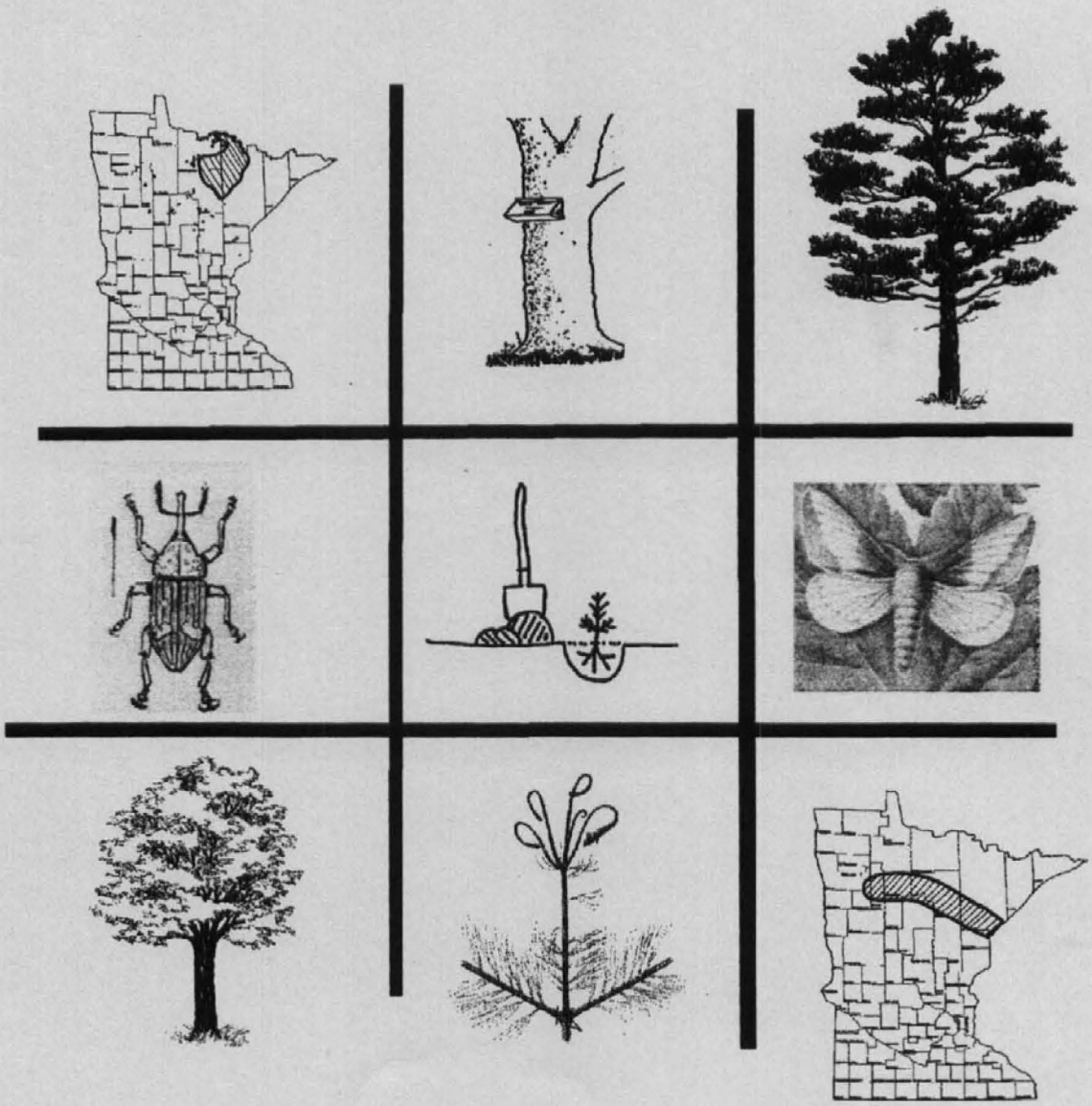
Minnesota Forest Health Annual Report

1998



Department of Natural Resources
Division of Forestry - Forest Health Unit

Preface

The Forest Health Report is an assessment of the overall health of Minnesota's forest trees and summarizes the insects, diseases and other pests which damage trees, primarily in the forest, but also in the urban environment. Our main purpose in publishing this Report is to record and interpret forest pest diagnosis, damage and trends. Secondarily, it is to inform readers about special project results and accomplishments in the Forest Health Program.

The forest types in this report are a combination of the fourteen forest types identified in the 1990 Forest Inventory. This report is organized into six cover types: aspen-birch, spruce-fir, maple-basswood, elm-ash-soft maple, oak and pine. Forest type definition, acreages, volumes and tree numbers are based on the publication, *Minnesota Forest Statistics, 1990* by Miles and Chen.

Because of the difficulty in aerially detecting visible symptoms, detection and monitoring of most forest diseases is accomplished via ground surveys. Diseases are reported only in general terms because of the sporadic and short duration of most foliar diseases and the relatively static nature of root, stem and branch diseases and the difficulty of assessing change. Since this report reflects the change in pest status from year to year, disease information is frequently omitted unless a significant change has occurred. It should not be construed that forest diseases are absent or unimportant within the state. In fact, diseases cause more direct mortality and likely cause more growth loss than do insects.

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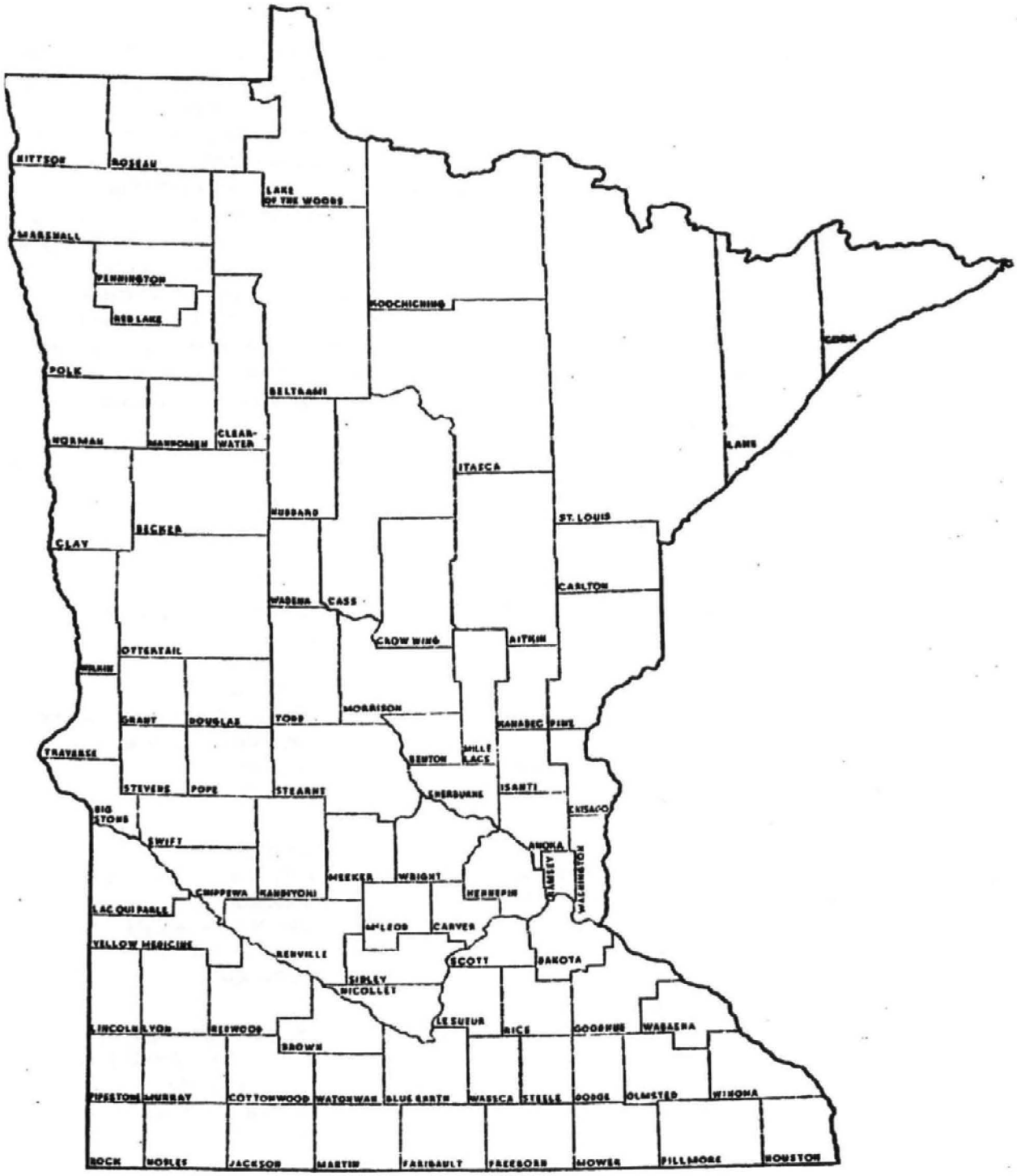
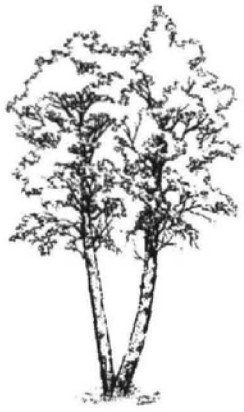
Minnesota Counties





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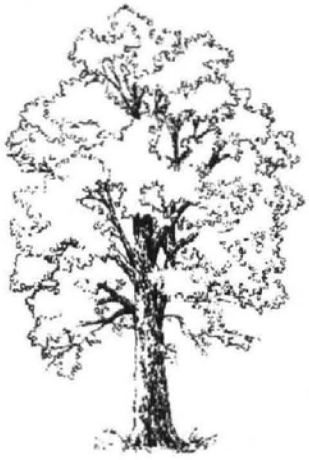


Forest Health Highlights

Since 1990, 64% of oak wilt sites controlled in state!

This was the first year that an oak wilt control program funded with state money was expanded beyond the Federal Cooperative Suppression Area. A major effort was made to identify oak wilt sites and market oak wilt control strategies in these new areas. Public information meetings, mailings, and direct contacts were made to inform local agencies and landowners about oak wilt on their lands, and to discuss and recommend control strategies. See Special Projects section of this report.

The Mn ReLeaf and LCMR monies were used to treat 473 sites in 19 counties in 1998. The total number of sites now followed in the state oak wilt control program is 8826 infection centers. Since oak wilt control work began in 1990, a total of 5637 sites have been treated. **This amounts to 64% of the known oak wilt in the 19 affected counties.** See Oak Forest section of this report.

Gypsy moth trap catch up by 265%

The 1998 Minnesota MDA/USDA cooperative gypsy moth trapping program was the largest to date, trapping covered 62 entire counties and six partial counties with total traps set exceeding 25,000. The program's expansion was based on dramatically increasing moth catches and moth movement in Wisconsin the last several years. See the Oak Forest section of this report.

Traps were distributed at one trap per square mile in the seven metro counties, six southeastern counties, and Chisago and Pine Counties. St. Cloud, Duluth along with portions of six metro border counties were also trapped at one trap/ sq. mile. The remaining counties surveyed received one trap/ four sq .miles in rural areas and one trap/ sq. mile in all towns, cities and incorporated areas.

New, this year, was a nursery trapping program involving 70 cooperating nursery stock dealers and landscapers. Nurseries were selected based on stock sources from federally quarantined areas.

As expected moth catches in Minnesota increased dramatically. The final tally of 953 moths represents a 265% increase over 1997's catches. Also, not unexpectedly, most of the action is taking place in the six southeastern counties closest to Wisconsin. Counties trapped outside the metro and southeast regions produced no significant catches.

Overall the southeast reveals a clear east to west pattern but very few site locations coalesce into patterns that would indicate a possible source of infestation. Winona county produced the most moths at 209, an increase of nearly 680 % over last year. Olmsted county produced an even greater increase of 1750%, jumping from 8 moths in 1997 to 143 this season. Over all the six SE counties account for 65% of this years total moth catch.

In the Metro, moth catches basically doubled over last year. Hennepin county produced the most moths in the metro yielding 129 moths.

The newly instituted nursery trapping also produced its share of moths, a total of 33. One site in St. Paul produced the season's highest trap catch of eight moths. Responding to this find, MDA staff located three fresh egg masses and other indications that GM has probably been active at this site for at least two seasons. Most discouraging is that this particular site was being used as a holding yard by four different landscaper/dealers and the City of St. Paul. This was the only commercial site where regulatory action is warranted.

A hallmark of this season's GM finds is a nearly total absence of any indication of specific infestation centers. Other than the previously mentioned catch of 8 moths, only 7 traps caught 4-5 moths. All others were 3 or less, the vast majority being single moths.

Until pending egg mass scouting or survey indicates otherwise, no spray programs are scheduled for the 1999 season. Gypsy moth activity is increasing significantly and can be expected to continue at an increasing pace in the coming years. Increased delimiting trapping in 1999 for the southeast and metro is a certainty. Other plans for 1999 regarding re-trapping out-state counties with few or no moth catches this season or expansion into counties not trapped have not been decided. Any decisions will be based on distribution of available resources and current risk for those counties.

Windstorms

Minnesota saw some exceptional weather activity in 1998. The spring and summer of 1998 were fraught with several major storm events that swept across the Minnesota landscape causing tremendous damage to property and the loss of thousands of trees. These storms included tornadoes, straight-line winds, heavy rains, and hail. The magnitude of the economic and ecological losses incurred from these storms is still being assessed but preliminary results of many surveys indicate that the total losses are staggering. Five major storm events occurred between March 29th, 1998 and July 20th, 1998. These storms impacted some 79 cities throughout the southern half of the State. At the end of July some reports put the total incurred losses (preliminary estimates of the damage) at $16,550,000. In late December 1998 the Insurance Federation of Minnesota reported that the total damage claims for the year resulting from these storms had reached at least $1.51 billion, exceeding the sum of all insurance losses recorded in the state from 1948 to 1997.

Spruce budworm in 45th year of outbreak

Statewide, 240,242 acres were defoliated by spruce budworm. Populations and defoliation levels remain very high in northeastern Itasca, northwestern St. Louis and eastern Koochiching Counties. White spruce as well as balsam fir continue to be damaged. Budworm populations and levels of defoliation throughout the rest of Region II were at lower levels than last year. Light defoliation continued in scattered white spruce plantations in Itasca County. In Regions 1 and 3, white spruce plantations continue to be targeted by the budworms. In Region I, heavy defoliation occurred in 1998, but egg mass counts were down for 1999. In Region III, both defoliation and egg mass counts were down compared to 1997. Some white spruce plantations are beginning to experience topkill and low-level mortality.

Aspen and hardwood insect defoliators on upward trend

Over 18,000 acres of hardwoods were defoliated in 1998 by a large array of forest insects including forest tent caterpillar, large aspen tortrix and the fall defoliators. This is up from last year's 2,064 acres defoliated by these insects.

Program Accomplishments

GENERAL DETECTION SURVEYS (Target: 11 million acres)

13.5 million acres surveyed.

