lessons learned be transferred to day-to-day DNR operations?
a. It seems too early to consider this a success.
b. We anticipated the need for follow-up seedbed treatments, but didn't include any in the initial project because we wanted to see where they would eventually be needed and where they wouldn't.

7. What resources are needed to complete this project?
    a. time for seeding to occur and seedlings to develop
    b. Additional regen surveys (Roy Lake, Menahga)
    c. Develop new prescriptions for seedbed treatments and release
    d. Data management
    e. An ancillary study of the viability of seeds collected from older stands would help us determine effective jack pine rotation ages in FDc communities

8. Background information about jack pine in FDc communities
    a. Shorter lived than northern jack pine (needs shorter rotation)
    b. Higher percentage of non-serotinous cones, meaning less available seed at time of harvest (may need a persistent live seed source)
    c. Adapted to frequent ground fire, as opposed to northern jack pine adaptation to less frequent crown fire (continual seeding and recruitment on receptive seedbeds)
    d. Woodland characteristics are more common (maintain lower expectations for full stocking)
    e. More shrubs
    f. Patchy
    g. Long recruitment window (30+ years) after natural regeneration
    h. Closely tied to jack pine budworm and pine oak gall rust ecology (keep a substantial percentage of the landscape in younger age classes; don't mix seed sources with northern jack pine).

Conversion of historical aerial survey maps to ARCMAP shape file format

There is a wealth of historical DNR aerial survey maps, some going back as far as 1949. In order to capture and preserve this information, paper maps were digitized and EPIC files were converted to ARCMAP shape file formats. Ultimately, these files will be stored in the DNR's Quick Theme database and will be available to all employees and outside agencies and researchers.

Subsection Forest Resource Management Planning: Minnesota-Ontario Peatlands Section

Stand damage and mortality

Introduction

This is an assessment of forest insects and diseases known to cause tree mortality, growth loss, and quality reduction in forest stands in the Minnesota Ontario Peatlands Section. The presence of forest insect and disease agents as well as animal and abiotic agents has been documented in reports by the Minnesota Department of Natural Resources (MN DNR) Forest Health Team; University of Minnesota; USDA Forest Service State and Private Forestry; and North Central Forest Experiment Station.

Role of insects and pathogens

Native forest insects and disease organisms influence forest ecosystem dynamics as pests and agents of stress, but also play a beneficial role in the natural processes. Many native insects and diseases are an essential natural component of healthy forests and may contribute to compositional, structural, and functional diversity. By selectively affecting tree growth and mortality rates, they alter forest composition, structure, and succession. They thin and prune host populations, reducing density and competition. They can slow or stall the process of succession, or they can accelerate it. Through decay and biomass decomposition, they contribute significantly to carbon cycling, nutrient cycling, and energy flow in forest ecosystems. Insect and disease organisms serve as food for many invertebrates and vertebrates. Of vertebrates, birds consume the most tree-feeding insects, but many mammals consume insects to some degree as well. Insects and diseases create structural habitat for shelter and nesting. Many species of woodpeckers are attracted to trees with decay where they excavate cavities for nesting. Many animals use dead wood to roost, nest, or forage.

These same native forest insect and diseases are perceived as problems or pests when occurring at a level or on a site where they interfere with human goals, plans, and desires for trees and forests. Native insects and diseases can reduce timber productivity, lumber grade, site aesthetics, wildlife habitat, and water quality, and can increase the hazard of falling trees and branches and the occurrence of fire hazards, etc. Data from the 1990 Forest Inventory and Analysis for Minnesota indicate that 37 percent of the wood volume produced by all tree species annually is lost due to mortality. Insects and disease organisms account for more than 53 percent of this loss or more than 143 million cubic feet of wood (Miles et al., 1995). MN DNR Division of Forestry surveys of oak and birch mortality triggered by drought and attacks by boring insects and root rot organisms found in excess of 300,000 oaks and 200 million birch dying during the late 1980s and early 1990s (Albers, 1998). More than 40 percent of the birch type in Minnesota was affected.

What is perceived to be beneficial from one perspective may be viewed as detrimental from another. A very low level of decay would be required on a site being managed for high timber productivity; a higher level of decay may be acceptable on a site being managed under extended rotation, while any level may be acceptable on an old-growth site. Some level of decay will occur on every site regardless of the level of management. A forest tent caterpillar outbreak might be viewed as both beneficial and detrimental. The outbreak may benefit some birds that eat them but, be detrimental to others by leaving nests exposed to predators and bright sunlight, which can overheat, dehydrate,

and kill young birds in nests.

A forest tent caterpillar outbreak may increase the growth of shade-tolerant understory trees due to increased nutrients from insect droppings and dead caterpillars, and due to increased sunlight getting through the defoliated overstory canopy. The same outbreak is detrimental to the overstory aspen due to slower growth and increased mortality caused by the loss of leaves.

While native insect and disease organisms have co-evolved with native trees and forests, exotic insects and disease organisms have not. Exotics do not have a natural "role" in our native ecosystems and have and will continue to alter forest ecosystem diversity, function, and productivity. Exotics historically have caused intensive and severe disturbances over large areas. In extreme cases they have virtually eliminated their host species. The elm resource has been devastated by introduction of the Dutch elm disease fungus and its bark beetle vector. The white pine blister rust fungus, accidentally introduced near the start of the twentieth century, has played an important role in reducing the amount of white pine in Minnesota. Gypsy moth, while not yet established in Minnesota, is established in Wisconsin and Michigan and will become established here. While future impacts of gypsy moth in Minnesota are difficult to predict, especially in the northern aspen-birch forest, the insect has the potential to cause widespread mortality and will alter the composition and structure of the forest.

An ecosystem perspective requires that strategies to maintain the health of individual stands consider the beneficial, as well as the detrimental effects of insects and disease organisms. Forests must be considered as an ecosystem and manipulation to one part of that ecosystem affects the other parts. Pests have long influenced forest management, but forest management also affects pest populations. Vigorous trees tend to suffer less damage from these agents. Forest management aims to promote stand vigor and productivity by matching tree species to the planting site; manipulating rotation age, stand density, and species composition; avoiding wounding and root damage during thinning and harvesting; removing diseased and infested trees during harvesting operations, etc. Forest management does not attempt to eliminate native insect and diseases or their processes, but rather to control their activity and impact to a level that allows goals for timber production, water quality, aesthetics, recreation, wildlife, etc. to be realized.

In contrast, a much more aggressive approach is needed with exotic (non-native) organisms. It is important to avoid the introduction of exotics and attempt to contain and eradicate them when first found. Often it is not possible to eradicate or contain exotics once they are established. Attempts to slow their spread and management techniques to minimize their damage are then needed. Dutch elm disease and white pine blister rust are exotics that have become permanent components of the ecosystem. This will also happen with gypsy moth and Emerald ash borer after they become established in Minnesota.

Specific insects, diseases, and declines known to cause volume reductions or mortality

Covertype	*Agents that cause mortality*	*Agents that cause volume reductions*
All species	Armillaria root disease Storm damage	Stem decay and root rot fungi
Aspen	Aspen decline Hypoxylon canker Bronze poplar borer	White trunk rot Forest tent caterpillar Gypsy moth *
Ash	Ash decline Emerald ash borer *	
Birch	Bronze birch borer	Gypsy moth *
Oak	Two-lined chestnut borer	Gypsy moth *
Tamarack	Eastern larch beetle	Larch casebearer
Jack pine	Jack pine budworm	Red rot Diplodia shoot blight
Red pine	*Ips* bark beetles	Red rot Diplodia shoot blight
White pine	White pine blister rust *	Red rot
Black spruce	Eastern dwarf mistletoe	
White spruce	Spruce budworm	
White cedar		Red rot
Balsam fir	Spruce budworm	

*Exotic insect or disease

Implications for forest management for selected agents

Eastern dwarf mistletoe

Eastern dwarf mistletoe (DMT) is a native parasitic flowering plant that causes the most serious disease of black spruce throughout its range. Black spruce is primarily a lowland species and is often the only commercially important species that can grow on those sites. Therefore it is important to protect black spruce from dwarf mistletoe infection (Baker et a.l 2006). DMT can reduce the volume of infested stands so much that a harvest is not economically feasible. Anderson (1949) estimated that up to 11% of the black spruce type in the Big Falls Management Unit was out of production because of dwarf mistletoe. The area of mortality was up to 19% in his survey. A recent study Baker et al. (2012) reported that the FIA survey grossly underestimates the amount of DMT in Minnesota. FIA data lists 11% of plots as infested with DMT. In Baker's study they found that up to 55% of FIA plots actually were infested and that 20% of stand areas was infested and volume losses were at least 14% of the rotation volume. Baker's paper may be found here.

The acreage of black spruce infested with DMT in Minnesota is increasing over time, as pockets of infection continue to expand. The spread rate through a stand, as indicated by the enlargement of mortality centers, is 4.7 feet per year on average. Birds and other animals spread the sticky mistletoe

seeds to new sites creating new mortality centers. Dwarf mistletoe kills black spruce trees quickly often within 15 years of infection. Once DMT infests a stand, it remains infested as long as live black spruce trees (of any size) remain on the site. There are no effective insects or diseases of DMT that serve as natural control agents, so DMT is not eliminated from infested sites naturally. Therefore the amount of DMT in black spruce in Minnesota is increasing.

It is important to try to protect black spruce from DMT infection in order for stands to produce enough volume so that harvest is economically feasible. Elimination of DMT from infested sites can only be accomplished if all black spruce on the site are killed at the time of harvest. This is difficult if not impossible to accomplish. In most stands DMT infections remain on sites after harvest. Even prescribed burning of a site following harvest leave areas unburned where potentially infected live black spruce are left to continue the infection of the regenerating stand. The larger the trees and the more trees left on harvest sites the more likely DMT is being left of the site and the faster infection will spread to the regenerating black trees, the faster mortality centers will develop and the greater the reduction in volume of wood produced on the site.

The 5 foot cutting rule requiring loggers to cut or kill all black spruce trees 5 feet tall or taller was instituted as a means of reducing dwarf mistletoe and its spread within a stand knowing it would seldom eliminate DMT from the site and that follow up treatment would often be necessary to further reduce DMT infection on the site. Hand felling as well as shearing after the harvest has sometimes been used to reduce DMT infection in an attempt to ensure production of an adequate volume to allow commercial harvest. A survey of sites should be conducted one year or so after harvest, to determine if follow-up treatment is necessary. Leaving infected trees standing on or next to harvested sites will ensure that the regenerating stand is infected by mistletoe. If dwarf mistletoe is not aggressively controlled in black spruce stands when harvesting and regenerating the stands, the total merchantable acreage of this cover type will decline over time.

Eastern larch beetle

Currently, Minnesota and Canada are experiencing an outbreak of eastern larch beetle (ELB), a native insect that has been previously categorized as a “secondary pest,” i.e., a pest that is only successful on a weakened or stressed tree. Following outbreaks in the 1970s and 1980s in Canada and elsewhere in the US, eastern larch beetle has been acting as a “primary pest,” killing otherwise healthy trees. Mortality from the current Minnesota outbreak started to be mapped in 2000 and has accelerated at a steady pace since then. By 2013, most tamarack trees larger than 4 inches DBH have been killed on 180,000 acres. Mortality has occurred on lowland sites, upland sites, and in pure and mixed stands of tamarack. Multi-year flooding beginning in the early 1990s and a winter warming trend since 2005 have been suggested as possible tamarack health stressors that allowed an inroad for eastern larch beetle populations in the northwestern part of the state.

At this time, the pace of mortality is still increasing and a silvicultural solution to this insect outbreak is not apparent. Entomologists at the University of Minnesota are investigating the biology and population dynamics of eastern larch beetle in order to offer insights on the causes of the outbreak, why it is perpetuating itself, and possible silvicultural solutions. Faced with thousands of acres of dead and dying tamarack, poor markets and limited experience regenerating this species, the development of silvicultural systems to enhance and maintain this resource will remain a challenge for foresters well into

the future. Given the lack of research results, it is prudent to manage and salvage as much of the tamarack as possible.

Emerald ash borer

Guidelines for ash management on Minnesota Forestry Lands

• Landscape perspective: Manage ash populations in the landscape to protect sensitive wetland ecotypes, reduce outbreak costs, and restrict emerald ash borer introduction and spread without eliminating ash within forest ecosystems.
• Stand perspective: Create conditions that will reduce potential impacts and increase the resilience of forested stands by keeping forested sites forested, maintaining an ash component but reducing the size and number of ash in the stand and increasing tree species diversity.
• Management objectives should focus on ecosystem health and management, not on the emerald ash borer. The intent is to limit habitat attractiveness to EAB.

Gypsy moth

Defoliation of the aspen/birch and oak/basswood stands in the eastern portions of the Section is likely to occur in the next fifteen to twenty years. That gives us some time to manage the high quality stands during the next two planning periods to prevent defoliation or to prevent mortality. See Gypsy moth silvicultural for Minnesota and Gypsy Moth silvicultural Considerations for Minnesota TATUM GUIDE . There are two broad strategies to consider in forest stand management. When and where you apply these strategies depends on your land use objectives, stand composition, and site-specific conditions. The combination will determine which practices are feasible for individual stands.

Managing for stand diversity is the best means of limiting any insect defoliation. Encourage a mix of tree species, forest types, ages, and sizes. Managing for tree health and vitality is the best means of limiting tree mortality associated with defoliation (no matter how diverse your stand, some defoliation still may occur). Thin overly-dense stands to reduce competition. Where consistent with management objectives, harvest and regenerate oak and aspen stands growing beyond their normal rotation age. Remove suppressed trees likely to die anyway and create growing space for seed and crop trees. Maintain oak as an important component of the stand, but encourage other species where possible. See Minnesota DNR silvicultural tipsheet: minimizing gypsy moth damage.

Prolonged drought

Midwestern forests result from a variety of interacting factors, including, climate, soils, landform, post-glacial vegetation migration, fire and wind events, and human management. Climate is the biggest driver that dictates whether a forest can exist in a given area and what species occur, and both temperature and precipitation patterns have an important influence. Forests occur within a range of suitably warm and wet conditions, with conifer forests more common in drier and cooler environments and broadleaf forests more common in warmer and wetter environments.

Apart from long-term climate, precipitation patterns over shorter time scales can have a big influence on forest health and productivity. Droughts have been shown to affect forests in a variety of ways. Seasonal droughts can cause trees to prematurely shut down photosynthesis or even drop their leaves early during the growing season. Moisture stress can be particularly damaging for seedlings and young trees, though mature trees can still be affected by multi-year droughts. Droughts can also disrupt the reproduction of tree species with particular moisture and timing requirements for germination.

Drought can have a major impact on tree health and survival by effectively slowing and reducing growth. If drought is severe enough or lasts for a prolonged period of time, it also can cause death to all or portions of a tree. More common, however, is the effect drought has on a tree's ability to withstand insects and diseases.

Prolonged drought also provides an ideal environment for insect and pathogen populations to build up and then kill pockets of trees or most of the trees in a stand. Examples of these pests are Armillaria root disease, *Ips* bark beetles of pines, bronze birch borer, two-lined chestnut borer on oak, bronze poplar borer and eastern larch beetle. See the table in Section 3 to find the internet link for each of these pests.

How climate change affects specific forests will depend on a variety of factors, including site conditions, forest health, and management. We will not be able to fully anticipate all of the consequences of climate change, particularly the interactions among stressors like drought and forest pests. Forest managers can be proactive in adapting to climate change, however, even in the face of future uncertainty.

In this context, "adapting" means taking action to enhance the ability of forests to thrive in future conditions. There is no single best answer of how to adapt to climate change, because adaptation responses will vary by forest type, site conditions, landowner goals, and other factors. Often, the adaptation process will begin with an assessment of risk or vulnerability across a range of future climates. Foresters are beginning to test adaptation practices in the real world, such as: planting species anticipated to tolerate future conditions, thinning forests to reduce moisture stress and fire risk, and encouraging greater diversity. For more information, see the MI Extension Climate Change and Variability web page.

White spruce plantation decline

White spruce trees with more than 40% LCR are productive and healthy. When white spruce plantations with a high basal area reach age 30-40, they are losing vigor, growth is slowed, and trees have low percentage of live crown ratios (LCR). To compound this, they are increasingly susceptible to damage from pests like spruce budworm, Rhizosphaera needlecast, spruce weevils, and decay fungi. Thinning has been used to reverse this trend.

Thin young plantations to lower BA and increase live crown ratios. Thin healthy 35 to 45-year-old plantations down to 275-350 stems/acre to increase LCR and growth of residual trees. If plantations are more than 55 years and have never been thinned or if they are showing signs of pest problems, they are unlikely to do well after thinning. In this case, consider clearcutting. Old, unthinned or pest-infested stands will not benefit from thinning and may do worse if thinned. Pre-commercial thinning should aim at creating trees with more than 40% LCR. Commercial thinning should always retain trees with more than 40% LCR.

Pre-commercial thinning: In plantations where stem density is high (more than 800 stems/acre), remove number of stems by 50% to increase live crown ratios (LCR). Retain trees with more than 40% LCR. Trees with more than 40% (LCR) are still vigorous and healthy and those plantations may benefit from thinning by a careful operator.

Commercially thin healthy 35-45-year- old plantations down to 90-110 sq ft. or 50% of basal area. If plantations are >55 years and have never been thinned or if they are older and showing signs of pest problems, they are unlikely to do well after thinning. In this case, consider clearcutting.

Thinning in white spruce plantations is not a panacea for their problems. After thinning, it is still common to get tree mortality in spruce plantations. Also present are serious root injuries, debarking, cracking and breakage near the root collar, because roots grow right on the surface of the soil. These injuries are caused by heavy equipment operation. Thinning often leads to windthrow and root and butt decays. In fact, where there have been multiple entries, root damage builds up, productivity decreases and decayed stem volume increases.