Aerial survey results:

		ACRES AFFECTED		
CAUSAL AGENT	DAMAGE	TOTAL	<50% Host Affected	>50% Host Affected
INSECTS - CONIFERS				
Bark beetles	Discoloration	2,880	634	2,246
Spruce budworm	Defoliation	240,233	6,607	233,626
Larch Sawfly	Defoliation	96		96
INSECTS - HARDWOODS				
Forest tent caterpillar	Defoliation	15,207	3,990	11,217
Large aspen tortrix	Defoliation	3,078		3,078
DISEASES - HARDWOODS				
Aspen canker	Dieback	1,091		1,091
ABIOTICS				
Drought	Dieback/decline	673		673
Flooding	Discoloration	27,856		27,856
Flooding	Mortality	3,837		3,837
Hail	Defoliation	387	387	
Wildfire	Mortality	757		757
Windstorm	Mortality	30,060		30,060
Windstorm	Broken stem	8,895	8,895	
TOTALS		335,050	20,513	314,537

GYPSY MOTH MONITORING (Target: 500 pheromone traps)

700 pheromone traps

General Detection - Pheromone Traps		
	1998	1997
DNR: # Traps	700	700
DNR: moths caught	12	10
DNR: # of sites	7	4
DNR: # of counties*	4	4
Total # of traps	25,362	12,965
Total # moths caught	953	261
Total # sites	679	154
Total # of counties	26	25

* Counties where moths were trapped in DNR traps: Fillmore, Houston, Rice, and Winona.

Delimiting trapping. Delimiting trapping was carried out at 5 locations in northern Minnesota. Sites were located in Beltrami, Clay, Itasca, Polk, and St. Louis Counties. No moths were trapped at any of the sites.

EVALUATION (Target: 500,000 acres)

1,500,000 acres evaluated for the following:

SPRUCE BUDWORM

55 egg mass plots

32 larval plots

Results: 1998 was the 45th year of spruce budworm outbreak in northeastern Minnesota. Defoliation was high in northeastern Itasca, northwestern St. Louis, and eastern Koochiching Counties. Of most concern in these areas is the continued feeding damage in white spruce plantations. In central Minnesota, defoliation severity decreased in white spruce plantations.

JACK PINE BUDWORM

38 larval plots

32 egg mass plots

Results: One parasitized egg mass and 7 larvae were found. Populations continued to be very low and no defoliation was evident.

PINE TUSSOCK MOTH

35 pheromone traps

Results: Trap catches remain high in northeastern Wadena and southeastern Hubbard Counties. However, no defoliation is visible, and there were no larvae caught in drop cloth sampling or in tree felling of jack pine adjacent to pheromone trap sites with high catches last year.

FOREST TENT CATERPILLAR

5 defoliation plots

3 areas checked for egg mass

Results: There were large areas of oak, basswood and aspen defoliated near Mille Lacs Lake in Aitkin County, and in areas in Morrison, Mille Lacs, and Kenabec Counties. No defoliation was detected in northeastern Minnesota, but cocoons were found at one site in Lake County and at another site in St. Louis County. In southwestern Minnesota, about 2,400 acres of moderate to heavy defoliation was detected. Defoliation was primarily confined to basswood and bur oak. Three ground checks for egg masses were conducted in Gilchrist and Scandinavian Lakes areas in Pope County. Viable egg masses were found on basswood indicating continued populations during 1999.

FALL DEFOLIATOR COMPLEX

8 defoliation plots

Results: Scattered areas of defoliation were observed from Crow Wing County south to Benton County. In Ottertail County, defoliation was detected, but ground surveys were conducted too late to identify the cause of the defoliation.

FOREST HEALTH MONITORING (Target: 110 plots)

348 total plots - 105 forested

52 New plots installed and measured

53 plots remeasured

1998 data analysis in previous section of this report.

PREVENTION

FOREST MANAGEMENT GUIDELINES

Site level forest management guidelines for mitigating impacts to soil productivity, wildlife management, riparian area management, and cultural resources were reviewed

from a forest health perspective. These teams have been formed by the Minnesota Forest Resources Council and will affect all landowners and agencies in Minnesota.

WHITE PINE (Target: Prune 326 acres, Bud cap 738 acres, underplant 330 acres)

331 acres pruned (state lands)

671 acres bud capped (state lands)

51 acres tree shelters, wire cages, and deer exclosures (state lands)

275 acres underplanted (state lands)

OAK WILT (Target: Treat 500 sites)

485 sites treated

Discussion: This was the first year that an oak wilt control program funded with state money was expanded beyond the federal Cooperative Suppression Area. A major effort was made to identify oak wilt sites and market oak wilt control strategies in these new areas. Public information meetings, mailings, and direct contacts were made to inform landowners about oak wilt on their lands, and to discuss and recommend control strategies. Survey continues to find oak wilt pockets in the Sand Dunes Scientific and Natural Area in Sherburne County.

BARK BEETLES (Target: 1,500 traps)

1,224 traps

Discussion: Most of the traps (1,200) were placed in Itasca State Park in a continuing response to the blowdown of old growth pine 3 years ago. As the warm season progressed, traps without repeated multiple catches were removed. By year's end, it was decided that only 200 traps would be used in 1999 in areas adjacent to jack pine stands damaged by snowstorms in November, 1998. Beetle populations seemed to have returned to endemic levels. In northeastern Minnesota, there were 19 traps placed for *Ips pini*, and 5 for the red turpentine beetle.

VEGETATION MANAGEMENT (Target: 2,000 acres)

3,800 acres treated

NURSERY (Target: 50 acres)

60 acres treated for insect pests.

Discussion: 40 acres of seedbeds were fumigated with metam sodium in August. Twenty acres of seedlings were treated for insects including 1-0 pines and spruces to control cutworms and white pine transplants to control cottony aphid. A white spruce windbreak was also treated to control yellowheaded spruce sawfly.

NORTH AMERICAN MAPLE PROJECT (Target: Remeasure 8 clusters)

8 plot clusters remeasured
1 crew trained and certified to remeasure the clusters
Early season and late season defoliation checks completed.
Attended NAMP national meeting in Pennsylvania in February.
Results: Both dieback and foliage transparency decreased slightly. Decreases reflect a continued rebuilding of damaged crowns that occurred during a severe late spring freeze in 1995.

FOCUS FUND PROJECT - INTERACTIVE INTERNET DIAGNOSTIC TOOL (Target - Completion)

Project not completed

SPECIAL PROJECTS

OAK WILT ASSESSMENT (Assess 20 townships for oak wilt)

Interpretation of color infrared photography taken during September, 1997 was completed and transferred to topographic maps during the winter of 1998. Some 429 oak wilt infection centers were identified in central and southeastern Minnesota. Survey results are summarized in the following table:

County	Number of Infection Centers
Chisago	1
Filmore	17
Goodhue	59
Houston	12
Isanti	3
Mille Lacs	7
Olmsted	124
Stearns	11
Wabasha	151
Winona	44
TOTAL	429

TORNADO AFTERMATH - ASSESSING HAZARD TREES

In the spring, a tornado did extensive damage to several communities in southern Minnesota. A hazard tree assessment crew made up of personnel previously trained in hazard tree detection and assessment was organized. This crew assessed in excess of 3,000 trees in the communities of St. Peter and Le Center during a two-day period in early April. In St. Peter, 1,085 trees were marked as hazardous; all were to be removed except for 460 that were marked for corrective pruning. Of the 625 trees recommended for removal, severe crown damage was the major defect. Trees that had not failed due to weak unions or windthrow had their crowns ripped apart. The only trees that survived the storm averaged 6 to 8 inches in diameter. Larger trees were either destroyed by the storm or were marked for removal.

EPIC (Target: Complete development of Windows-based version)

Release of EPIC for Windows Version 1.2

INFORMATION REQUESTED/DISTRIBUTED

1,700 - Phone calls, office visits, samples diagnosed, and written materials distributed
300 - Field visits

TRAINING and PRESENTATIONS (Target: 10 events - 1,000 people)

Name of Event	# of events	# people
ROW Pesticide Applicators	1	200
Programs for school children	4	185
Shade Tree Short Course - Hazard Trees	2	175
Tri-State Forestry Meeting	1	175
Nursery Tours	14	158
WP Regeneration Workshops	2	110
Christmas Tree Shortcourse at U of MN	1	95
MN Logger Ed Program	1	90
Tree Inspector Recertification Workshops	2	85
Horticultural Groups, Master Gardeners, and Arbor Day Celebrations	4	80
Forest Ecosystem Health	2	78
Vermillion Community College lectures	2	66

Name of Event	# of events	# people
NE Urban Forestry Workshop	1	65
Urban Hazard Tree Training - Crookston	1	60
Woodland Advisors Training	2	60
Tree Farm Tour	1	60
Oak Wilt Info Meetings - S. MN	3	50
Fire Ecology (RX 340)	1	45
Pesticide Recertification for Foresters	1	42
Hazard Tree Training	2	41
Balsam Bough Harvesting Workshop	1	40
Teachers Workshop - School Forests	1	40
Northeastern Area Nursery Association	1	34
Itasca Community College	2	32
Aitkin County Fair (Basic I&D)	1	28
Timber Appraisal Workshop (Tree Defects)	1	26
Applying for Forest Health Grants Workshop	3	26
Spruce Budworm Info Meeting - Andover	1	25
Presentation to MN Logger Education Program in SE MN	1	20
Talk to Lake Association	1	18
FIA Crew Training	1	16
FHM Crew Training	1	12
MN ReLeaf Meeting	1	12
White Pine Management Open House	1	12
Area Field Days	1	8
EPIC Demo	2	7
State Park personnel training	1	4
TOTAL	69	2,280

WRITTEN MATERIALS

REPORTS (Target: Brookston and Cooperative Oak Wilt Suppression)

Brookston Project - report completed
Cooperative Oak Wilt Suppression Project - final report submitted
Forest Pest Conditions Report for the U.S. Forest Service
Forest Health Highlights for the U.S. Forest Service

PUBLICATIONS - (Target: 10 publications.)

New

6 Forest Health Newsletters
1 Annual report

Distributed

4,000 Bark Beetle Management and White Pine Care Guide publications to Stewardship Program participants

NEWS RELEASES

1 - article for *Better Forests* magazine
1 - briefing paper on forest health for the Governor's Office
1 - radio spot for MMN on forest tent caterpillar
1 - aspen bronzing article for the *Pioneer Press*
1 - fall color article for the *Star Tribune*
1 - bark beetle alert article for release to newspapers in northeastern MN
Gypsy Moth, Tree Care, and Storm Damage articles for northwestern MN newspapers

TOURS

Oak wilt legislative tour in central Minnesota

POSTERS and DISPLAYS

2 Oak Wilt Posters - Vegetation Management Assoc. of MN Conference and North Central Forest Pest Workshop

COMMITTEE, COORDINATION and MEETING ACTIVITIES

Minnesota Gypsy Moth Technical Advisory Committee
Tri-State Gypsy Moth Group
Minnesota Shade Tree Advisory Committee (MNSTAC)
Forest Health Sub-Committee (MNSTAC)
Asian Long-horned Beetle Interagency Working Group
MN Exotics Interagency Working Group
Oak Wilt Interagency Working Group
Minnesota Stewardship Committee
North American Maple Project

North Central Forest Health Cooperators Meeting
Annual Community Forestry Workshop (NE MN)
Northeastern Area Forest Nursery Association
Minnesota Society of American Foresters
Annual Gypsy Moth Review

OTHER ACTIVITIES

U.S. Forest Service reviewed Minnesota's Forest Health program.
Participated in the February 1998 U.S. Forest Service review of Kentucky's Tree Improvement and Nursery Program.

Forest Resources

Included in this report:

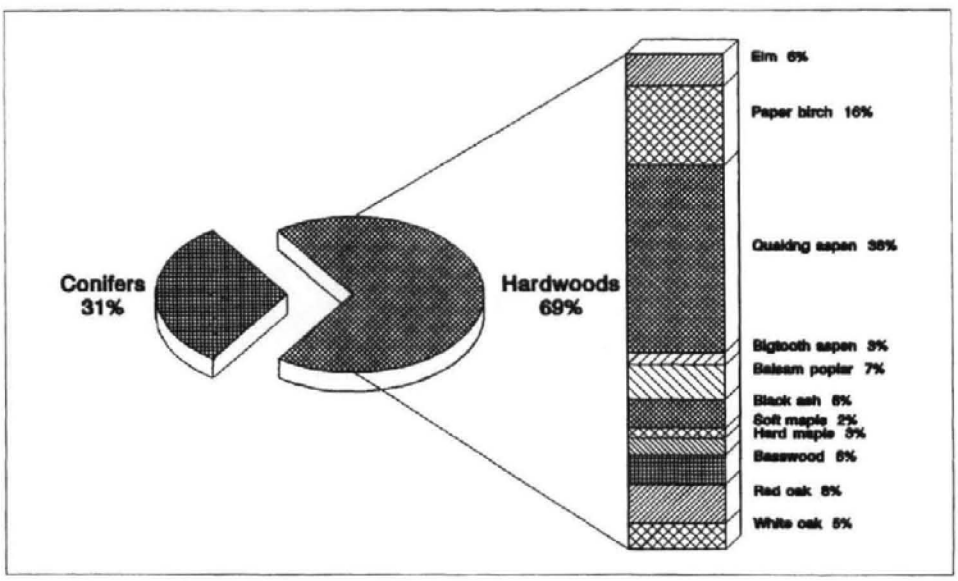
FIA-1990: The resource and mortality losses
1998 Forest Health Monitoring data

Forest Inventory Analysis - 1990: The resource and mortality losses

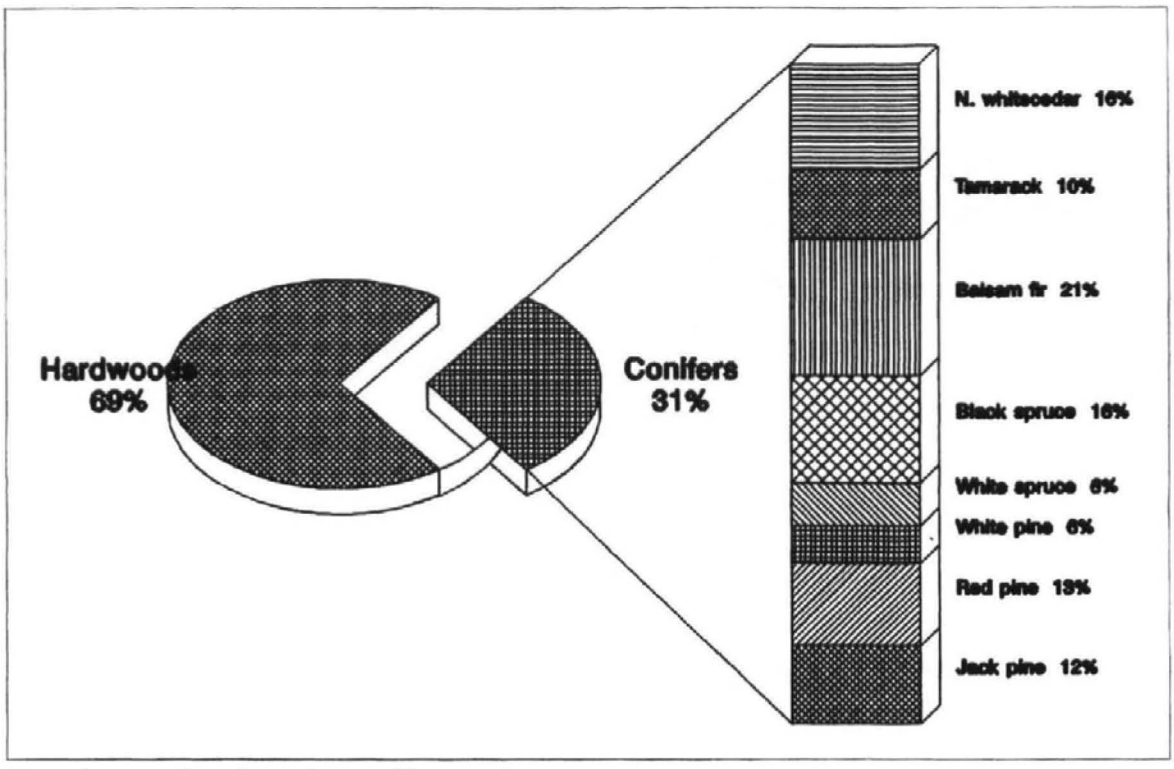
The latest Forest Inventory Analysis in Minnesota covered the period of 1977-1989. Acreages, volumes and other values found in this Report are based on data from the FIA and can be found in "Minnesota Forest Statistics, 1990" by Miles and Chen.