Sales design: Select trees with more than 40% LCR for retention. Avoid thinning from above; white spruce with larger diameter have larger LCR, are more vigorous and are likely to fare better after thinning. Skid trails perpendicular to rows of trees are not constrained by row width and allow equipment to stay farther from the base of the tree and large, exposed roots. Leave three feet or more between equipment and trees on both sides of the skid trail to prevent root damage. Do not allow any work when soils are wet. Preferred option for operations are on frozen soils with snow cover.

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White spruce thinning study: 10 year results

A white spruce plantation thinning study was initiated in 1999 in cooperation with the USFS State and Private Forestry (S&PF) and the University of Minnesota (UMN) with the assistance of a federal focus fund grant. Mike Albers, MNDNR, and Steve Katovich, S&PF, initiated the study. Klaus Puettmann, UMN, agreed to be the principal investigator. Following Puettman's departure for a position at Oregon State, Steve Seybold, UMN, became the principal investigator until his departure to USDA Forest Service Pacific Southwest Research Station. Tony D'Amato, UMN, took over as principal investigator until his departure for the University of Vermont at which the role was taken over by Matt Russell, UMN.

The study was developed to look at thinning of white spruce plantations affected by spruce budworm defoliation to see how the thinning affected growth and survival of the trees. One goal was to see if thinning could be used as an alternative to insecticides to reduce the impact of spruce budworm. However, while this study was being established spruce budworm activity declined statewide, so that only two of the stands in the study experienced moderate or heavy levels of defoliation with the others experiencing no or light defoliation levels.

Data for this study were collected from 10 white spruce plantations established across northern Minnesota on lands owned and/or managed by MNDNR, the USDA Forest Service, and UPM-Blandin. All plantations were thinned between 1999 and 2002. A minimum of three plots were established in the thinned and unthinned portions of each site. Plot design followed USDA Forest Service Forest Health Monitoring protocols. Plots were measured throughout the course of this study by MNDNR Resource Assessment staff. Plots were measured annually for the first five years. A final re-measurement was made of all plots 10 growing seasons after thinning. Data on spruce budworm defoliation levels was collected on all plots each year at the end of the growing season by MNDNR Forest Health staff.

Plantations ranged in size from 3 to 83 acres. Plots in thinned and unthinned parts of each plantation were separated at least 50 feet by an unharvested buffer. Site index varied from 39 to 75. Thinning was done through a combination of row and low thinning and occurred at ages ranging from 25 to 46 years of age. On average 51% of the stand basal area was removed.

The primary finding of the study was that thinning of white spruce plantations should be conducted at a young enough age to maintain adequate live crown ratio of the remaining trees to allow them to respond quickly to the release. A crown ration of 40 percent was found to be necessary to get good growth response following thinning.

The five year results of this study can be found in the following paper: D'Amato, A.W., S.J. Trombly, M.R. Sanders, K.J. Puettmann, and M. Albers. 2011. Five-year response of *Picea glauca* plantations thinned following spruce budworm outbreaks in Minnesota. Northern Journal of Applied Forestry 28:72-78.

The ten year results of this study can be found in the following paper: Russell, M.B., A.W. D'Amato, M.A. Albers, C.W. Woodall, K.J. Puettmann, M.R. Saunders, and C.L. VanderSchaaf. 2015. Performance of the Forest Vegetation Simulator in Managed White Spruce Plantations Influenced by Eastern Spruce Budworm in Northern Minnesota. Forest Science (Month and page numbers not yet determined)

Jack Pine Budworm in Red Pines: Impact Study 2005-2006

Jana Albers, DNR Forest Health Specialist

Three defoliated stands in west-central Minnesota were selected to study the impact of budworm defoliation on red pines in 2005. This was the first year since 1958 that jack pine budworm caused extensive defoliation in red pine plantations that were not contiguous to jack pine stands or plantations.

Site name	**County**	**Location**	**Average DBH, inches**	**Sampling date**	**Sampling date**	**Percent infestation of buds on entire tree**	
			2006	**2005**	**2006**	**2005**	**2006**
Boyer	Cass	N 46 21.001 W 94 23.516	7.4	7/19/05	8/8/06	93	66
Badoura	Hubbard	N 46 51.785 W 94 48.497	13.2	5/2/06 (Pre-season)	8/1/06	5	68
Fosston	Beltrami	N 47 35.323 W 95 03.351	10.7	7/20/05	9/12/06	78	70

Since documentation of red pine damage by jack pine budworm is not standardized, we based our study on early methods used by Miller and Stewart to describe jack pine budworm defoliation. The following procedure was used in 2005 and 2006. At the Fosston site, a different set of trees was investigated in 2006 but they were growing adjacent to each other.

1. Ten trees were selected at each location. Each tree was inspected with binoculars to determine the percent infestation of buds. Diameter at breast height (DBH) was measured. Impact on the tree's leader was determined from the ground: terminal bud alive or dead, percent foliage remaining on the terminal leader, and occurrence of top-kill in feet.
2. From each tree, 4 branches were cut from the mid-crown (40 branches per site each year). Branches were 36 inches long.
3. In the lab, each branch was examined in order to document:
    - Impact on branch terminal: terminal bud alive or dead, terminal shoot length, amount of current foliage remaining on terminal
    - Impact on 3 of the lateral branches: lateral buds alive or dead, amount of current foliage remaining on lateral branches
    - Infestation of vegetative shoots and male cone clusters: counted all vegetative shoots and male cone clusters to determine infestation
    - Signs of infestation: inspected all foliage on 36 inches of the branch for fresh egg mass cases: Determined if the egg mass was parasitized; documented the age of needle upon which they were laid; documented the presence of pupae and frass on terminals and lateral branches.
4. Data was described and analyzed using STATISTIX 8.0.

Results of impacts of jack pine budworm on red pine study, 2005-2006

Location	Impact on tree leader			Impact on upper- and mid-crown branches *							Signs of JPBW *	
Year	% leaders w/ live buds	% foliage left on current shoot	Top-kill in feet	% terminal leaders w/live buds	Terminl shoot length in inches	% foliage left on current shoot	% live lateral buds	% foliage left on current laterals	% veg. shoots infested	% male cone clustrs infectd	% branches with frass or pupae	Egg masses (% egg masses prstzd)
Boyer												
2005	80	21	0	100	7.1	41	99	20	99	100	100	167 (34)
2006	70	56	1.10	98	7.4	81	98	75	93	96	80	23 (70)
Badoura												
2005	100	73	0	100	2.6	87	98	NA	NA	NA	NA	2 (0)
2006	100	89	0	100	3.5	76	100	76	77	97	65	1 (0)
Fosston												
2005	100	27	0	95	3.4	48	94	27	99	98	90	21 (10)
2006	100	92	0	100	3.7	95	99	93	52	80	5	1 (0)
All sites												
2005	93	40	0	98	4.3	59	97	24	99	99	72	190 (32)
2006	90	79	0.37	99	4.9	84	99	82	74	96	50	25 (64)

*Numbers represent average of 40 branches per site each year. Branch length was 36 inches and all foliage was inspected.

Other observations and analyses:

a. On all three sites, the amount of defoliation and egg mass cases declined between 2005 and 2006. Defoliation was mapped aerially in 2005, but was barely visible from the air in 2006; this was a short-lived outbreak. There was some evidence of defoliation in 2004 on one of the sites (Boyer).
b. What was the effect of two years of defoliation on the number of male cone clusters? There was a general decrease in the number of male cone clusters after the 2005 defoliation (cone cluster data not available from Chimney site in 2005). Using the Boyer data, no single factor or any combination of factors could predict the number of male cone clusters following the first year of defoliation.

Average number of male cone clusters:

Boyer site: 2.84 (2005) and 0.90 (2006)
Fosston site: 2.32 (2005) and 0.22 (2006)

c. Can the number of infested male cone clusters in 2006 be predicted by any 2005 variable? Using data from all sites and both years, the number of infested male cone clusters in 2006 could be classified into two statistically significant groups based on the number of infested vegetative shoots on the branch during 2005. When the number of infested shoots was less than 13 in 2005, then the number of infested shoots would be low (mean = 0.369) in 2006. When the number of infested shoots was greater than 13, the number of infested shoots was high (mean = 1.200).
d. Can the amount of topkill in 2006 be predicted? Yes, using the Boyer data, the only site where topkill was observed. Over a two-year period, if the upper crown branch leaders suffer more than 60 percent defoliation each year and there was 50 percent or more defoliation in the rest of the upper crown branches, then topkill averages 2.7 feet.
e. Can the amount of defoliation during 2005 predict another variable in 2006? The length of the terminal on upper crown branches in 2006 can be predicted by the amount of foliage remaining on their leaders and the percent of infested vegetative shoots in 2005. The terminals will be short in 2006 (mean = 5.0 inches) when the defoliation of the terminal exceeds 95 percent in 2005. The terminals will be long in 2006 (mean = 9.6 inches) when there were less than 9 infested vegetative shoots on the branch and defoliation was less than 95 percent in 2005.
f. Can the number of egg mass cases be predicted by some other variable during the same year? In 2005, when the amount of vegetative shoot infection was low (<13 percent), then few egg mass cases (mean = 1.4) are found. In 2006, when the amount of vegetative shoot infection was low (<21 percent), then very few egg mass cases were found (mean = 0.07).
g. Can the number of egg mass cases be predicted by a variable from the year before? In 2006, the number of egg mass cases was high (mean = 1.4) when the defoliation of the terminal branch foliage was > 95 percent in 2005.
h. Near Park Rapids, north of the Badoura site, the combination of budworm defoliation, severe drought and bark beetle attack caused limited mortality in a few stands.

Conclusion:

In many ways, jack pine budworm behaves on red pine the same way it does on jack pine growing in the northern floristic region. Near Park Rapids, north of the Badoura site, the combination of budworm defoliation, severe drought, and bark beetle attack caused limited mortality in a few stands.

Results of Impact of Jack Pine Budworm (JPBW) on Red Pine, 2005-2006

Impact on tree leader

- Leaders with live buds: 93 percent (2005), 90 percent (2006)
- Foliage remaining on current shoots: 40 percent (2005), 79 percent (2006)
- Topkill: 0 feet (2005), 0.37 feet (2006)

*Impact on upper and mid-crown branches**

- Terminals with live buds: 98 percent (2005), 99 percent (2006)
- Terminal shoot length: 4.3 inches (2005), 4.9 inches (2006)
- Foliage remaining on current shoot: 59 percent (2005), 84 percent (2006)
- Live lateral buds: 97 percent (2005), 99 percent (2006)
- Foliage remaining on current shoot of laterals: 24 percent (2005), 82 percent (2006)
- Vegetative shoots infested: 99 percent (2005), 74 percent (2006)
- Male cone clusters infected: 99 percent (2005), 96 percent (2006)

*Signs of jack pine budworm**

- Branches with frass or pupae: 72 percent (2005), 50 percent (2006)
- Number of egg masses found/percent of egg masses parasitized): 190/32 (2005), 25/64 (2006)

*Numbers represent average of 40 branches per site each year. Branch length was 36 inches and all foliage was inspected.

Abstracts: Posters and Publications

Detection of the *Diplodia* shoot blight and canker pathogens from red and jack pine seeds

Denise R. Smith, Glen R. Stanosz and Jana Albers
Canada Journal of Plant Pathology 2014
(Accepted 25 September 2014)

The shoot blight and canker pathogens *Diplodia pinea* and *D. scrobiculata* commonly and abundantly sporulate on seed cones of red pine (*Pinus resinosa*) and jack pine (*P. banksiana*) collected from Wisconsin and Minnesota forests. Cultural methods were used to investigate the incidence of these fungi in seed lots obtained from government nurseries in these states. In each of three replicate trials, seeds of each lot were assigned to four treatments before incubation on semi-selective medium: (1) not surface-disinfested; (2) surface-disinfested; (3) surface-disinfested, then inoculated with *D. pinea* conidia; or (4) not surface-disinfested, then inoculated with D. pinea conidia. For red pine seeds, the mean percentage positive was 2.7% for treatment 1 and 1.3% for treatment 2. Jack pine seeds were less frequently positive than red pine seeds for both treatments 1 and 2. The *Diplodia* species cultured was identified as *D. pinea* in almost every case. *Diplodia pinea* was much less frequently recovered from seeds that were not surface-disinfested and then inoculated (treatment 4), when compared with seeds that were inoculated with *D. pinea* after surface-disinfestation (treatment 3). Results confirm the potential for dissemination of *D. pinea* on red pine and jack pine seeds, and caution is warranted before concluding absence of the pathogen based on results using cultural methods with relatively small numbers of seeds. Although the frequency of pathogen-positive seeds was low, the large numbers of seeds planted in nurseries suggest that seeds may be a potentially important route of entry of D. pinea into nursery beds.

Abstract: Stand-level factors associated with resurging mortality from eastern larch beetle

Susan J. Crocker, Greg C. Liknes, Fraser R. McKee, Jana S. Albers, and Brian H. Aukema
For *Forest Ecology and Management*

The current infestation of eastern larch beetle, *Dendroctonus simplex* LeConte, in Minnesota, ongoing since 2000, has been characterized with a severity and duration unprecedented in previous outbreaks. In the absence of predisposing biotic stresses, such as defoliation, this study aims to investigate underlying mechanisms of increased tamarack mortality. Observations of tree attribute information and site condition collected from over 25,000 tamarack trees in three different ecological regions of Minnesota were modeled using linear mixed effects regression to describe the relationship between tamarack mortality due to eastern larch beetle and host characteristics. Relatively few tested variables were found to correspond to eastern larch beetle mortality; however, diameter, proportion of tamarack basal area and presence of water were consistently important. Diameter was positively related to tamarack mortality in the north, suggesting that mature tamarack likely under increased stress are attacked more frequently than younger, healthier trees. While drought conditions occurred over the course of the outbreak, the increased probability of eastern larch beetle mortality on sites containing water suggests that localized flooding may be increasing host stress, thus making trees more susceptible to attack.

Key words: *Dendroctonus simplex*, eastern larch, tamarack, *Larix laricina*, flooding, forest inventory

Unprecedented host use by an eruptive forest defoliator

Samuel J. Fahrner, Jana Albers, Michael Albers, Todd Lanigan, Robert Murphy, Kenneth F. Raffa, and Brian H. Aukema

To be submitted to *Agricultural and Forest Entomology*

1) The jack pine budworm *Choristoneura pinus pinus* is a defoliator distributed throughout the boreal forest in North America and is typically monophagous on jack pine *Pinus banksiana*. However, more than six thousand acres of defoliation of red pine *P. resinosa* was noted during an outbreak of *C. pinus pinus* from 2004-2008 in Minnesota and Wisconsin, USA.

2) Defoliation of red pine of that magnitude is a significant deviation from historical records.

3) Fifty-eight study plots were established across sixteen counties of Minnesota and Wisconsin to quantify densities and impacts of jack pine budworm defoliating both red pine and jack pine. Sampling methods for insect populations on red pine were adapted from classic studies of jack pine budworm feeding on jack pine.

4) Populations of jack pine budworm behaved similarly on red pine as on jack pine, infesting pollen cones and feeding on vegetative shoots. Pollen cones appear important in oviposition decisions by jack pine budworm on red pine. Up to 10× more egg masses were found on red pine than jack pine. It remains unknown what led to the widespread defoliation of red pine. Hypotheses regarding the mechanisms behind this alternative host use by jack pine budworm are discussed.

Eastern spruce budworm in managed white spruce plantations in northern Minnesota

Matthew B. Russell, Anthony W. D'Amato, Michael A. Albers

Silvicultural strategies such as thinning may minimize productivity losses from a variety of forest disturbances, including forest insects. In Minnesota, eastern spruce budworm (*Choristoneura fumiferana* Clemens) activity has been observed annually since 1954 and defoliation has impacted between 30,000 and 60,000 ha across the northeastern portion of the state in recent years. We analyzed the 10-year post-thinning response of stands and individual trees in thinned white spruce (*Picea glauca* [Moench] Voss) plantations in northern Minnesota, USA with light to moderate defoliation from SBW. Thinned stands continued to maintain target live crown ratios in excess of 0.40, suggesting long-term promotion of vigor and productivity. Using the Lake States variant of the Forest Vegetation Simulator, model results suggested over-prediction of stand basal area growth and tree diameter increment in these stands. Simulation results indicated that trees growing in unthinned stands and with greater defoliation levels would need the largest adjustment for diameter increment. Results highlight the need for forest management tools that represent appropriate responses to stands and trees impacted by forest insects and diseases. Ultimately, accurate representations of growth and development in these models that account for influences of biotic disturbance agents are essential under future global change scenarios, particularly as silvicultural strategies are sought that may reduce impacts of forest health threats and other stressors.

Eastern Spruce Budworm in Managed White Spruce Stands in Northern Minnesota: Ten-Year Productivity Results

Matthew Russell[1], Anthony D'Amato[1], Michael Albers[2]
[1]University of Minnesota, Department of Forest Resources
[2]Minnesota Department of Natural Resources, Division of Forestry

Spruce budworm in the Lake States

The eastern spruce budworm (*Choristoneura fumiferana* Clemens; SBW) is a native forest insect influencing spruce-fir forests across the northern US and Canada. Since SBW is a disturbance agent that has the ability to influence forest composition and structure, incorporating the risk that SBW may play in influencing growth and productivity is a particular concern. Incorporating these risks into forest management planning is essential to better understand spruce-fir forests. types.

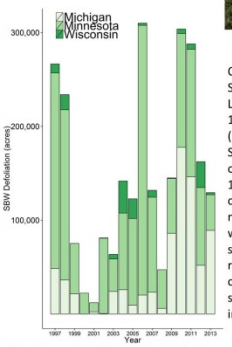


Figure 1. Recent SBW defoliation in the US Lake States (*Source*: FHTET Insect and Disease Detection Survey).