The total land area of Minnesota is 51 million acres, of which 33% is forested. This includes 1.1 million acres of reserved forest land where harvesting is prohibited by statute or administrative designation. In 1990, there were 14,773,400 acres of timberland.

Growing stock volume increased from 12.4 billion cubic feet in 1977 to 15.1 billion cubic feet in 1990, a gain of 22%. During the same period, saw timber volume increased from 24.3 billion board feet to 34.8 billion board feet, up 43%. Hardwoods comprised 69% of the growing stock volume, about 10.5 billion cubic feet and softwoods accounted for the other 31%. See charts below.



Growing stock volume by hardwood species



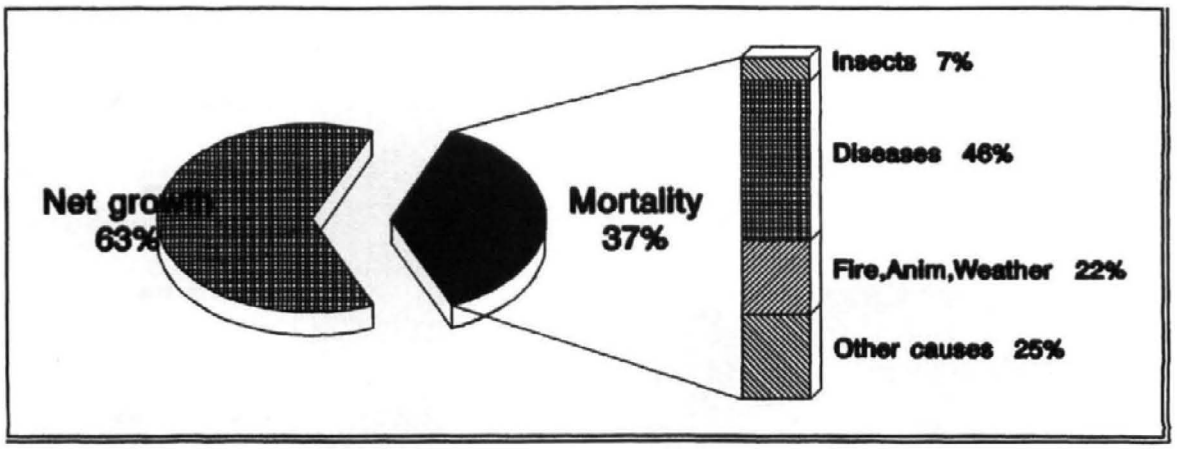
Growing stock volume by conifer species

Net annual growth of growing stock on timberland averaged 368 million cubic feet per year during the inventory period, or 2.4% of the 1990 inventory. Growing stock mortality on timberland averaged 219.2 million cubic feet per year, or about 14.8 cubic feet per acre per year, or an average of 1.5% of the 1990 inventory.

GROWTH AND NATURAL CAUSES OF MORTALITY

Insects, diseases, fire, animals, weather and several other agents are natural causes of damage and loss in trees. These are measured as mortality losses, cull due to decay, losses due to degrade and losses in growth. The latest statewide inventory, Forest Inventory Analysis (FIA), occurred in 1990 and measured losses due to mortality and cull. To date, only volumes and values regarding tree mortality have been published; information regarding decay losses will be available soon. For all species, the values and volumes are based on the acreage determined to be timberland and represent statewide survey results. In this edition of the Annual Report, the annual growth and mortality volumes and percents are based on the published FIA data. This information is based on sound wood volumes and values and does not include decayed wood, in living or dead trees.

Each year, 37% of the wood volume produced by all species died due to natural causes. See chart below. Insects and diseases accounted for 53% of the losses and this amounted to 117,190,800 cubic feet of wood. Losses from fire, animals and weather have been grouped together and caused 22% of the mortality. Other causes, amounted to 25%, is composed of unknown causes, suppression and logging/ mechanical damage.



Annual growth and mortality volumes for all growing stock species

The table below lists annual growth volumes and mortality volume losses by species.

Net annual growth and average annual mortality for tree species in Minnesota, 1987- 1989. (In thousand cubic feet)

Species	Net annual growth	Ave. annual mortality
Jack pine	11,012	10,308
Red pine	23,687	386
White pine	8,767	873
White spruce	12,800	2,048
Black spruce	11,515	14,076
Balsam fir	17,030	32,234
Tamarack	12,328	4,452
E. red cedar	649	30
N. white-cedar	14,700	1,828
Other conifers	213	NA
White oak	14,845	993
Red oak	17,864	6,990
Hickory	879	75
Basswood	17,576	3,091
Yellow birch	104	278
Hard maple	12,365	1,071

Net annual growth and average annual mortality for tree species in Minnesota, 1987- 1989. (In thousand cubic feet)		
Species	**Net annual growth**	**Ave. annual mortality**
Soft maple	14,995	2,219
Elm	-10,809	25,971
Black ash	18,585	3,787
Green & white ash	6,916	510
Cottonwood	1,205	332
Willow	506	351
Hackberry	406	92
Balsam poplar	9,292	14,937
Bigtooth aspen	8,359	2,600
Quaking aspen	114,996	67,100
Paper birch	23,388	20,984
Black cherry	408	132
Black walnut	465	20
Butternut	689	104
Other hardwoods	1,814	NA
Total	367,969	219,228

FIA Glossary

Mortality = The volume of sound wood in growing stock trees that die annually.

Growing stock volume = Net volume of growing stock trees greater than 5 inches dbh., from 1 foot above the ground to a 4 inch top diameter. This does not include decayed wood, rotten or dead trees.

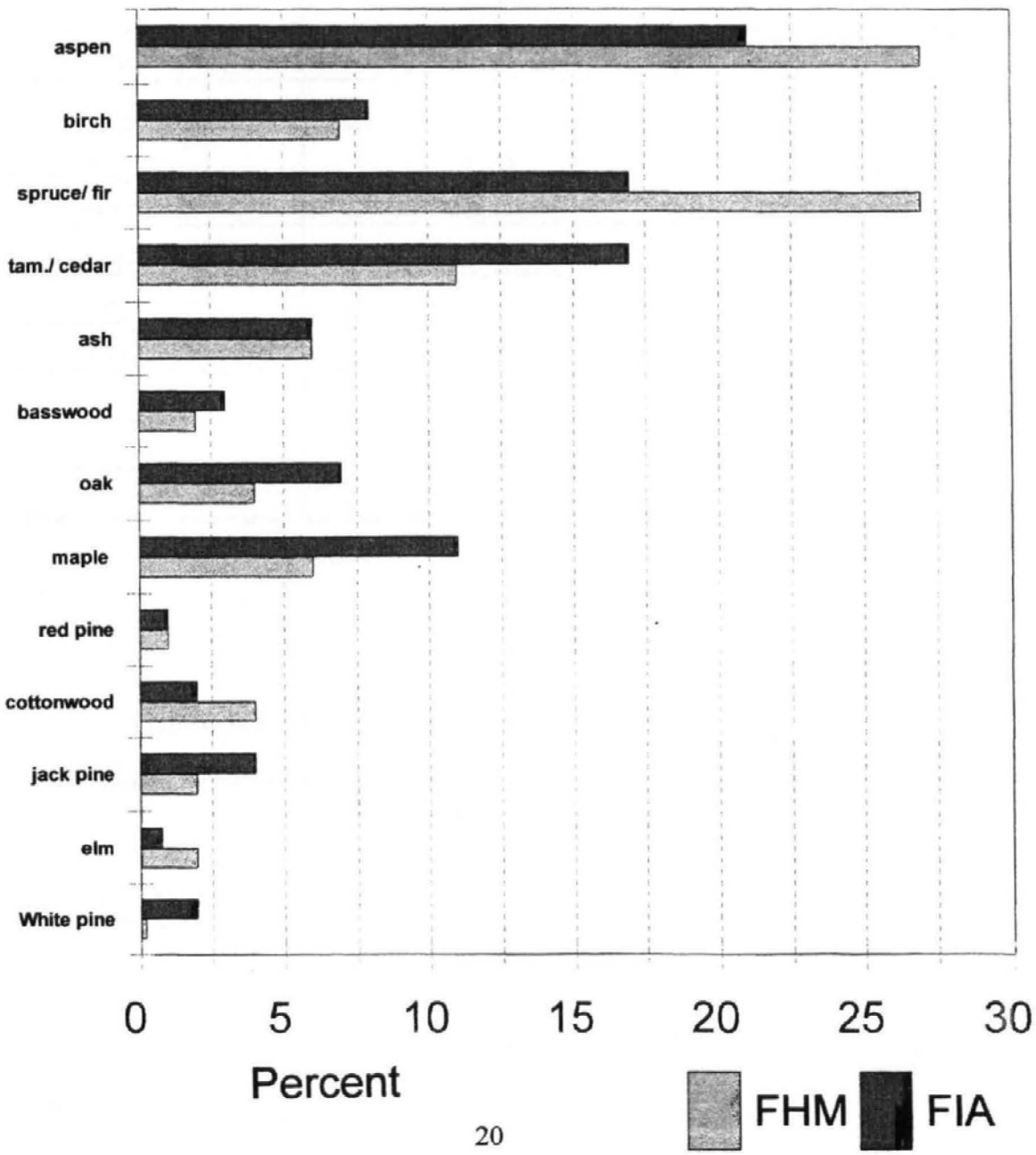
Net growth = The annual change in volume of sound wood in live trees and the total volume entering these classes through ingrowth, less volume losses resulting from natural causes.

Timberland = Forest land that produces 20 cubic feet per acre per year of wood and that is not withdrawn due to urban or rural development or in reserve (ie: national park, scientific and natural area, etc.).

Comparison of FHM and FIA databases

All of the following comparisons are derived from Minnesota Forest Statistics, 1990 by Miles and Chen and unpublished data from the same inventory. The FIA database is designed to statistically represent the cover types in Minnesota. The strength of the FHM database is in its sensitivity to forest health as measured by crown parameters. It is designed to represent the cover types across the northeastern USA. In terms of plot numbers, the FHM database is about 1/100th the size of the FIA database. It is beyond the scope of this report to do a plot by plot comparison, instead, the entire FIA database will be compared to the 1998 FHM database.

The species populations in the 1998 FHM database is very different than the species populations in the FIA database. See diagram. Compared to the FIA, the FHM database over-sampled the aspen, spruce/fir, cottonwood and elm cover types while slightly under sampling the tamarack/ cedar, oak, maple, jack pine and white pine cover types.



TREE DAMAGE MEASUREMENTS

Damage caused by pathogens, insects, weather extremes, or other agents can adversely affect tree health, either by killing trees or by reducing the growth or development. Information is collected on up to three types of damage per tree, limiting observations to certain types of damage which may potentially either kill the tree or adversely affect long-term survival. For each damage the location of where it occurs is also recorded, along with an assessment of the degree of severity.

A certain amount of damage in the population of trees is expected and even desirable. For example, openings in trees are used as shelters by wildlife, and decaying wood harbors insects which are a critical part of the ecosystem food chain. The purpose of collecting data on tree damages is to establish a baseline of expected damage levels, against which future trends may be measured, and to provide tree-specific data useful in determining potential causes of decline based on measurements of other variables.

Although it was possible to record three damage codes per tree, only 4.4% of the trees had two or three damaging agents recorded. In all analyses, only the first damaging agent was used. This will facilitate comparison of the FHM and FIA databases. The table below summarizes the first damage code recorded for each tree on all the FHM plots. 70% of the trees did not show any sign of measurable damage. The decay had the highest incidence, 12% and three other categories had 4% damage, crack, dead top and broken branches.

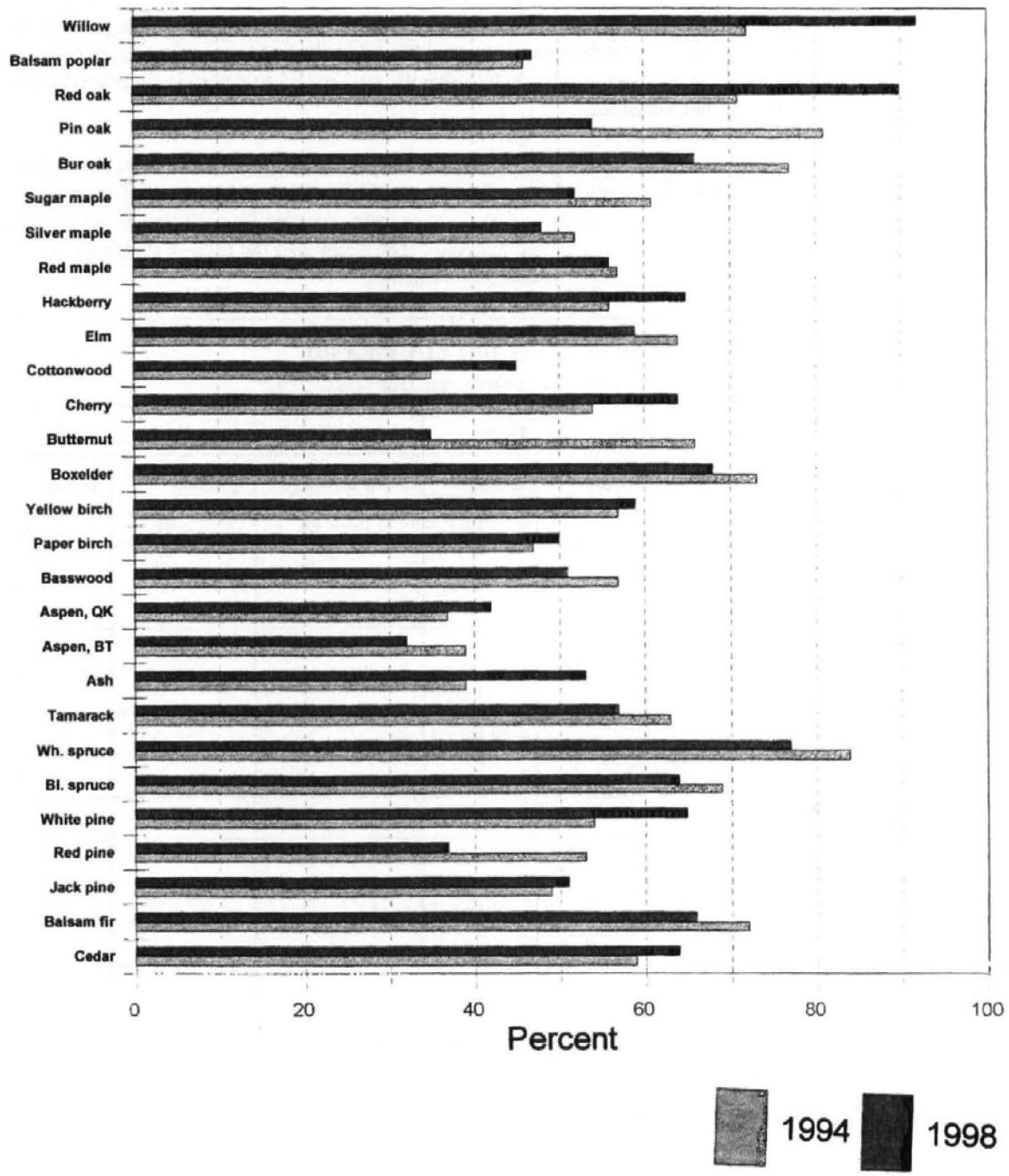
Comparison of FHM and FIA data for selected damage categories. In percentages.

Species	Forest Health Monitoring 1998			Forest Inventory Analysis 1990		
	No damage	Canker	Decay	No damage	Canker	Decay
Aspen	69	5	18	69	12	6
Birch	78	2	9	70	4	5
Spruce/ fir	85	1	1	77	1	1
Tamarack and cedar	63	1	19	71	1	9
Ash	71	2	10	79	2	2
Basswood	71	2	14	74	2	3
Oak	65	1	10	67	2	4
Maple	47	8	18	57	12	9
Red pine	96	0	0	83	1	1
Cottonwood	49	8	12	71	6	5
Jack pine	80	5	3	69	8	2
Elm	55	5	11	71	2	1
White pine	86	8	0	64	9	5

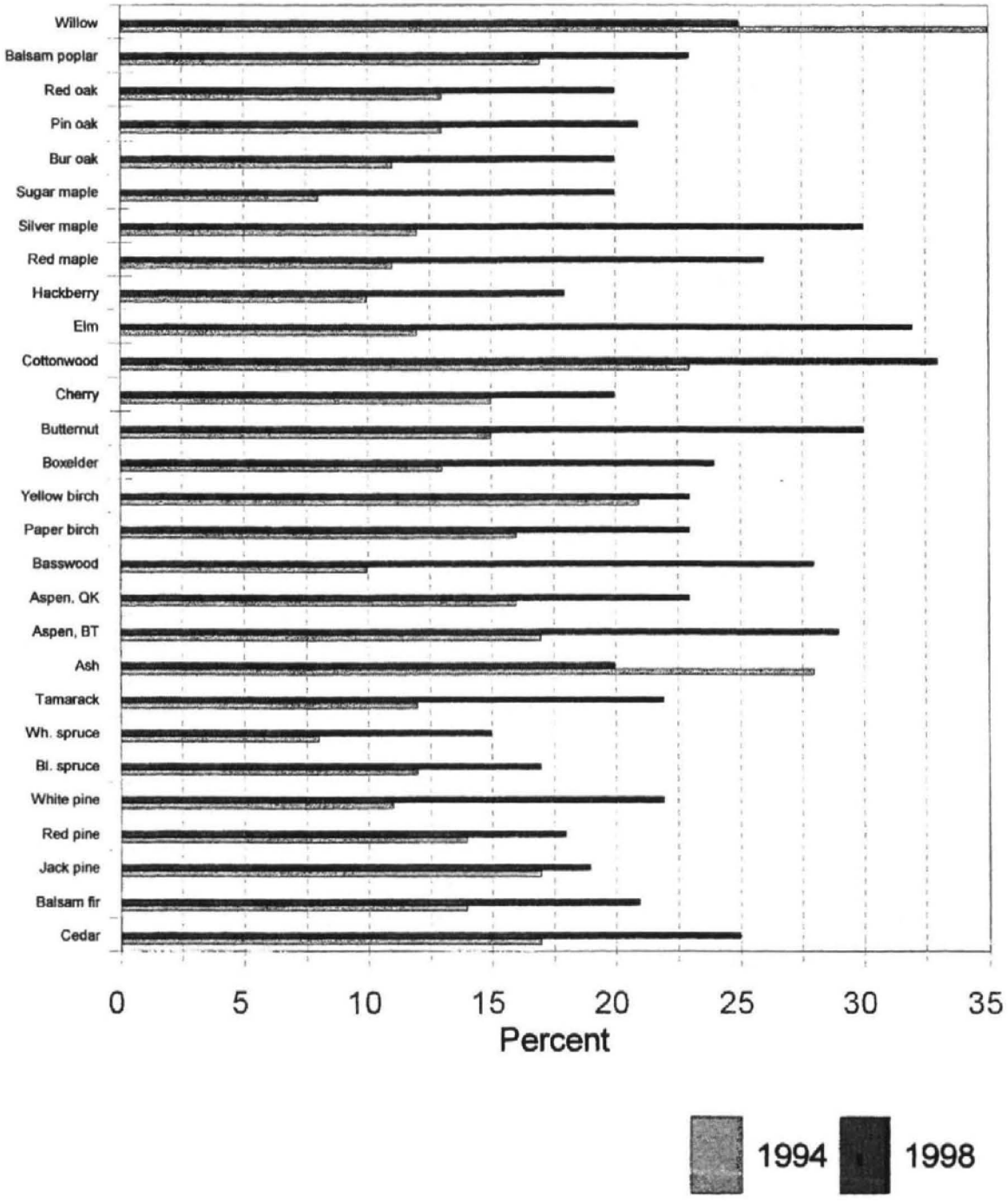
TREE CROWN MEASUREMENTS

Four different measurements, live crown ration, foliage transparency, crown dieback and crown density, were collected for trees greater than five inches in diameter on the 1994 FHM and 1998 FHM plots. The following discussions are comparisons between the two sampling dates and two tree sample populations.

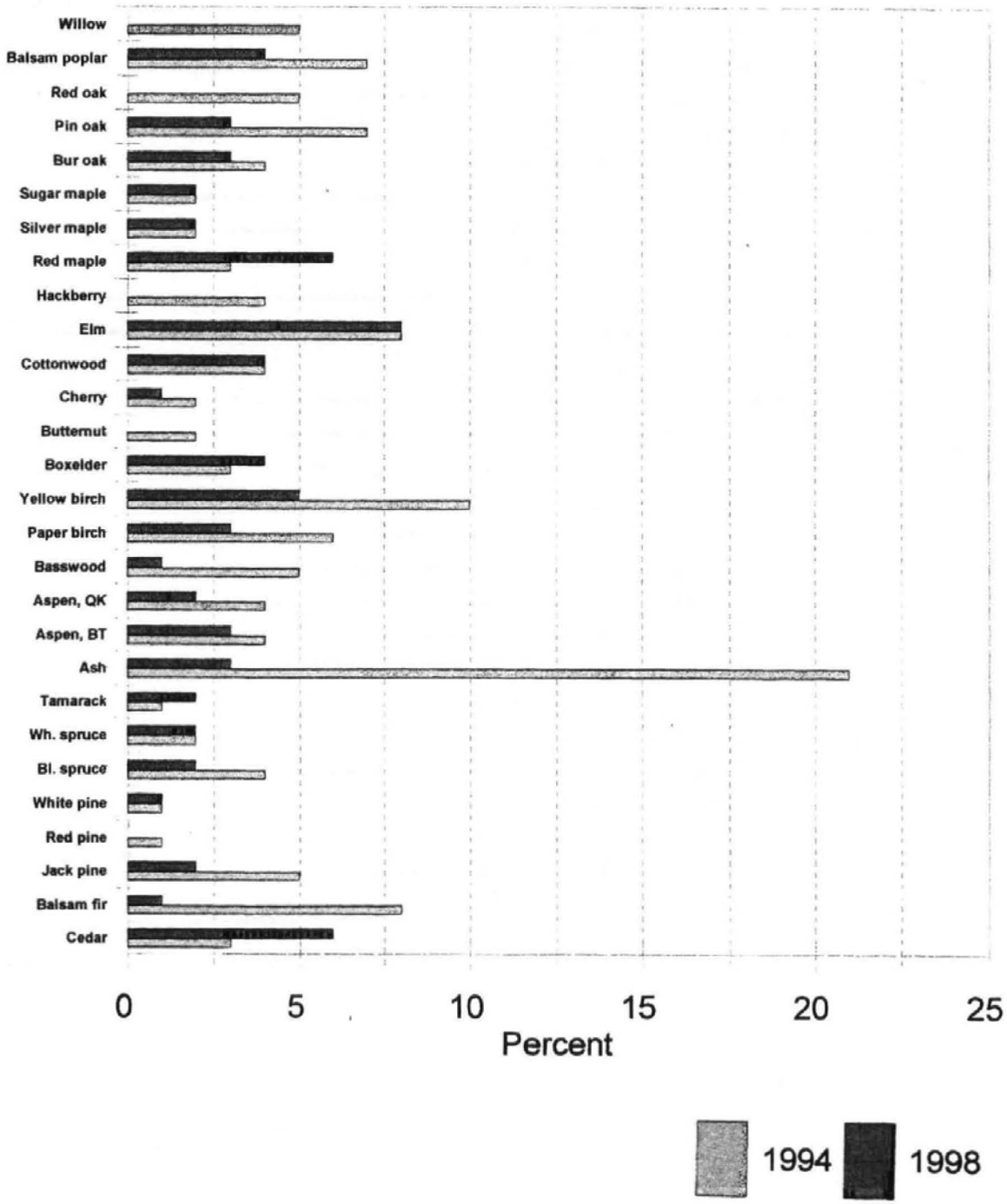
Live crown ratio is an estimate of the percentage of total tree height which supports live green foliage that is effectively contributing to tree growth. If the live crown ration is less than 30%, the tree is under poor growing conditions, perhaps overstocking, suppression or serious dieback is the cause. If the live crown ratio is greater than 80%, the tree is growing in the open. The table below compares the average live crown ratio for each species for two sampling dates and tree populations, 1994 and 1998. The 1998 sample population had better live crown ratios for the following species compared to 1994: ash, white pine, quaking aspen, cherry, cottonwood, hackberry, red oak and willow. The remaining species had poorer or similar crown ratios compared to 1994.



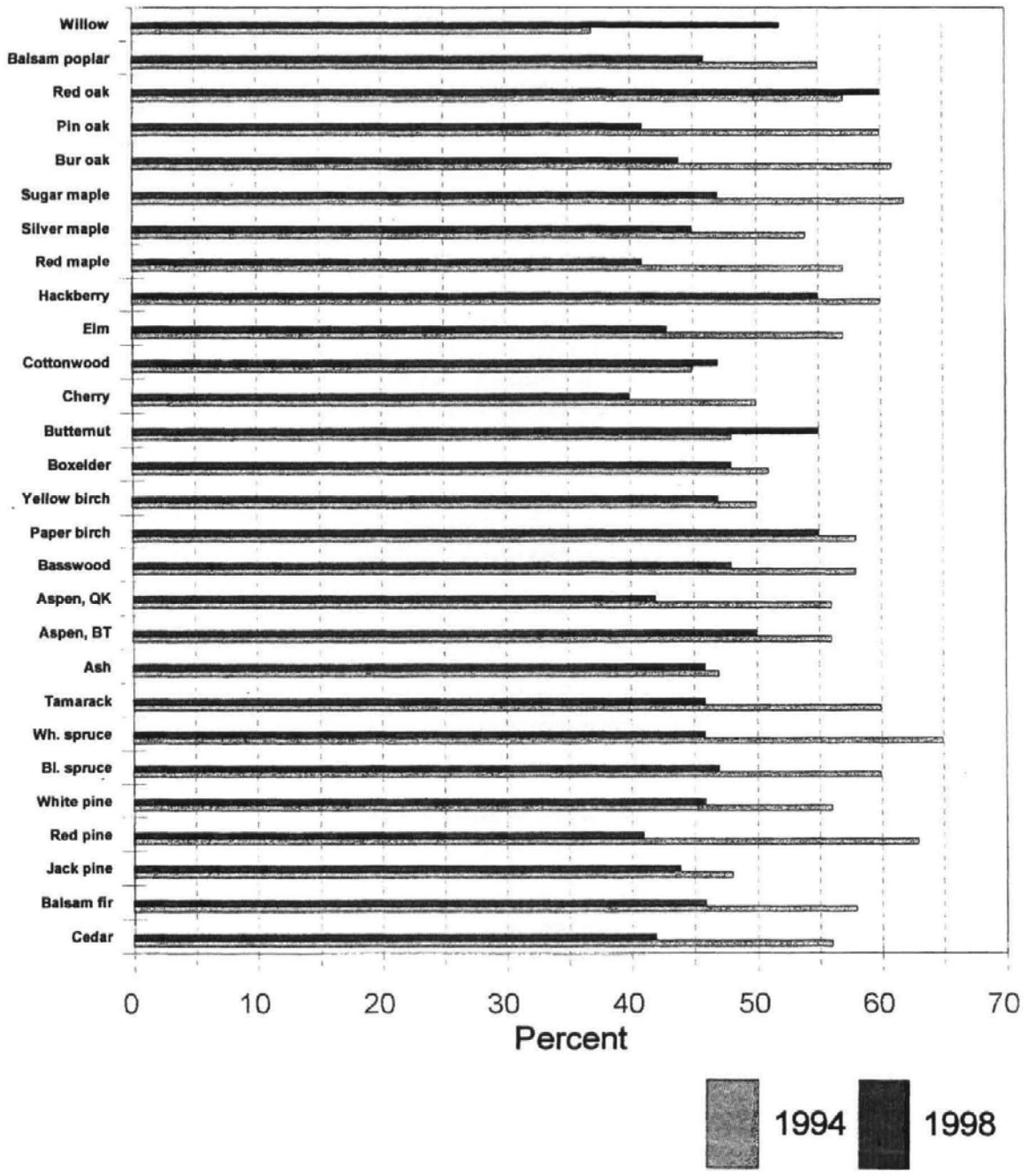
Foliage transparency is an estimate of the amount of skylight visible through the foliated portion of a tree crown. The amount of foliage transparency differs by species and depends on the branching pattern plus the type and orientation of leaves. Foliage transparency serves as an estimator of defoliation caused by insect damage, pathogens, or environmental stress. There appeared to be large differences in the average transparency ratings between the sampling dates for most species. See table below. Willow and ash had greatly improved transparencies, that is, they had fuller and denser foliage in 1998 compared to 1994. All the rest of the species had poorer foliage transparencies in 1998.