Over the past 17 years, SBW defoliation in the US Lake States has averaged 150,000 acres each year (Figure 1). In Minnesota, SBW activity has been observed annually since 1954 representing a continuous presence of nearly 60 years. Although white spruce and other species can tolerate repeated defoliations of current-year foliage, the subsequent growth of individual trees is reduced.

Minnesota DNR experiment data

Data for this study were collected from ten white spruce plantations established across northern Minnesota on lands owned and managed by MNDNR, the US Forest Service, and UPM-Blandin (Figure 2). Plantations were established in areas where SBW was active at study initiation. Each site contained (1) a thinned portion, where approximately 50% of basal area was removed, and (2) an unthinned control. Plantations ranged in age from 25 to 46 years at time of thinning. Permanent sample plots were established in each portion prior to thinning and have subsequently been remeasured through ten years.

Figure 2. Locations of the study plantations in northern Minnesota.

Key variables measured are:
- Tree DBH, height
- Crown attributes (crown ratio, foliage transparency, crown density
- Current-year SBW defoliation

Silviculture and forest ecosystem health

To minimize the effects of disturbances like SBW, silvicultural strategies may be implemented that seek to increase vigor, mitigate growth declines, and decrease mortality in stands vulnerable to SBW activity. One such strategy for reducing stand vulnerability and susceptibility to forest insects is thinning. This study was initiated to examine the growth and mortality of white spruce in thinned and unthinned plantations affected by SBW.

We hope to determine the role that thinning might play in minimizing the impact of SBW in lieu of more costly alternatives such as insecticides.

Crown ratio and vigor

Through ten years, thinning generally had a stronger influence on stand-level growth than did SBW defoliation. On average, nearly 25% of trees died over the 10-year period in unthinned portions compared to 8% in thinned portions. Tree crowns in thinned stands receded more slowly than crowns in unthinned stands. Crown attributes in thinned stands continued to display live crown ratios in excess of target values of 0.40 (D'Amato et al. 2011). Tree vigor continues to be sustained with high crown ratios and tree volume (Figure 3).

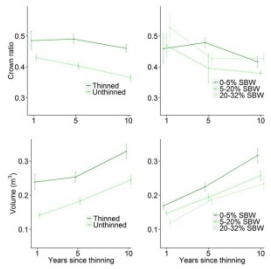


Figure 3. Trends in crown ratio and individual tree volume of white spruce.

Performance of FVS-Lake States

The performance of growth and yield simulators representing these stand conditions and SBW activities is largely unknown throughout the Lake States. We used the Forest Vegetation Simulator (FVS-LS) to compare observations with predicted values, and are beginning to develop SBW modifiers that consider growth and mortality losses from various defoliation scenarios. Such modifications appear to better capture ten-year basal area growth and diameter increment (Table 1).

Table 1. Comparing observed and 10-year predictions from FVS-LS.

Thinning	SBW Defoliation	n	Ten-year basal area growth (ΔBA; m²ha⁻¹)		Ten-year diameter increment (ΔDBH; cm)	
			Mean difference ± SE			
			FVS-LS	Modified FVS-LS	FVS-LS	Modified FVS-LS
Unthinned	0-5%	9	-4.41±1.25	-3.54±1.15	-1.44±0.21	-1.22±0.20
	5-20%	19	-4.57±1.01	-1.62±0.69	-2.03±0.26	-0.74±0.22
	20-32%	3	-8.59±1.37	-2.37±0.89	-1.42±0.12	-0.66±0.11
Thinned	0-5%	12	-1.07±0.86	-1.68±0.99	-0.89±0.40	-1.29±0.42
	5-20%	12	-0.79±0.71	-1.00±0.73	-2.66±0.73	-0.94±0.68
	20-32%	7	-2.01±0.51	-0.49±0.33	-0.67±0.43	-0.82±0.43
ALL PLOTS	-	62	-3.53±0.68	-1.70±0.37	-1.40±0.10	-0.87±0.09

The diameter increment equations for white spruce within FVS-LS tend to overpredict diameter increment in unthinned stands, and in all stands where greater SBW defoliation has occurred. Development of modifiers for the key submodels within FVS-LS are currently being sought to better depict growth in these low- to moderately-disturbed stands.

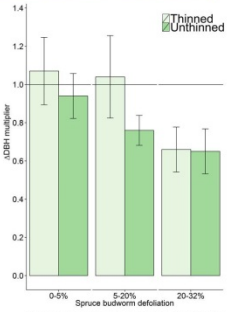


Figure 4. Growth modifiers for FVS-LS predictions based on ten-year observations.

Take-home messages

- Thinned stands continue to maintain target crown ratios for white spruce in excess of 0.40.
- Ten-year results shows that thinning continues to promote tree vigor and productivity.
- Improvements to the predictive capability of FVS-LS in stands impacted by SBW are being sought by using experiment data.
- Growth modifiers indicate that management and SBW defoliation may improve the growth and yield model performance.

References

D'Amato AW, Troumbly SJ, Saunders MR, Puettmann KJ, Albers MA . 2011. Growth and survival of *Picea glauca* following thinning of plantations affected by eastern spruce budworm. *Northern Journal of Applied Forestry* 28:72-78.

Minnesota Department of Natural Resources. 2012. Minnesota forest health annual report. Division of Forestry, Minnesota Department of Natural Resources, St. Paul, MN. 83 pp.

For more information on this project, contact russellm@umn.edu

Climatic signals associated with landscape-scale mortality of tamarack from eastern larch beetles

Brian H. Aukema, Greg Liknes, Jana Albers, Susan Crocker, and Fraser McKee

The eastern larch beetle, *Dendroctonus simplex* LeConte, colonizes eastern larch (tamarack) *Larix laricina*, trans-continentally across northern North America. Outbreaks, where vigorous trees may be killed, tend to be sporadic and short-lived. Since 2000, tree-killing behavior has been evident across much of the Lake States region, such as in Michigan, Ontario, Wisconsin, Manitoba, and Minnesota. Almost 200,000 acres of tamarack have now been killed by eastern larch beetle in Minnesota. These outbreaks are of longer duration than usual, and frequently lack any signs of biotic predisposing agent(s). These patterns suggest that climatic factors may be causing the sustained mortality.

A changing climate is exacerbating the outbreak of eastern larch beetle along the southern margin of its range. A late spring can enhance synchronicity of emergence and host procurement, and increased spring warmth can increase developmental rate of the first brood. Warmer summers may facilitate more insects via success of a second or third sister brood that over winter as adults.

Training Accomplishments

Northwest Region (DNR Region 1)	***Attendees***
Our FHU hosted the Annual North Central Forest Pest Workshop: Minnesota State Report	75
DNR/Chippewa National Forest Collaboration: Forest Health Workshop in Walker	95
CFANS: Dwarf mistletoe biology and management	105
Federal Program Review: University research projects using MN aerial survey data	20
Woodland Owners Conf: Forest Health Update, also broadcast as a webinar	50
Minnesota Forest Resource Council: Forest Health Update	10
ELPF orientation: Forest Health Basics	22
Webinar for MYMNWOODS: Forest Health Update	webinar
Women-to-Women Walk in the Woods: What is forest health?	11
MFI meeting: Forest Health Update	15
Green Valley Fire: Insects and management/ for legislators and agencies	20
Green Valley Fire: Insects and management/ for landowners	35
Informal sessions:	
Itasca State Park "Forestry Day": Insects and Diseases booth	25
NW Region RMT: Forest Health Update	15
Blackduck Area: Outdoor session on root diseases	3
Nimrod Field day: Green Valley fire/ insects	3
Blackduck Area: Indoor and outdoor sessions	12
Baudette Area: Field day	7
Big Falls Station: Field day	7
Wannaska Station: Field day	3
Kelliher Station: Field day	3
Bagley Station: Field day	5
Red Lake Band Ojibwe: Field day	10
Total	**551**

Northeast Region (DNR Region 2)	***Attendees***
Deer River Forestry Wildlife coordination meeting I&D update	25
Carlton County Master Gardeners Forest tent caterpillar	40
Hazard tree training, Region 2 State Parks	40
Region 2 Region and Area meeting Spruce budworm and Exotics	20
Two Harbors DNR Forestry Area meeting Spruce budworm and aspen decline	10
Littlefork Area meeting Dwarf mistletoe management	12
Bough meeting Forest History Center Gypsy moth and pine shoot beetle quarantines	25
Minnesota Forest Industry I&D update, GM, EAB, TCD, MPB, HRD	35
Silviculture statewide annual meeting I&D update	40
McGrath DNR Diplodia training	3
DNR/Chippewa National Forest-Forest Health Workshop, Walker	95
Total	345

Central Region (DNR Region 3)	*Attendees*
MNSTAC Forum: Bur Oak Problems	50
DNR Silviculture Program: Heterobasidion Root Disease	
Informal sessions:	30
Red Wing: Small woodland owner field session	10
Sandstone Area: Oak Wilt Control	7
Little Falls Area: Forest Health Update	8
Total	**105**

Forest Pest First Detector Workshops

Now in its seventh year, the Forest Pest First Detector program continues to train dozens of volunteers to respond to reports of exotic forest insects and diseases called in by the public to the Minnesota Department of Agriculture (MDA). Trained First Detectors are contacted by MDA to connect them to a caller located in their part of the state, and the First Detector responds to help diagnose the issue and report their findings to MDA.