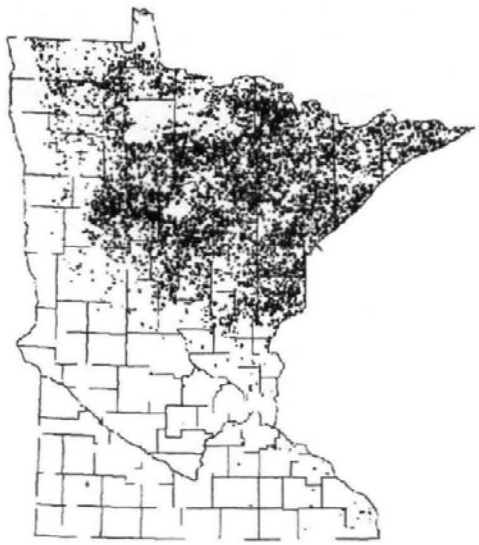


Crown dieback is defined as recent branch mortality that begins at the terminal portion of branches and proceeds toward the trunk. Dead branches in the center and lower crown or below the live crown are assumed to have died from competition of shading and are not included. Crown dieback is caused by severe stress, frequently to the root system of the tree, though some species exhibit light levels of dieback as part of their normal growth and development. In 1998, most species had less or similar average dieback compared to 1994. See table below. Ash species made the most improvement, going from 21% to 3%. Species with more average dieback in 1998 were red maple, boxelder, tamarack and cedar.



Crown density represents the amount of foliage, reproductive structures (e.g., seeds or cones) and branches that obstruct skylight visibility through the crown. A normal, healthy, forest-grown tree is used as the standard. A dead top is included but dead lower branches are excluded. Estimates of low crown density have been correlated with reduced tree growth for several species. Higher crown densities are better. Average crown densities were compared between species and sampled populations in 1994 and 1998. See table below. Overall, the average crown densities decreased between 1994 and 1998. The exceptions were, butternut, cottonwood, red oak and willow, which increased.





Aspen-birch forests

Aspen birch forests comprises 6,377,700 acres or 43.2% of the commercial forest in Minnesota. The main tree species are quaking aspen, balsam poplar and paper birch. Tree species commonly associated with the aspen-birch forest are balsam fir, elm, ash and maple.

Damaging agents and their effects

Defoliators and wood boring beetles are the major insect pests of aspen. The forest tent caterpillar, *Malacosoma disstria*, and the large aspen tortrix, *Choristoneura conflictana*, occasionally defoliate areas of several thousand square miles. Severe defoliation reduces growth but rarely causes mortality unless coupled with other stresses. Wood boring beetles of the genus *Saperda* cause increased wind breakage and lumber and veneer degrade. Insects accounted for less than one percent of the volume losses due to mortality (FIA, 1990).

The major diseases of aspen are Hypoxylon canker, *Hypoxylon mammatum*, and white rot, *Phellinus tremulae*. Hypoxylon canker is a fatal disease and causes serious volume losses. On an annual basis, 37% of the volume of aspen wood produced is lost to natural causes (FIA, 1990). Diseases accounted for 63% of these volume losses, with Hypoxylon canker being the likeliest cause. Losses from decay cannot be discerned from FIA data because the volumes already reflect deductions for decay.

The bronze birch borer, *Agrilus anxius*, is the major insect pest of paper birch. This flat-headed borer attacks and kills trees already stressed by environmental or human-caused conditions. On an annual basis, at least 47% of the volume of birch wood produced is lost due to insect and disease agents (FIA, 1990). Various decay causing organisms, notably, *Inonotus obliquus*, lowers stem quality through decay and discoloration.

Included in this report:

Forest tent caterpillar
Large aspen tortrix
Aspen blotch miner
Aspen webworm
Birch leaf miner
Pale green weevils

Forest tent caterpillar

Malacosoma disstria (Hubner)

Host: Basswood, oak and aspen
Damage: Defoliation
Area: 15,207 acres
Severity: Light to heavy
Trend: Increasing

Forest tent caterpillar 1998		
County	**Acres of light defoliation**	**Acres of heavy defoliation**
Aitkin	2043	595
Crow Wing	338	81
Douglas		1020
Isanti		24
Kanabec	360	518
Kandiyohi		2448
Mille Lacs	1119	4474
Pine	59	
Pope		1544
Stearns	71	323
Todd		74
Wright		116
Totals	**3,990**	**11,217**

Typically, forest tent caterpillars survive in detectable numbers in basswood stands around lake edges and last year's field surveys revealed only a few, widely scattered forest tent caterpillar populations. Some of these populations have been active for several years, causing moderate to heavy defoliation. Several lakeshore associations sprayed insecticides to control defoliation as they did in past years.

As of June 22nd, aerial survey detected small and large areas of FTC defoliation in Aitkin, Cass, Crow Wing, Douglas, Kandiyohi, Meeker, Mille Lacs, Stearns, Todd, and Wright Counties. See map. Populations were detected from the ground only in Ottertail and Lake of the Woods Counties. Again this year, the caterpillar's primary host was basswood but defoliation was also noted on aspen, birch and oak, particularly in Aitkin County. Some natural controls, primarily diseases, were observed at scattered locations.

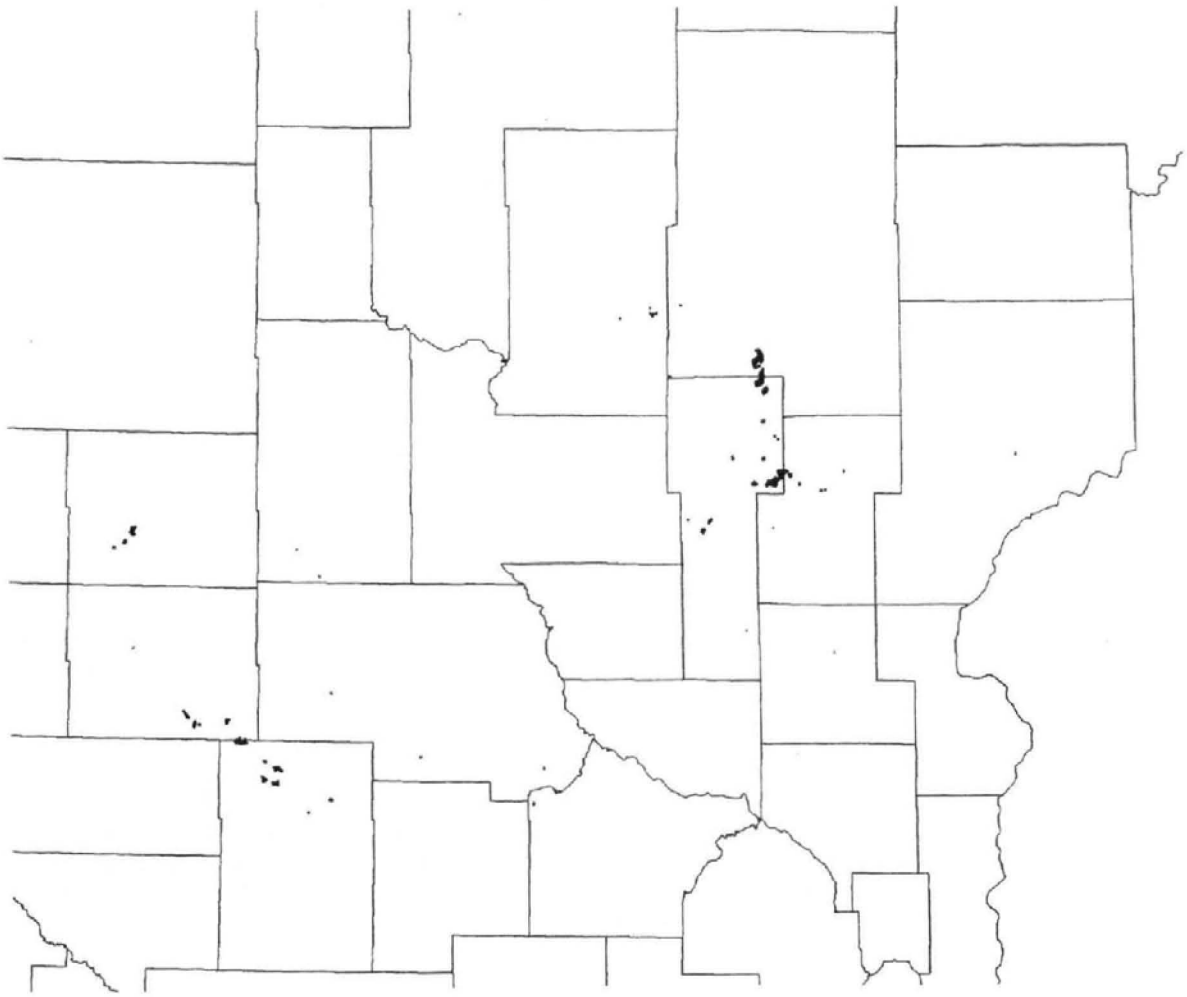
In Aitkin County, forest tent caterpillars consumed basswood leaves in Father Hennepin State Park, near Isle, and on an island in Borden Lake, just west of Lake Mille Lacs. Their numbers had increased in 1997 so that defoliation of 70 to 90% of the deciduous trees occurred in June. This year, a May 8th check of the Isle population revealed larger numbers of caterpillars, many ¾ of an inch in length. By June 17th , caterpillars had started spinning up; they had formed tents of a few leaves held together by silk threads. Inside these tents, the caterpillars had spun

yellow cocoons and changed into pupae.

Cocoons of forest tent caterpillars were found in a few of locations in Region II this summer, notably, in one location just east of Ely and in a couple of spots south of International Falls.

Egg mass counts from basswood twigs cut in mid-September confirmed the potential for moderate defoliation in 1999. Sampling confirmed the presence of pupal and egg parasites; but it will be the severity of the winter, that determines the survival of the egg masses and the true potential for outbreaks in 1999.

Forest tent caterpillar defoliation 1998



Large aspen tortrix

Choristoneura conflictana (Walker)

Host:	Aspen
Damage:	Defoliation
Area:	3078 acres
Severity:	Light to moderate
Trend:	These smallish pockets of tortrix defoliation seem to wax and wane quickly in northeast and north central counties.

Aerial surveys followed by ground checking revealed that the large aspen tortrix was defoliating 3078 acres of aspen near Duluth this spring. Defoliation of aspen, as well as, pupal cases of the tortrix were found in T51N-R13W and in T50N - R14&15 W. The large aspen tortrix populations sometimes develop into large outbreaks, just like the forest tent caterpillar, consuming aspen leaves on millions of acres. The last large outbreak of tortrix in Minnesota lasted from 1969 to 1973. Since then, pockets of tortrix defoliation have been found, like this year, but they quickly declined and did not develop into large outbreaks. Time will tell what happens with these populations.

Aspen blotch miner

In late July, many aspen trees in northeastern and central Minnesota appeared to be losing their green coloration by turning yellow to white to brown in blotchy patterns. The cause of this discoloration is the aspen blotch leaf miner, *Phyllonorycter salicifoliella*, which has been noticeable for the last four years. The blotch miner is a small caterpillar that feeds inside the leaf between the upper and lower surfaces. As its name implies, its pattern of feeding results in circular area or blotch being mined out. This damage is often heaviest on the smaller trees along roadsides but can affect entire large trees, as has occurred this year in some stands near Duluth. The caterpillars change to a pupae in the mine and tiny moths emerge in August. The tiny moths are able to survive the winter by hibernating under the bark of pine and spruce trees and then lay eggs on aspen leaves the next spring.

Aspen webworm

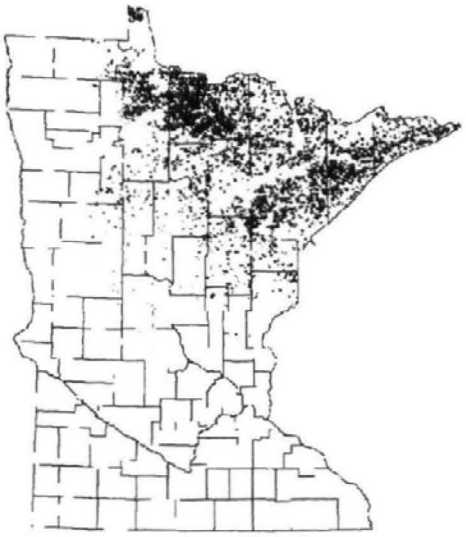
In late August, the aspen webworm, *Tetralopha aplastella*, was found on a few aspen east of Ely. Each two to three-inch diameter web consisted of several leaves tied together with silk. Inside each web was a 3/4 to 1 inch long yellowish-brown caterpillar with a darker brown head, thoracic shield and broad subdorsal stripes. In several webs there were remnants of the cocoon of the forest tent caterpillar, indicating that the webworm took advantage of this feeding site without having to create its own shelter.

Birch leaf miner

Damage from birch leaf miners remains at a fairly low level. However, scattered individual trees with heavy damage can be found throughout the Northeast Region.

Pale green weevils

Pale green weevils, *Polydrussus impressifrons*, is an exotic insect that was first reported in North America in New York State in 1906. The adult weevil feeds on the leaves of many broadleaf plants from strawberries to birch trees. Large numbers have been observed in northern Minnesota for the past five or six years. Largest numbers of adults were present in June and July, but by the last week of July only a few adults were still feeding.



Spruce-fir forests

The spruce-fir forests comprises 3,535,800 acres or 23.9% of the commercial forest land in Minnesota. Black spruce, balsam fir, tamarack, northern white cedar and white spruce are the main components and associated species are aspen, maple and paper birch.

Damaging agents and their effects

The major disease problems on black spruce are dwarf mistletoe, *Arceuthobium pusillum*, and root and butt rots. Black spruce is attacked and killed in all stages of its development by dwarf mistletoe. On an annual basis, 55% of the volume of black spruce wood produced is lost due to natural causes (FIA, 1990). Losses in black spruce were due primarily to blow down and beaver flooding, although dwarf mistletoe accounted for 22% of the losses. Root and butt rots caused by *Armillaria* spp. and *Inonotus tomentosus* are present in most stands over 30 years of age. Losses from root and butt rots may range up to 40% of the merchantable volume of the stand. Root rots are the major contributing factor to wind damage.

The spruce budworm, *Choristoneura fumiferana*, is the most destructive insect in Minnesota forests and causes the greatest mortality volume loss. It attacks, injures and kills all age classes of balsam fir. The spruce budworm outbreak in northeast Minnesota has been continuous since at least 1954, when aerial mapping started. Budworm caused 32% of the mortality losses during the latest inventory period. Fire, animals and weather events also caused 32% losses. Root and butt rots caused by *Armillaria* spp. or *Inonotus tomentosus* are present in most stands of spruce-fir older than 30 years. *Stereum sanguinolentum*, a heart rot, enters the trees through broken tops, branches, and other injuries and causes the majority of the decay found in living fir trees.

Included in this report:

Spruce budworm
Pine spittlebug on balsam fir
Rhizosphaera needlecast
Spruce spider mites on arbor vitae
Larch sawfly
Cedar borer

Spruce budworm

Choristoneura fumiferana (Clements)

Host:	Balsam fir and white spruce
Damage:	Defoliation, topkill and mortality
Area:	239,967 acres
Severity:	See table
Trend:	Intensifying in Koochiching and northern St. Louis Counties; decreasing in white spruce plantations in counties south and west of Itasca County.

Spruce budworm defoliation 1998		
County	**Low to moderate defoliation**	**Heavy to severe defoliation**
Aitkin	133	622
Anoka	798	
Becker	126	
Beltrami		2448
Carlton	89	
Cass	506	2658
Clearwater	37	
Crow Wing	32	76
Hubbard		1131
Itasca	1166	28,418
Koochiching	1910	71,127
Lake of the Woods	1030	49
Mahnomen	35	
Morrison	98	
Ottertail		24
Pine	42	
St. Louis	605	127,073
Totals	**6,341**	**233,626**

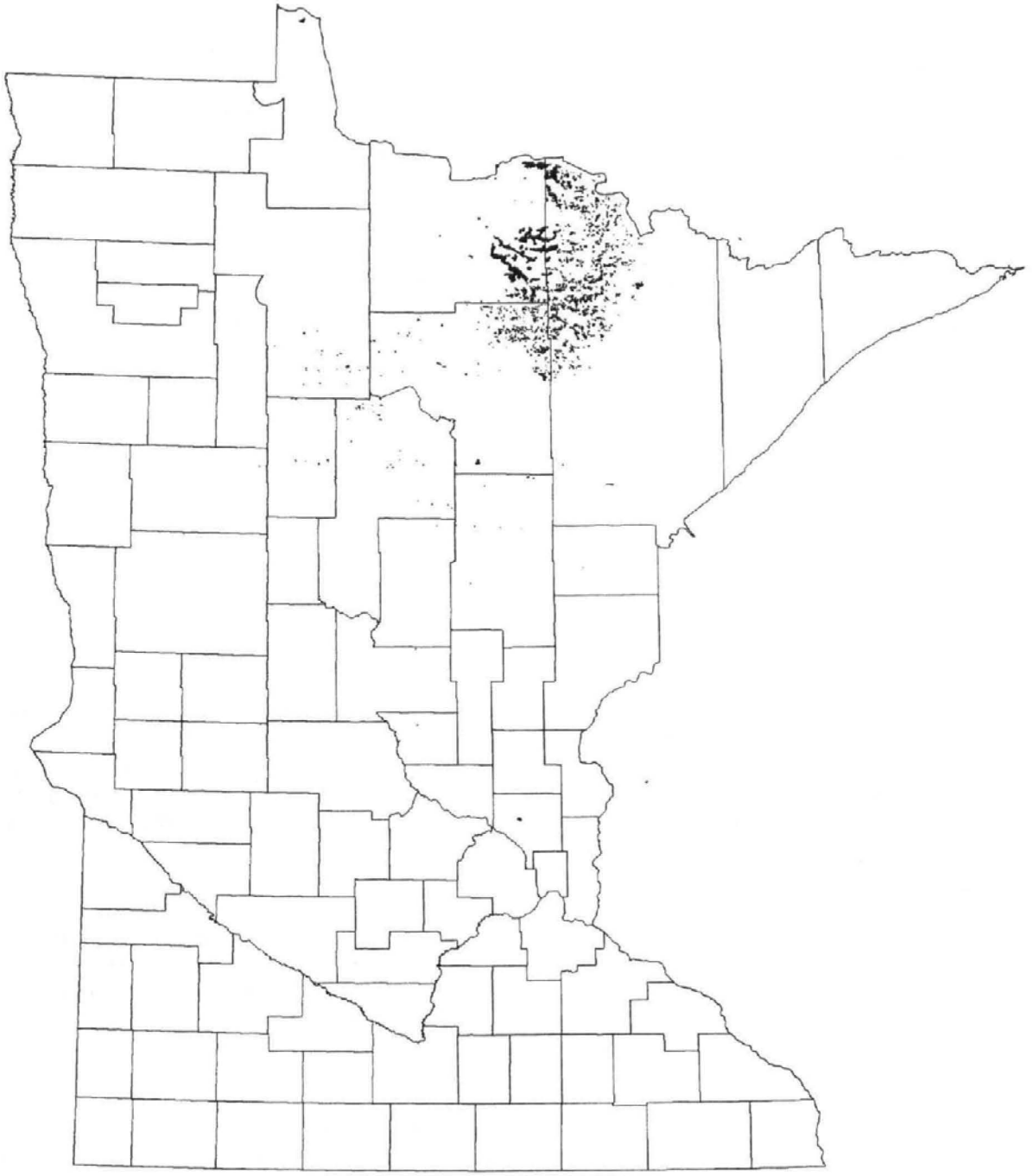
A statewide snapshot: Populations and defoliation levels remain very high in northeastern Itasca, northwestern St. Louis and eastern Koochiching Counties. White spruce as well as balsam fir continue to be damaged. Budworm populations and levels of defoliation throughout the rest of Region II were at lower levels than last year. Light defoliation continued in scattered white spruce plantations in Itasca County. In Regions 1 and 3, white spruce plantations continue to be targeted by the budworms. In Region I, heavy defoliation occurred in 1998, but egg mass counts were down for 1999. In Region III, both defoliation and egg mass counts were down compared to 1997. Some plantations are beginning to experience topkill and low-level mortality. See map.

The effect of our El Niño` spring played a major role in changing the timing of insect emergence this spring. The timing of larval surveys was three to four weeks ahead of last year. In Region 1, larval surveys indicated that budworm numbers and defoliation were greater in 1998 than in previous years. Many of the stands have had heavy defoliation for more than six years and appear somewhat stagnated. One stand in Cass County, Sec. 21-T145-R30W has severe defoliation again this year following considerable top killing and whole tree mortality due to past years' defoliation and stress.

In Region 2, budworm caterpillars were ⅛ to 3/16 of an inch long in Itasca County as of May 12th. By June 16th, approximately 60 to 70 percent of the budworm had pupated in St. Louis County near Ely. On June 23rd moth flight was well underway in northwestern St. Louis County. Very heavy defoliation occurred in northwestern St. Louis

and eastern Koochiching Counties. Heavy rains knocked many of the damaged needles off the trees making damage appear less severe than actually occurred. Near Linden Grove in west central St. Louis County, 50% of the moths emerged as of June 22nd. In general, balsam fir suffered heavy defoliation as did the white spruce.

1998 Spruce budworm defoliation



In Region 3, very little damage occurred in white spruce plantations and natural stands in Morrison and Crow Wing Counties. In northeastern Morrison County, caterpillars had grown to ¼ inch by May 8th, and over 50% of the spruce bud caps had fallen off. Perhaps with the warm spring, needles and shoots became lignified earlier and were unpalatable to the caterpillars.

The spruce budworm outbreak in central Anoka County, in the Region VI , picked up again this year where it left off from last year. The feeding damage from intense budworm activity was reported in a large residential area just north of the Andover City Hall in early July. The entire area has been developed in recent years amidst abandoned Christmas tree plantations composed of white spruce. Consequently, white spruce dominates the conifer component throughout this residential area. Most of the trees defoliated by the budworms were between 25 and 50 feet tall. The Anoka County outbreak is now in its sixth year and has several homeowners in the area quite concerned and wondering what they can do to save their trees. In fact, the outbreak has helped the city forester bring several of these concerned neighbors together in an effort to work together in getting some help with this ongoing problem.

Biological note: Spruce budworm induces epicormic branching

(Excerpted from Insect and Disease Newsletter)

Did you know that all trees have "back-up" systems for replacing lost foliage and branches? Epicormic shoots originate from preformed, suppressed buds that are carried along as the tree grows and, once stimulated by tree stress or changing tree conditions, are induced to grow and develop. Here's where spruce budworm comes in for balsam fir and white spruce trees. Spruce budworm stresses a host tree by causing defoliation and that induces epicormic buds to break and epicormic shoots to elongate in order to replace the lost foliage. Replacing foliage consumed by budworm is a high priority for the survival of the host trees.

What makes this story really interesting is the fact that balsam firs and white spruces have very different strategies for dealing with defoliation by altering the timing of epicormic shoot formation[1]. And, it is based on whether needles alone or needles and buds are consumed by the budworms.

First, the host trees' similarities: When budworms are at high densities, they consume needles and buds on both host species. Both balsam firs and white spruces compensate for the loss of this foliage with prolific epicormic shoot production. This makes a single twig tip look tufted because as many as twelve epicormic shoots are present. After a few years of severe defoliation, the branches have had multiple episodes of epicormic proliferation and you can find hundreds and hundreds of epicormic shoots on them.

Now for their differences: When budworms are at low densities, defoliation is much less and does not include bud destruction; only needles are consumed. The response of the two host species differs dramatically. When only needles are consumed, white spruces form epicormic branches and balsam firs do not. So at low budworm densities, white spruces produce epicormics to compensate for the lost foliage and are able to generate and store energy. White spruces are extremely sensitive to needle loss. In fact, if about 50% of the current year's needles are lost, there is a 40% increase in the amount of epicormics the next year.

This is what we've observed in Minnesota over the past decade. Spruce budworm populations have spread into white spruce plantations as far south as the Twin Cities and as far west as Park Rapids. After just a few years of defoliation, white spruce branches begin to have prolific epicormic shoot production. In balsam fir, our experience has shown that excessive tufting of branches is the beginning of the end for those trees. So we were anticipating

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[1] For more information, read "Spruce budworm defoliation-foliage production: differences between white spruce and balsam fir" by Harald Piene, 1998. In USFS General Technical Report NE-247.

that the infested white spruces should not live long. Much to our surprise, they lived and are still living.

Here's Piene's theory on how most white spruce and balsam fir trees react to spruce budworm outbreaks.

White spruces form lots of epicormics at low budworm densities. Since foliage on epicormic shoots is very palatable and highly nutritious to budworms, this stimulates the budworm population to increase. At first this is not a problem for the white spruces because the epicormic shoots are also producing lots of food and energy for the trees. Later, as budworm densities build, spruces are weakened both by the loss of foliage caused by budworm feeding and by the loss of energy caused by creating epicormic shoots that were immediately consumed. So white spruces only lose energy during the later half of an outbreak and this allows them to live a little longer. Early epicormic shoot formation is advantageous for white spruce. When the spruces run low on energy, they start dying. A few large, mature white spruces in native stands do survive, though, because budworm outbreaks generally collapse before all the white spruces have run out of energy. These surviving spruces are the "seed-sources" for the future forest.

In contrast, balsam fir trees loose energy during the whole outbreak. In the early stages of the outbreak, the firs continually loose needles and store little or no energy each year. Balsam firs are only stimulated to form epicormic shoots when needles and buds are destroyed by high budworm densities. Foliage on balsam firs' epicormic shoots are also very palatable and nutritious. These epicormics are quickly consumed and boost the already high budworm population. With fewer needles on the twigs producing food and energy and the energy used up in epicormic shoot production, balsam firs start dying off rapidly. Large, mature balsam firs in native stands generally do not survive because they use up their energy and die before the budworm outbreak collapses. Fortunately, balsam firs are prolific seeders during the early phases of the outbreak, seedlings establish well and aren't terribly bothered by budworms. These young balsams are the future forest.

Although white spruce and balsam fir have different strategies, both species do survive spruce budworm outbreaks. And, because these trees persist in the forest, they will provide a ready food source for the next spruce budworm outbreak.

Pine spittlebug on balsam fir

The pine spittlebug, *Aphrophora parallela* (Say), is often abundant on white pines and jack pines as well as other conifers. Other conifers being balsam fir, tamarack and spruce. And in fact, several Christmas tree growers in the north central counties reported the occurrence of this insect in their balsam fir fields this summer.

Heavy infestations of spittlebugs may cause twig, branch and tree mortality the following year. In natural stands, spittlebug population build-up is often prevented by a fungal disease caused by *Entomophthora aphrophora*. In Christmas tree fields, control may be required and since the spittle masses give protection to the young, contact insecticide sprays must be applied with force before mid-July.

Rhizosphaera needlecast

Rhizosphaera needlecast was found on many Colorado blue spruce trees in the same residential area where an ongoing spruce budworm outbreak has occurred for the past six years near Andover in Anoka County. Many residents in this area have planted Colorado blue spruce trees as ornamentals, which now comprise the second largest number of conifers in the area after white spruce. The intensity of the damage to this species was very severe.

Spruce spider mites on arbor vitae

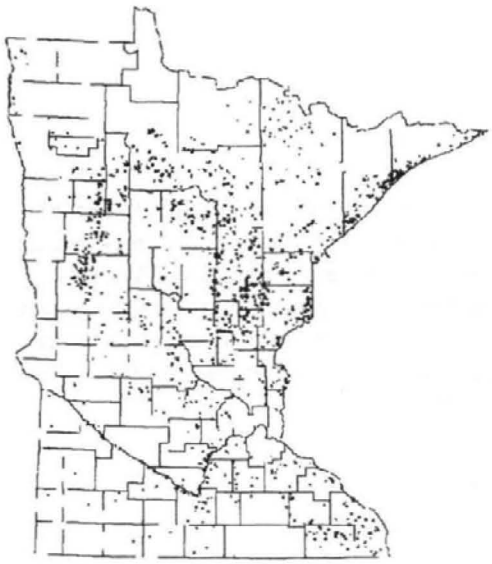
Spruce spider mite damage on thirty foot tall white cedars was observed during the week of July 13th in Bemidji. Spider mites, *Oligonychus ununguis*, are most active during warm, dry weather on a variety of conifers including spruces, pines and cedars. . Initial symptoms of mite damage to foliage often appear as bronzed and/or sticky foliage. From a distance the leaves appear grayish-bronze due to mottled chlorosis of the leaves that is a result of mites sucking plant fluids from the leaf tissue. Heavily defoliated trees are weakened by the loss of plant fluids being rerouted (to producing high populations of mites instead of being stored in the roots of the host trees). This insidious damage goes unnoticed for a long time before the problem is recognized.

Larch sawfly

On June 10th, adults of the larch sawfly were laying eggs in a stand in S17-T52-R21 in St. Louis County. This stand was completely defoliated in 1997 and in 1998. Some eggs had already hatched and larvae from ⅛ to ¼ inches long were feeding on the needles. Although a few pockets of defoliation caused by this sawfly are found most years, the population usually collapses after one or two years.

Cedar tree borer

The cedar tree borer, *Semanotus ligneus*, is a wood boring beetle that attacks most dying conifers, but its preferred host is eastern white cedar. By feeding for two summers on the inner bark and ¼ inch of sapwood, the larvae excavate frass-filled, meandering tunnels or galleries that increase in width. When the bark and frass are removed and these logs are cleaned, their surfaces are covered with beautiful grooves that rustic furniture and log home craftsmen utilize and arrange on visible surfaces of their products. Customers are willing to pay higher prices for such "insect sculptured" wood.



Maple-basswood forest

Maple basswood comprises 1,402,900 acres or 9.5% of the commercial forest in Minnesota. The main tree species are sugar maple, red maple, basswood, yellow birch and American elm. An associated species is white pine.

Damaging agents and their effects

The greatest volume losses in northern hardwood species are the result of disease organisms which discolor, decay, or deform standing timber. Occasional tree mortality can be caused by shoestring root rot fungus, *Armillaria* spp., and sapstreak disease, caused by *Ceratocystis coerulescens*, in wounded or stressed trees. Mortality in the northern hardwood type is not common. On an annual basis, 7% of the volume of basswood and maple wood produced is lost to natural causes (FIA, 1990). This does not include harvest removals. There were no outstanding causes of mortality as identified by the Inventory. Growth losses and periodic declines can occur following insect defoliation or adverse climatic conditions. Defoliators include basswood thrips, saddled prominent, orange-humped mapleworm, green-striped mapleworm and maple trumpet skeletonizer. Canker diseases caused by *Nectria galligena* and *Eutypella parasitica* can reduce yields, cause minor mortality in young trees and serve as openings for decay organisms.