Six workshops were held in locations around Minnesota, including the University of Minnesota Landscape Arboretum in Chaska, Coyote Moon Grille in St. Cloud, Maplewood Community Center in Maplewood, the Minnesota Family Woodlands conferences in Bemidji and Rochester, and the Cook Co. Higher Education facility in Grand Marais. Training topics in 2014 included emerald ash borer, gypsy moth, brown marmorated stink bug, thousand cankers disease of walnut, oak wilt, Oriental bittersweet, and pathways for invasive species. Continuing education credit is offered for the International Society of Arboriculture, the Society of American Foresters, and Minnesota Tree Inspectors.

The First Detector team consists of agency partners who organize registration, take turns giving presentations, and proctor the Tree Inspector Certification exam at the various workshop locations. Currently the team includes Mark Abrahamson, Monika Chandler, Kathy Kromroy, and Lucy Hunt (MDA); Brian Aukema (Department of Entomology, University of Minnesota); Val Cervenka and Ken Holman (DNR); and Mary Kay Ferguson, Angie Gupta, Jeff Hahn, Dean Herzfeld, Gary Johnson, Mike Reichenbach, and Gary Wyatt (University of Minnesota Extention). This year the team trained 114 individuals.

News Releases

New Disease Impacting Pines Confirmed in Minnesota

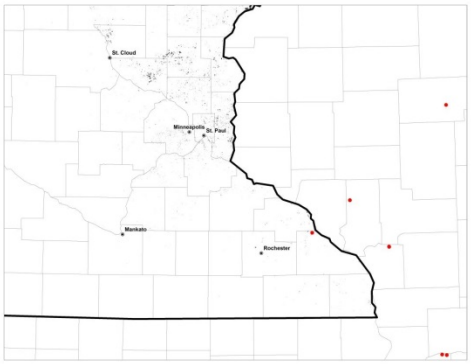
For the first time in Minnesota, *Heterobasidion* root disease (HRD) has been confirmed killing red pines. University of Minnesota workers found HRD, also known as Annosum or Annosus, on state land in Winona County, approximately 30 miles southwest of the nearest known HRD-positive site in Trempealeau County, Wisconsin.

The fungus *Heterobasidion irregulare* causes HRD of pines in the Upper Midwest. Heterobasidion root disease is found in eastern and western North America, but is not common in the central part of North America. The disease causes decline and death in expanding circular patterns in pine stands and can be a serious economic disease in certain situations (e.g. thinned pine plantations in flat sandy country). It can also kill balsam fir and eastern red cedar.

The disease starts when windblown spores of the fungus land on a freshly cut pine stump. The spores infect the stump and the infection spreads through root contact to nearby pines, where the disease slows growth and causes death. Disease can also be spread through movement of infected logs and possibly through logging debris and contaminated soil.

Fortunately there is a highly-effective, preventative fungicide called Cellu-Treat® available for use against HRD in Minnesota. It can be applied by backpack sprayer or through sawbars on harvesters. Once HRD infects a plantation, it will persist there for decades, so any plantation owner within close range of a confirmed HRD site should seriously consider protecting their investment through fungicide application to freshly cut stumps during thinning. Any person hired to apply Cellu-Treat® needs to be licensed and certified as a commercial pesticide applicator by the Minnesota Department of Agriculture. Learn how to obtain this certification by visiting Minnesota Dept. of Agriculture and searching the keywords “pesticide license,” or by calling 651-201-6615.

After confirmation of the disease, Department of Natural Resources (DNR) Forestry staff surveyed several additional plantations in southern Minnesota, with lab support from University of Minnesota personnel. So far, no other HRD sites have been located. The DNR’s forest health unit will continue to survey for Annosum in 2015, tracking infestations and assessing disease severity in Minnesota; more infection centers are expected to be found. Look for HRD information on the DNR’s forest health website later in 2015. In the meantime, consult the Wisconsin DNR website (dnr.wi.gov, keyword “annosum”) for general information about HRD. Any suspected HRD pockets should be reported to the local Minnesota DNR forester.



Terrestrial Invasive Species Program

Addressing Invasive Plants on State Forest Lands

Extra Funds for Field Projects

Three sources of funding support invasive species management on state forest lands: Outdoor Heritage funds from the Fish and Game fund, grants from the Division of Ecological and Water Resources (EWR) and grants from the U.S. Forest service. Management projects got an extra boost in 2014 with a one-time influx of general funds. As a result, forestry field staff took on a large number of field projects to address invasive species concerns. A total of 9 projects were funded with EWR dollars and 15 projects were funded with general fund dollars. The largest of these projects were the knapweed project discussed below, treatment of a large number of gravel pits to help minimize the spread of invasive plants in material used for road grating, and control of woody plants invading the blow down area of the St. Croix State Forest. Buckthorn, spotted knapweed, tansy and wild parsnip were among the targets of the smaller projects scattered around the state, as were gates to limit the spread of invasive plants associated with the activity of off-road vehicles.

Buckthorn Detection Project

To address the apparent leading edge of buckthorn invasion, MNDNR received a federal grant in 2012. As per statewide data in the MNDNR data deli, the southern portion of the state is thoroughly infested with buckthorn. North of a diagonal line running through Morrison, Todd and Otter Tail counties, the number and density of reported observations of buckthorn drop off sharply. While buckthorn has been reported in just about every Minnesota county, the incidence is quite low north of that line. So the purpose of the project was three-fold: 1) test aerial detection methods at a large scale, 2) detect likely buckthorn infestations ahead of the apparent leading edge of infestation and 3) provide managers the means to prioritize key infestations on state managed lands.

In the late fall of the first two years of the project, full-color aerial photography was taken on over 600K acres of state managed lands stretching from Sand Stone west to Detroit Lakes and north to Mahnomen. To detect buckthorn, photographs are taken after leaf drop for oak, but before leaf color change for buckthorn, so the residual green can be easily spotted from the air. Using stereo paired photographs interpreters were able to see three-dimensional stand structures, allowing them to pick out buckthorn in the understory 4’ or greater in size. They mapped 397 polygons as suspected buckthorn, 217 of which were on private lands within state land boundaries. The data was then digitized and distributed to state land managers. Five percent of the polygons mapped on state lands as suspected buckthorn were ground truthed in 2013. In 2014 another 43% of the polygons on state lands were ground truthed. Additional ground truthing will be conducted the summer of 2015 in an attempt to check the remaining state land sites. Treatments began on selected stands in the fall of 2013 and will continue as funding allows.

On the sites visited to date, very little buckthorn was found. Forty four of the 87 sites checked had no buckthorn present. Thirty one of the positive sites had small scattered buckthorn seedlings 2-6' tall. Mature plants were found scattered on 12 of the 43 positive sites. Nowhere was buckthorn present as the kind of thicket prevalent in southern Minnesota.

Almost all of the false positives were lowland hardwood swamps. Once that pattern was established, hydrological maps were used to set aside the remaining lowlands for future consideration. Ground inspections during the summer were prohibitively time consuming. However, because glossy buckthorn can thrive under these conditions, these sites can't be ignored. Future monitoring will rely on winter inspections.

Knapweed Biocontrol

The division of forestry had not been particularly involved in biological control of invasive plants in the past. Any biocontrol work implemented was due to the diligence of a few individuals. However, it can be a cost effective way to limit both the reproduction and spread of invasive plants. To kick off more active participation, two workshops were organized in 2014 for state land managers. The first was held at General Andrews and focused on how to establish a new biological control program for spotted knapweed. The second was held near Crookston and focused on how to monitor and maintain an established program. Included was how to survey for, collect and distribute root and flower weevils specific to spotted knapweed.

The tiny flower or seed-head weevils are common and disperse readily on their own. They feed on the seed and can thus greatly reduce viable seed production. While small they can be easily found because of their habit of perching on top of knapweed flowers.

The root weevils on the other hand are difficult to spot. They are large and lumbering. But they hang out on knapweed bracts where they are well camouflaged with their speckled coloring. They also tend to drop immediately to the ground if someone or something comes near the plant. Because they do not disperse well, it is best to purchase them from the collectors out west. Arriving in boxes of 100, releasing the lumbering beasts can be quite entertaining. 5000 root weevils were released on state forest lands and the sites recorded for future monitoring. A few of the sites at the General Andrews nursery will likely serve as good insectaries providing weevils for future release on other sites.

Occurrence Data Management

All information technology (IT) in now organized under a single department, Minnesota IT or MNIT for short. In a pilot project to explore data governance among state agencies, MNIT is currently involved in a scoping process to address how best to integrate invasive species occurrence data across divisions and genera, and ultimately across state agencies. Once complete the system will facilitate observation data collection, reporting, verification and management such that state employees, partners and clients have ready access to reliable observation data.