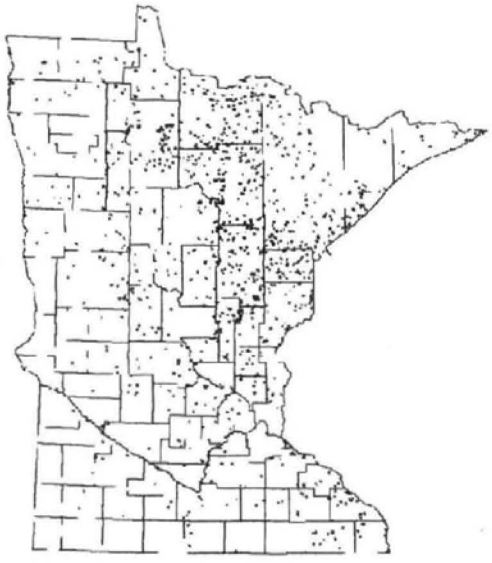
Included in this report:
Mapleworms
Maple-basswood leaf roller

Mapleworms

Large numbers of rosy maple moths, *Dryocampa rubicunda rubicunda*, with bright yellow bodies, light yellow wings with pink forewing patches and a single pink stripe on the rear wings were seen around lights in Cass, Crow Wing, Kanabec, and Isanti Counties from May 19th to May 30th. During the first week in July, their offspring, called greenstriped mapleworms, caused heavy defoliation of red maples in Crow Wing County on the southeast side of North Long Lake. The insect pest was first observed in 1997 on July 29th at this location. Little branch dieback is expected due to the effects of defoliation. Its adult stage, the rosy maple moth, was seen in great numbers around night lights, in several counties of central Minnesota, into late May of this year. Scattered and spotty, heavy defoliation of red, sugar, and silver maples is predicted next July, especially in cities and towns where lights have attracted the moths.

Maple-basswood leaf-roller

Caterpillars rolling leaves of sugar maples and basswoods were detected in Becker County north of Detroit Lakes while inspecting North American Maple Project plots for early defoliation. The maple-basswood leafroller, *Cenopis pettitana* has occurred in epidemic numbers on sugar maples and basswood in parts of southern Ontario and other parts of southern Canada recently. There is one generation per year and the eggs overwinter on the tree and hatch in early spring. The young larvae feed initially in the swollen buds but, later in May and June, older larvae construct conical leaf rolls from which they emerge to feed on surrounding foliage. The adult moths emerge from late June to early August.



Elm-ash-red maple forest

Elm-ash- red maple comprises 1,291,500 acres or 8.7% of the commercial forest in Minnesota. The main components are elms, ashes, red maple, silver maple and cottonwood. Trees commonly associated are birch, spruce and balsam fir.

Damaging agents and their effects:

The greatest volume losses in the lowland hardwood species occur from disease organisms which discolor, decay or deform standing trees. Dutch elm disease, caused by *Ophiostoma ulmi*, has caused widespread mortality in elm species across the state and has virtually eliminated elm species as viable species for management. On an annual basis, 58% of the volume of elm wood produced is lost due to natural causes.

Black ash is relatively free of serious insect and disease problems. However, black ash across the northern part of the state has suffered significant dieback. No specific pathogen or insect has been associated with this problem. It is believed to be due primarily to fluctuating water tables caused by drought in the mid 1970's, record high water tables in the mid 1980's, and drought in the late 1980's.

Included in this report:
Ash anthracnose
Black-headed ash sawfly
Fall webworms
Mt. ash sawfly

Ash anthracnose

Reports of anthracnose on green ash were received at Perham in Otter Tail County in late May. Leaves appeared blackened and deformed with brown sunken spots. This fungal disease is particularly a problem in cool, wet springs but, can also be initiated if wet conditions follow hot humid conditions during leaf expansion. In severe cases, twigs die back and defoliation can occur however, new leaves form again by mid-summer.

Black-headed ash sawflies

Green ash leaf defoliation by the black-headed ash sawfly, *Tethida barda,* was observed in southern Clearwater County. Larvae have blackheads with green to yellowish-white bodies. The larvae feed gregariously in groups of

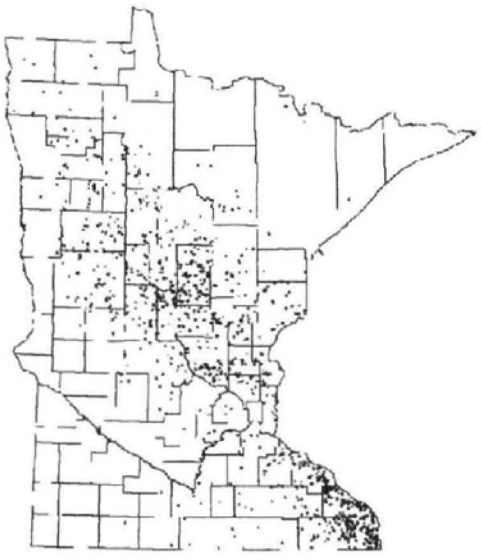
four to twenty, often lined up in rows feeding side by side. Young larvae chew holes in the leaflets, and older larvae eat entire leaflets. Heavily infested young trees may become completely defoliated in one to two weeks. Older trees may become so ragged that most of the leaves drop prematurely. Usually, natural enemies keep sawfly populations low, however, repeated defoliations of smaller trees can severely stress trees leading to crown mortality and even death.

Fall webworms

Webbed branches formed by the fall webworm, *Hyphantria cunea*, were found on species of cherry and serviceberry. In Region I, there were fewer reports of this pest this year and it was not as commonly seen along roadsides compared to the 1996 and 1997 general surveys. Most reports were in Hubbard County on crab apples. Webworms can cause some branch deformity but are mainly an aesthetic concern in ornamental plantings in yards or parks.

Mountain ash sawfly

In late June, sawfly larvae varied from 1/16 to 5/8 of an inch long in Grand Rapids. There are generally two generations a year.



Oak forest

The oak forest is comprised of 1,184,300 acres or 8% of the commercial forest in Minnesota. The main components are northern red oak, white oak, bur oak and, in the southeast, hickories. Trees commonly associated with oaks are jack pine, elm and maple.

Damaging agents and their effects:

The greatest volume losses in oaks are the result of disease organisms which discolor, decay, or deform standing timber. Mortality within the oak type is caused by Armillaria root rot fungus, *Armillaria* spp., the two-lined chestnut borer, *Agrilus bilineatus,* and oak wilt disease, *Ceratocystis fagacearum*. Trees that become stressed by drought, insect and disease defoliation, overstocking, over maturity or other detrimental site conditions are attacked and killed by Armillaria root rot and the two-lined chestnut borer. Oak wilt disease causes mortality in individual trees and groups of trees root grafted together. Oak wilt is common in the Metropolitan Region and the east central and southeastern counties.

On an annual basis, 20% of the volume of oak wood produced is lost due to natural causes (FIA, 1990). Diseases accounted for 39% of the losses and this was primarily due to Armillaria root rot. Insect losses probably account for more than the 2% tallied during inventory because two-lined chestnut borer symptoms often are higher on the bole and are difficult to see. In addition to this, Armillaria root rot and two-lined chestnut borer are commonly found on the same trees but only one pest can be coded for the FIA Inventory.

Included in this report:

Oak wilt
Gypsy moth
Oakworms
Two-lined chestnut borer
Blister gall mites
Kermes scale on bur oak
Hypoxylon canker of bur oak
Oak anthracnose
Butternut wooly sawfly

Oak wilt

Ceratocystis fagacearum (TW Bretz) J.Hunt

Host: Oaks, primarily northern pin oak
Damage: Mortality
Area: 16,551 acres
Severity: Variable, see table below
Trend: Increasing

Photo interpretation of color infrared photography taken in July of 1997 has been completed and transferred to topographic maps. Some 429 new oak wilt infection centers have been identified in nine counties that have a known history of oak wilt disease and were targeted in the photography. Below is a summary of the survey and acreages for all counties with oak wilt.

County	Number of new infection centers, 1997 survey	Acres of oak wilt, all surveys combined
Anoka		5713
Chisago	1	862
Dakota		2639
Fillmore	17	42
Goodhue	59	135
Hennepin		37
Houston	12	39
Isanti	3	1284
Mille Lacs	7	19
Olmsted	124	308
Ramsey		242
Scott		7
Sherburne		2957
Stearns	11	59
Wabasha	151	190
Washington		1895
Winona	44	103
Wright		12
Totals	**New centers = 429**	**Total acres = 16,543**

1998 Oak Wilt Forest Health Grants

This was the first year that an oak wilt control program funded with state money was expanded beyond the Federal Cooperative Suppression Area. A major effort was made to identify oak wilt sites and market oak wilt control strategies in these new areas. Public information meetings, mailings, and direct contacts were made to inform local agencies and landowners about oak wilt on their lands, and to discuss and recommend control strategies. See Special Projects section of this report.

Data compiled from the following three tables shows that the Mn ReLeaf and LCMR monies were used to treat 473 sites in 19 counties in 1998. The total number of sites now followed in the state oak wilt control program is 8826 infection centers. Since oak wilt control work began in 1990, a total of 5637 sites have been treated. This amounts to 64% of the known oak wilt in the 19 affected counties.

Metro Region			
Community & Project Name	**DNR Area & Number**	**Amount of Grant**	**Number of Sites Treated**
City of Andover Andover Oak Wilt Suppression Program	North Metro #611	$10,000	35
City of Mounds View Mounds View Oak Wilt Control	North Metro #611	$3,400	11
City of New Brighton New Brighton Oak Wilt Control	North Metro #611	$6,000	12
Anoka County Conservation District Oak Wilt Control	North Metro #611	$10,000	19
Anoka County Parks & Recreation Dept. Oak Wilt Suppression	North Metro #611	$10,000	17
City of North Oaks Oak Wilt Control Program	North Metro #611	$5,000	60
City Of Shoreview Community Oak Wilt Control	North Metro # 611	$10,000	no data yet
White Bear Township Oak Wilt Control	North Metro #611	$2,500	1
City of Ramsey Oak Wilt Suppression Costshare	North Metro # 611	$9,950	54
City of Blaine Oak Wilt Control Program	North Metro # 611	$10,000	no data yet
Town of Columbus Oak Wilt Disease Control Program	North Metro # 611	$10,000	15
City of Ham Lake Oak Wilt Control Program - Ham Lake	North Metro # 611	$10,000	52
City of Eagan Eagan Oak Wilt Control	East Metro # 612	$10,000	68
Ramsey County Dept. of Public Works Oak Wilt Control, Private Land	East Metro # 612	$3,000	19

Ramsey County Dept. of Public Works Oak Wilt Control, County Owned Land	East Metro # 612	$10,000	3
City of Lakeville Oak Wilt Suppression Program	East Metro # 612	$10,000	4
City of Apple Valley Oak Wilt Control Program	East Metro # 612	$10,000	125
Stillwater Township Oak Wilt Disease Control Program	East Metro # 612	$4,500	3
City of North St. Paul North St. Paul Forest Health	East Metro # 612	$3,700	1
City of Mahtomedi Oak Wilt Control Program	East Metro # 612	$6,000	5
City of Savage Community Oak Wilt Suppression Program	West Metro # 613	$5,000	4
TOTAL 21 Communities	--------	$159,050	**318**

Region 3	
Community or county	**Number of sites treated**
City of St. Cloud	2
Sherburne County (Tree Board)	38
Isanti County	22
Chisago County	33
Total	**95**

Region 4 and 5			
County	**Method**		
	Vibratory Plow ✳	**Herbicides**	**Other**
Goodhue	3		3☺
Wabasha	3	1	19☺
Olmsted	21	6	
Fillmore			
Winona	1		
Houston			3☆
Nicollet		2 (no cost share)	
Waseca	1		

Total	29	9	22
Average state cost share per project	$341	$125	no cost share
Region Total	**60 sites**		

* = All plowed site's locations are recorded on GPS.
☺ = These 19 sites on state land in Wabasha County, were field checked and confirmed for oak wilt by Forestry staff at Lake City. They are part of the inventory of sites identified from the September 1997 aerial survey. All nineteen were placed onto future timber sales and will receive post-sale treatment, as herbicide barriers.
☆ = These three sites in Houston County were confirmed and harvested or had the trees removed by the time the landowner was contacted.

Oak wilt on state lands

Of the nineteen suspected oak wilt infection centers in Sand Dunes State Forest, Sherburne County, seven were verified in 1998 and will be contracted out for control work prior to April 15, 1999. See Survey section of this report for a complete listing of all sites. Three sites are within the Uncas Dunes Scientific and Natural Area. See Special Projects Section for more about this. The remaining sites will be monitored in 1999.

1998 Oak Wilt Sites in Sand Dunes State Forest

Site ID	Perimeter estimate* and number of wilting trees	Location
96-4	≈2000' perimeter ≈ 6 - 14" Pin Oaks each. June wilting.	Scientific and Natural Area w of Lk Ann n along SNA trail. s21. Pos itive lab culture.
96-5	≈1000' perim ≈ 6 - 14" PO each .June.	SNA w of Lk Ann of 96-4. s21.
96-7	≈1000' perim = 10 clumps sprouts < 4" PO.	SNA Along FT 247 old CO A. Thick shrub and tree regen will need to be cleared for vibratory plow. s21.
98-2	450' perim = 5 - 16" PO. June.	E of Steve Seegers sled dogs. s35. Classic OW symptoms.
98-3	450' perim = 3 - 14" PO. June.	N of Woody sale s29. Pos lab culture.
98-4	perim 300' =1- 10" PO + 1 clump of sprouts. June.	E of Pistol range n side of FR 239. s26. Pos lab culture.
98-11	Est 400' perim = 2 - 14" PO. June..	s29 n of FT 180 access through Julh's tr to west of pond.

* = Perimeter estimated actual extent of wilt symptoms. Double primary control line to a 5' depth to break root graft barriers shall be properly located beyond wilted trees according to tree size.

On Friday, May 15th, 1998, a straight line wind caused wide spread tree breakage throughout the Anoka Sand Plain, in Sherburne and Anoka Counties. This is the worst time of year for wounding oaks because the oak wilt fungus is sporulating and the picnic beetles are very active. Through local news releases, landowners were encouraged to immediately paint injuries on oaks, including cut stumps. There hasn't been a storm of this magnitude since oak wilt became widespread in this area. This event may change the composition of the forest faster than we thought. Sherburne County will be aerially photographed next summer to locate all oak wilt infection centers on all ownerships and allow the effects of this storm to be documented.

Gypsy moth

Lymantria dispar (Linneaus)

Host:	Hardwoods
Damage:	None
Area:	None
Severity:	None
Trend:	Increasing trap catches. 2.5 time increase over last year. A hallmark of this season's GM finds is a nearly total absence of any indication of specific infestation centers.

Gypsy moth is a quarantined insect in Minnesota. As such, most of the activity relating to this insect is regulatory in nature. This effort is lead by the federal USDA's Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ) Division working in cooperation with the Minnesota Department of Agriculture's Agronomy and Plant Protection Services Division. The Minnesota Department of Natural Resources Division of Forestry works in direct, close collaboration with these agencies to detect and eradicate gypsy moth in Minnesota.

The 1998 Minnesota MDA/USDA cooperative gypsy moth trapping program was the largest to date, fielding 37 seasonal trappers. Trapping covered 62 entire counties and six partial counties with total traps set exceeding 25,000. The program's expansion was based on dramatically increasing moth catches and moth movement in Wisconsin the last several years. Traps were distributed at one trap per square mile in the seven metro counties, six southeastern counties, and Chisago and Pine Counties. St. Cloud, Duluth along with portions of six metro border counties were also trapped at one trap/ sq. mile. The remaining counties surveyed received one trap/ four sq miles in rural areas and one trap/ sq. mile in all towns, cities and incorporated areas. New, this year, was a nursery trapping program involving 70 cooperating nursery stock dealers and landscapers. Nurseries were selected based on stock sources from federally quarantined areas.