System requirements have been identified, so the next step is to determine which portions can be bought off the shelf and which can be built in-house. Project completion dates are in one to two years.

2015 Plans

2015 ushered in a number of changes within the MNDNR Division of Forestry that will help lay the foundation for a proactive approach to invasive plant management on state forest lands. For the first time, annual work targets were established for each forestry area for both invasive plant survey and control work. These targets formalize our commitment to managing invasive species in order to ensure forest sustainability and setting an example for other landowners. While we have a long way to go towards those goals, our best foot is now forward and on the move.

Invasive plant survey work will be integrated into all summer field work. Planned activities that will now include invasive plant survey work include ground-based regeneration checks, native plant community determinations, summer stand exams done in preparation for future harvesting and site visits related to contract administration. Invasive plant occurrences will be reported and added to the geo-referenced layers on the DNR data deli and our internal Quick Themes geographic data library. Along with the occurrence data, field staff will determine treatment needs and integrate those recommendations into our annual work and budget planning processes. That will provide a systematic approach to prioritize and tackle those projects likely to make the greatest impact.

Management Team

Representatives from each region and from each forestry area were identified to serve as an invasive species team. Region staff will provide coordination across areas and the area staff will provide coordination across forestry programs. Coordination at the area level will be critical to ensure all field staff are observing the appropriate prevention measures and reporting infestations as they are discovered. Both area and region staff will be involved in making sure invasive species are addressed as needed in all future contracts, leaves and permits.

One of the first team projects will be to outline a system of prioritization that allows area staff to effectively utilize limited resources to survey for and control infestations capable of impacting long-term forest sustainability. The second team project will be to review and update the division's invasive species prevention guidelines. It is through these guidelines that the division is working to create a "safety" culture among the all staff. The third team project will be to tackle the gravel pits managed by the division. Invasive species protocols are needed for both active and inactive gravel pits. While guidelines exist to help make sure material taken from active gravel pits is weed seed free, the guidelines do not effectively address the full range of sites on state forest lands. Treatment regimens have been too sporadic to prevent the build-up of a large seed bank in many of our gravel pits. Space to scrape off and store infested material isn't always available. Methods to protect clean material from reinfestation have not been fully explored. These and other concerns will keep the team busy for some time to come.

Disrupting Pathways of Spread for Terrestrial Invasive Species

Forest Service Grant Number: R29G3012152
Reporting Period: October 1, 2013 to September 30, 2014

1. Title: see above
2. Grantee:
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3. Project Contact:
   Susan Burks
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4. Project Overview *(include the focus of the project, timeline, methods, innovative approaches, and geographic scope)*:
   Prior to launching the **PlayCleanGo: Stop Invasive Species In Your Tracks** campaign, public outreach regarding the impact of terrestrial invasive species on natural resources and recreational areas was piece-meal at best. Without a large-scale coordinated effort, local organizations did what they could with local resources. The result was a confusing array of messages with limited reach and effectiveness. As a result, the public was largely unaware of their role in spreading terrestrial invasive species. Among Minnesota recreationists surveyed in 2009, only 34% could name a terrestrial invasive species, while most had heard of one or more aquatic invasive species.

   Stop Aquatic Hitchhikers!, originally sponsored by the US Fish and Wildlife Service, has been adopted by a large number of organizations across the continent. By utilizing common brand messaging, the campaign has successfully increased public awareness of aquatic invasive species and pathways of spread. 2006 surveys results in the Upper Midwest show that boaters and anglers exposed to the campaign's brand messages were much more likely to take future action at water accesses (97%). In one year, the number of Wisconsin and Iowa boaters taking preventative actions increased by 15%. By using a similar model, **PlayCleanGo** could potentially produce similar results, changing public behaviours at risk of spreading terrestrial invasive species, thereby protecting native forest and prairie resources.

   This project will formally launch and expand the **PlayCleanGo outreach campaign**, to enhance public awareness, build personal responsibility and disrupt the link between recreation and the spread of terrestrial invasive species. To measure "treatment success" and provide information

to guide future efforts, the project will also repeat the baseline survey of Minnesota recreationists conducted in 2009. The survey will be used to describe participant knowledge at the end of the project and measure the change in their behaviours relative to recreational pathways of spread for terrestrial invasive species.

5. Identify which Redesign National Theme or Themes this Project Addresses:
   NA Strategic Plan for FY 2008-2012 Goal 1: Promote Sustainable Forest Management; Objective 1.C: Maintain the health and vitality of forest ecosystems at risk from potentially damaging agents, Page 14).

6. Project budget: Estimated Project Expenses to Date (of $130K grant):

Categories	**Forest Service Share**	**Cooperators' Share**	**Total**
Personnel		Not calculated yet	$???
Supplies/Materials	$ 51,000.00	$ 116,000.00	$ 167,000.00
Contractual	$ 55,000.00	$ 30,000.00	$ 85,000.00
Total	$ 106,000.00	$ 146,000.00	$ 252,000.00

Project budget: **Estimated** Cooperators' Contributions:

Cooperator	**Cash**	**Materials (incl in cash)**	**In-kind Services**	**Total**
MNDNR Forestry	$ 72,000.00		Not calculated yet	$ 72,000.00
MNDNR EWR	$ 39,000.00			$ 39,000.00
MNDNR PAT	$ 35,000.00			$ 35,000.00
Total	$ 146,000.00		???	$ 146,000.00

7. List the partners that participated in implementing the project and how they contributed to its success:
   DNR Division of Forestry – administered soft launch of **PlayCleanGo** and USFS grant; project lead on outreach campaign.

   DNR Division of Ecological and Water Resources – contributed staff time to incorporate **PlayCleanGo** into DNR state fair exhibit, Served as co-lead on outreach campaign.

DNR Division of Parks and Recreation - contributed cash to produce PlayCleanGo materials, served on core team advising project leads

DNR Operations, OCO – contributed staff time to incorporate **PlayCleanGo** into DNR state fair exhibit

The following also served on the core team advising project leaders:

MN Tourism
MN Dept of Agriculture
MN Dept of Transportation
University of MN
Three Rivers Park District – contributed staff time and monies to promote **PlayCleango** messaging (contribution not yet included in estimated budget figures)

8. Describe the Agreed Upon Deliverables and Outcomes *(include quantifiable data where possible)*:

Year One:

- Develop marketing and communications plan
- Develop, design, layout and print outreach materials – **DONE**
- Develop web-based materials – **DONE**
- Develop a table top display and identify up-coming events where a booth would be appropriate - **DONE**
- Distribute posters and brochures through current partners – **DONE**
- Develop and distribute media as outlined in the marketing plan. - **DONE**

Year Two:

- Install trail and campground signage – **ON-GOING**
- Expand partners to include private campgrounds, resorts, retailers and sporting goods manufacturers – **ON-GOING**
- Participate in recreational events around the state – **ON-GOING**
- Distribute posters and brochures through events and expanded list of partners – **ON-GOING**

Year Three:

- Continue to expand list of participating partners – **ON-GOING**
- Continue to participate in recreational events around the state – **ON-GOING**
- Continue to distribute posters and brochures through events and partners – **ON-GOING**
- Implement phone survey using methods developed previously to measure "treatment success" **– NOT YET INITIATED,** to be conducted summer, 2015.

9. Describe Deliverables Successfully Accomplished to Date:
    - Hired a marketing firm to help us develop a marketing plan and to guide plan implementation.

- Developed a marketing plan, largely based on social media.
- Developed website and social media pages. See

- Distributed our partner packets to a wide range of audience groups.
- Set up a web-based contact management application (using Highrise) to facilitate marketing and follow-up.
- Developed a tri-fold table top display, tear-drop banner and three pull up banners for use at recreational events. Made three sets to loan to local organizations.
- Initiated weekly briefings with internal DNR partners.
- Met with core team members to provide an annual update of program accomplishments and to discuss ideas for 2014 and increasing partner participation.
- With ***Stop Aquatic Hitchhikers!*** co-hosted a large exhibit at the MN state fair on invasive species.
- Launched on-line ad campaigns on Facebook, Google and YouTube.
- Tripled the number of web-site visits. See attached summary of social media results.
- Tripled the number of participating organizations. There are currently 101 **PlayCleanGo** partners across the US and Canada. The North American Invasive Species Management Association (NAISMA) adopted **PlayCleanGo** as their national campaign.
- Developed and distributed a partner welcome kit to all participating organizations.
- Developed and posted order forms (for partners and non-partner organizations) through which other can purchase **PlayCleanGo** materials
- Set up the internal accounts and mechanisms to manage orders, payments, sales tax and donations.

10. Describe Deliverables in Progress or On-going:
    - Will host an all-partner meeting/webinar in January 2015 to discuss future directions.
    - The on-line ad campaign ran from 4/1/14 to 10/31/14. It will be resumed on 4/1/15.
    - In 2015, will apply for national trade and service mark registration.
    - Regular social media postings with information and announcements regarding terrestrial invasive species will continue.
    - Efforts to produce and install more trail signs will continue.
    - Will manage enquiries and requests generated by mailings and social web pages as needed.
    - Schedule and staff the year's compliment of trade and recreational shows.
    - Work with partners to identity unmet needs and explore opportunities to meet those needs through partner collaboration.
    - Repeat recreationists' survey to measure outreach success to date and help direct future outreach efforts.

11. What challenges/issues did the state face that they did not foresee and how did it impact progress:

Managing the on-line ad campaigns was challenging within the context of state fiscal year budgets. It required stopping one campaign at the end of the fiscal year and starting another the following day to separate bills and reporting.

Much like setting up the mechanism to handle on-line advertising through state purchasing procedures, setting up the mechanisms to handle the sales of PlayCleanGo materials was difficult. It took considerable time and energy to work through all of the laws, rules and internal policies.

Limited in-house staffing continues to limit the number of local workshops and large trade and recreation shows we can participate in. As **PlayCleanGo** expands it will be important to find a program coordinator to manage outreach efforts.

12. Does this project tie to larger strategic issues in your state, and if so, how:
The *2008 Minnesota Statewide Conservation and Preservation* Plan lists invasive species among the top six drivers of change negatively impacting our natural resources. The *2010 Minnesota State Forest Resource Assessment and Strategies* (the Minnesota action plan) lists maintaining forest health and productivity, and maintaining the strong tradition of recreation as two of the top ten issues currently facing the state. The document goes on to highlight challenges and opportunities to "identify, manage and reduce the threats to forest and ecosystem health", among them being the association between recreational activities and the spread of terrestrial invasive species.

As noted in the state action plan, "Minnesota has always had a strong tradition of nature-based outdoor recreation with participation in outdoor activities well above the national average, especially in hunting, fishing and boating. These activities and increasingly bird-watching, motorized and non-motorized activities all rely on access and interaction with abundant natural resources such as forest lands, lakes, rivers, blufflands, grasslands and parks and recreation facilities. The state is committed to preserving and enhancing outdoor recreational use for both present and future generations to enjoy." The state is also committed to preserving forest health and that means disrupting the association between recreation and the spread of terrestrial invasive species. Specific strategies listed in the Minnesota action plan to address these issues include: 1) Work with partners to identify opportunities for forest protection (page 33); and 2) Manage to reduce the spread of invasive species (page 50).

Addressing the Leading Edge of Buckthorn Invasion across Minnesota

Forest Service Grant Number: R29G3012185
Reporting Period: October 1, 2013 to September 30, 2014

1. Title: Addressing the Leading Edge of Buckthorn Invasion across Minnesota

2. Grantee:
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   Fax number: 651-296-5954
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4. Project Overview *(include the focus of the project, timeline, methods, innovative approaches, and geographic scope)*:

The invasive plant, common buckthorn (*Rhamnus carthartica)*, has been in Minnesota for over one-hundred and fifty years. During that time it has spread into many of the state's forests, pushing out native species, reducing forest regeneration by competing for space and nutrients, contributing to soil erosion and helping spread certain pests and pathogens. Detecting and mapping buckthorn in a timely and cost effective way is essential to the effort to slow its spread and mitigate its negative effects in high value forests.

Over the past four years, MN DNR forestry has developed and tested an aerial detection method that has been found effective for mapping the existence of buckthorn by taking advantage of the fact that buckthorn leaves remain bright green and attached to branches for one to two weeks after most over story species have dropped their leaves. Aerial photos at relatively small scales can then be acquired and interpreted for buckthorn. The interpreted detail is then transferred to an ortho-rectified photo which provides both a photo image and an accurate map of buckthorn location suitable for navigation in the forest to locate and remove the invasive buckthorn plants. Once confirmed, survey results can be incorporated into a set of shape files shared with partners through the MNDNR's data deli.

This project aims to utilize those methods to describe the leading edge of buckthorn invasive. With that data, we propose to identify infestations along the leading edge where treatment success is likely and slowing the spread of invasive is possible. A combination of state and private funds would be used to implement management practices.

5. Identify which Redesign National Theme or Themes this Project Addresses:
   NA Strategic Plan for FY 2008-2012 Goal 1: Promote Sustainable Forest Management; Objective 1.C: Maintain the health and vitality of forest ecosystems at risk from potentially damaging agents, p.14).

6. Project budget: Estimated Project Expenses to Date (of the $87K grant):

Categories	**Forest Service Share**	**Cooperators' Share**	**Total**
Personnel		$ 30,000.00	$ 30,000.00
Supplies/Materials		$ 10,000.00	$ 10,000.00
Contractual	$ 87,000.00	$ 25,000.00	$ 112,000.00
Other			
Indirect Costs			
Total	$ 87,000.00	$ 65,000.00	$ 152,000.00

Project budget: **Estimated** Cooperators' Contributions:

Cooperator	Cash	Materials	In-kind Services	Total
MNDNR Forestry			$ 20,000.00	
MNDNR FAW	$ 30,000.00		$ 5,000.00	
MNDNR EWR	$ 5,000.00		$ 5,000.00	
MNDNR RA				
Total	$ 35,000.00		$ 30,000.00	$ 65,000.00

7. List the partners that participated in implementing the project and how they contributed to its success:
   Division of Forestry – administered grant; contributed staff time to organize flights
   Division of Fish and Wildlife – contributed staff time to organize flights
   Forestry Resource Assessment – implemented 1st year flights & aerial photography

8. Describe the Agreed Upon Deliverables and Outcomes *(include quantifiable data where possible)*: Specific measureable results will include the following:

Year one:

- Fall and winter 2012 – At the end of October, acquire 1:22,000 scale, stereo aerial photography of eight state forests and one large wildlife management area (total of 257,500 acres) using a 25MB color camera and a 16 MB CIR camera. Photo acquisition will consist of parallel flight lines flown one-half mile apart - **DONE**. Interpret the data and generate digital layers and field maps - **DONE.**
- Spring and summer 2013 - Ground-check a subset of the polygons mapped to provide a formal accuracy assessment of the photo-interpretation and statistically valid input into multi-stage estimates of the buckthorn population densities. – **DONE.** Evaluate the results of ground surveys. Determine the need (if any) for additional aerial photography. – **DONE.** Identify isolated or newly expanding buckthorn infestations along the apparently leading edge of invasion. Line up the work to take place during the fall and winter treatment season. – **DONE.**

Year two:

- Fall and winter 2013 – If needed, acquire additional photography to complete the coverage. – **DONE.** Interpret any new data and generate digital layers and field maps. – **DONE**. Initiate buckthorn management practices in the top priority sites. – **DELAYED DUE TO OTHER WORK PRIORITIES.**
- Spring and summer 2014 – Complete any remaining ground-checks to complete the survey work. Inspect winter treatment sites and determine the need for spot treatments. Initiate spot treatments as needed. Line up the work to take place during the fall and winter treatment season.

Year three:

- Fall and winter 2014 – Complete assessment and description of the leading edge of buckthorn invasive. Continue pest management practices in high priority sites. – **IN-PROGRESS**
- Spring and summer 2015 – Inspect winter treatment sites and determine the need for spot treatments. Initiate spot treatments as needed. Identify areas still needing treatment and outline next steps to continue the work to slow the spread of buckthorn invasion. – **NOT YET BEGUN**.

9. Describe Deliverables Successfully Accomplished to Date:

- Identified program coord. for the DNR Div of Fish & Wildlife
- Identified stateland areas to be flown in years one and two.
- Took aerial photography over approximately 600,000 acres.
- All photo interpretation is complete.
- 40% of all suspected polygons ground truthed.
- Mgmt projects on FAW & SNA initiated.

10. Describe Deliverables in Progress:

- Final control projects are not yet complete.
- Follow-up monitoring not yet complete.

11. What challenges did the state face that they did not foresee and how did it impact progress:
Fall colors occurred two wks earlier than expected in year one. Weather was a little dicey during the flight window. But all flights were completed as intended. Flights in year two went relatively smoothly. Ground truthing found relatively few pockets of buckthorn. However, there were a number of false positives (mostly alder or understory conifers under hardwoods). So a larger percent of the suspected buckthorn pockets will be ground truthed this year to better flush out where buckthorn is occurring and how to fine tune our photo interpretation.

A shortage of pulp wood within the industry (extreme '13-14 winter conditions and a very wet spring in '14 limited normal winter harvests), redirected all available forestry staff time toward pre-winter timber sales of aspen pulpwood, usurping the fall buckthorn treatment season. Treatments will resume in 2015.

12. Does this project tie to larger strategic issues in your state, and if so, how:

The 2008 Minnesota Statewide Conservation and Preservation Plan listed invasive species among the top six drivers of change negatively impacting our natural resources. The 2010 Minnesota State Forest Resource Assessment and Strategies highlighted challenges and opportunities to "identify, manage and reduce the threats to forest and ecosystem health" Chapter four of that document lists among others, three strategies that can address invasive plants: *1) Work with partners to identify opportunities for forest protection (page 33); 2)Manage* to reduce the spread of invasive species (page 50); and 3) manage to control and reduce existing *invasive species populations (page 50*).