As expected moth catches in Minnesota increased dramatically. See table below. The final tally of 953 moths represents a 265% increase over 1997's catches. Also, not unexpectedly, most of the action is taking place in the six southeastern counties closest to Wisconsin. See maps. Counties trapped outside the metro and southeast regions produced no significant catches.

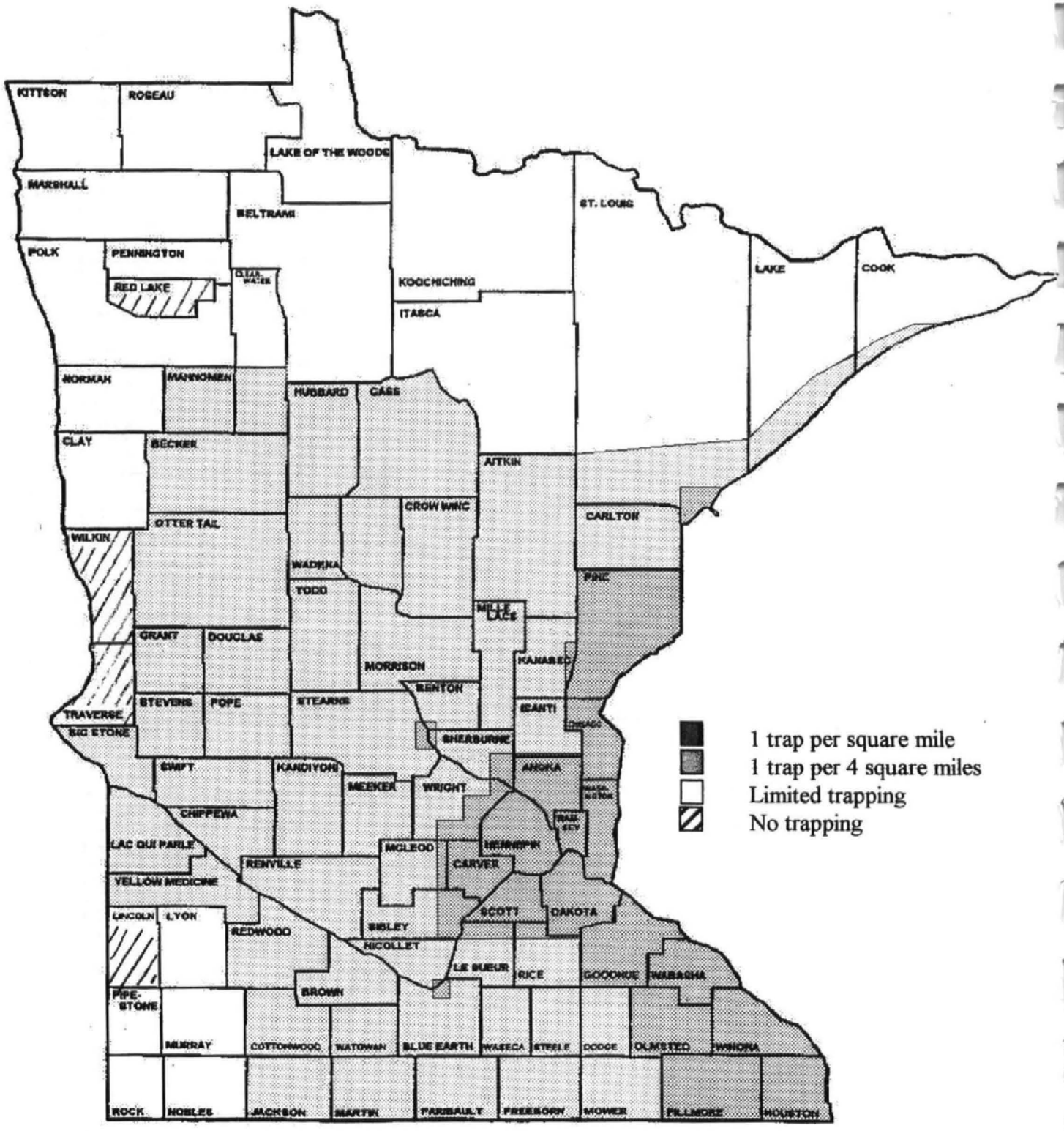
Overall the southeast reveals a clear east to west pattern but very few site locations coalesce into patterns that would indicate a possible source of infestation. Winona County produced the most moths at 209, an increase of nearly 680 % over last year. Olmsted County produced an even greater increase of 1750%, jumping from 8 moths in 1997 to 143 this season. Over all, the six southeast counties account for 65% of this year's total moth catch. In the Metro, moth catches basically doubled over last year. Hennepin County produced the most moths in the Metro Region yielding 129 moths. The newly instituted nursery trapping also produced its share of moths, a total of 33. One site in St. Paul produced the season's highest trap catch of eight moths. Responding to this find, MDA staff located three fresh egg masses and other indications that GM has probably been active at this site for at least two years. This was the only commercial site where regulatory action is warranted.

A hallmark of this season's GM finds is a nearly total absence of any specific infestation centers. Other than the previously mentioned catch of eight moths, only seven traps caught four or five moths. All others were three or less and the vast majority were single moth catches.

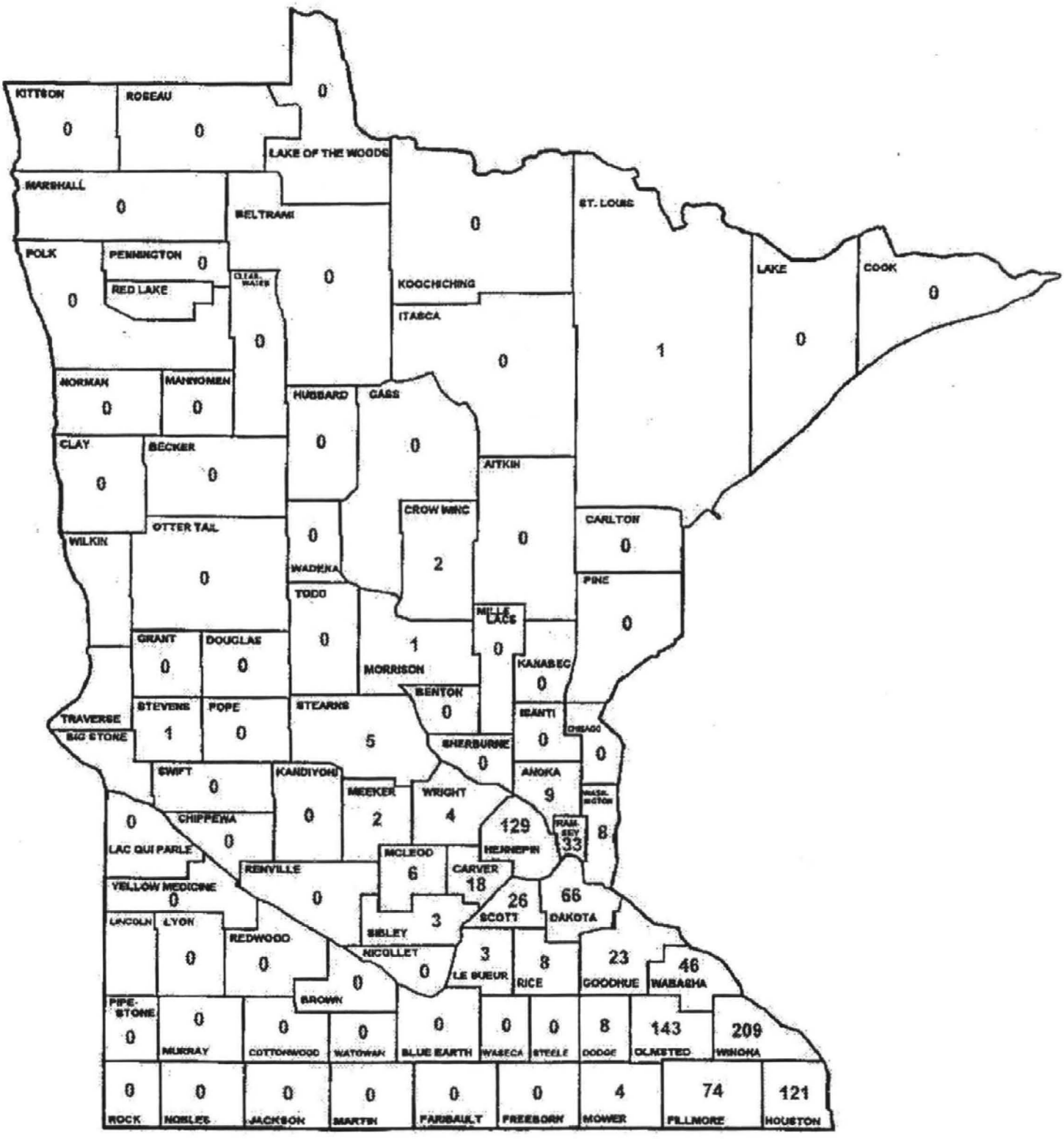
Until pending egg mass scouting or survey indicates otherwise, no spray programs are scheduled for the 1999 season. Gypsy moth activity is increasing significantly and can be expected to continue at an increasing pace in the near coming years. Increased delimiting trapping in 1999 for the southeast and Metro is a certainty. Other plans for 1999 regarding re-trapping out-state counties with few or no moth catches this season or expansion into counties not trapped have not been decided. Any decisions will be based on distribution of available resources and current risk for those counties.

1998 Gypsy moth trap catches by county				
County	**Number of moths**	**Number of sites**	**Number of traps per county**	**Average number of moths per trap**
Anoka	9	8	546	0.016
Carver	18	11	328	0.055
Crow Wing	2	1	387	0.005
Dakota	66	47	818	0.081
Dodge	8	7	201	0.040
Fillmore	74	50	1359	0.054
Goodhue	23	15	925	0.025
Hennepin	129	83	1237	0.104
Houston	121	91	875	0.138
Le Suer	3	3	208	0.014
Mc Leod	6	6	192	0.031
Meeker	2	2	222	0.031
Morrison	1	1	292	0.003
Mower	4	3	247	0.027
Olmsted	143	105	935	0.153
Ramsey	33	22	328	0.101
Rice	8	8	207	0.039
St. Louis	1	1	566	0.002
Scott	26	21	373	0.070
Sibley	3	2	295	0.010
Stearns	5	5	451	0.011
Stevens	1	1	159	0.006
Wabasha	46	43	840	0.055
Washington	8	7	645	0.012
Winona	209	132	1148	0.182
Wright	4	4	407	0.010
Totals 26	**953**	**697**	**546**	**0.049**

Gypsy moth trapping densities by county - 1998



Gypsy moth trap catches - 1998



Oakworms

Two oak defoliators, orangestriped and pinkstriped oakworms, caused scattered, heavy defoliation of white oaks and intermingled birch in Benton, Crow Wing, Morrison and Todd Counties during mid- to late-July. The adult stages of these two defoliators are moths. A sharp increase in their numbers was observed in 1997. This year, over 95% of the orange-striped oakworms completed their leaf feeding by mid-August. This forest insect can sometimes be found in great numbers in mid-September, but our early and warm spring weather allowed them to emerge a month earlier. More parasites of the eggs and pupae were observed this August, and more evidence of squirrels scratching the duff for pupae to eat was evident, also.

Parasites and predators generally help to terminate outbreaks, but field observations allow the prediction that these insects will cause heavy defoliation in 1999 in Benton, Crow Wing and Todd Counties. Since oaks had already set their buds for next year by the time they were defoliated, tree stress will be minimal.

Two-lined chestnut borer

The "Oak Decline Problem" continued to be the Insect & Disease challenge of most concern in Region I during the 1998 season, particularly Lake of the Woods, Beltrami, Hubbard and Becker Counties. New pockets of infested trees have been observed in Detroit Lakes in Becker County. Bur oaks appear to be the targeted host trees now that the large red oaks have declined. The two-lined chestnut borer causes girdling of the crown branches and tree trunk. Look for leaf browning with or without wilting symptoms, starting first in one or two upper crown branches that eventually spreads to the rest of the tree. Years of repeated environmental stress intermixed with anthracnose, aphids and other agents of foliar loss can lead to attacks by TLCB. Especially affected are trees growing on high, droughty soils. Armillaria root rot is commonly found on declining trees.

Blister gall mites

Blister gall mites on bur oak were common near Bemidji during 1998. *Aceria mackei* mites attack spring foliage, causing large blister-like swellings on the upper surface of bur oak leaves. The blisters are similar in size and shape to injury by the oak leaf blister fungus, *Taphrina corulescens*. The blisters are oblong and up to ½ inch long, glossy green and, later, turn brown. On the underside a dense, greenish to yellow concave pocket forms which later turns brown. Leaves roll, curl, or become grossly distorted because of the loss of sap caused by large populations of mites.

Kermes scale on bur oak

Kermes scales were found in scattered parts of Beltrami and Hubbard County. The reddish brown female scale bodies are the only durable sign of infestation. They are spherical in shape, about 1/4 inch in diameter and are tightly attached to the twigs. Scales suck plant juice from the twigs and stems causing the twigs to dry up and wilt. Immature scales, called crawlers, are found feeding on the undersides of leaves and petiole where they suck plant juices from leaves giving leaves a bronzed dried out appearance. The main injury caused by scale insects is the ingestion of plant sap, resulting in loss of plant vigor, poor growth, die back of twigs and branches and leaf drop.

Hypoxylon canker of bur oak

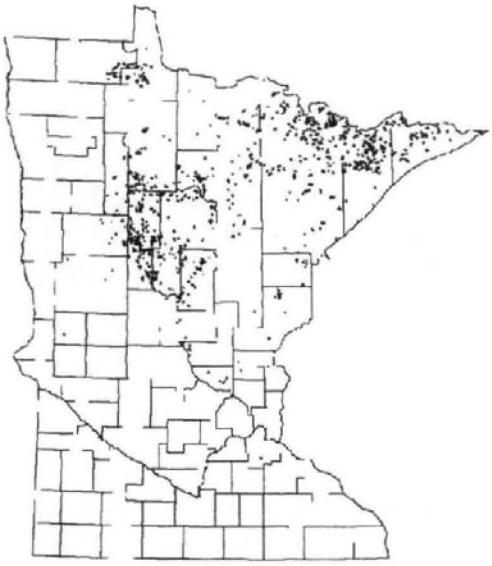
True, classic oak dieback and decline affecting mature bur oaks has been occurring across southern Minnesota over the last few seasons. This dieback is likely what is called Hypoxylon dieback of oak. Affected trees have wilting and yellowing leaves and branches and, ultimately, dieback. Old stromata, fruiting bodies produced by the *Hypoxylon* fungi, appear on the bark of trees with dieback. In all cases, the trees are mature and under stress from a variety of cultural and/ or environmental disturbances. The likely *Hypoxylon* species associated with main stem cankers are known to be opportunistic fungi. Unable to colonize trees of normal vitality, they quickly colonize weakened trees.

Oak anthracnose

By mid-August many scattered bur oaks across southern Minnesota experienced an outbreak of late season oak anthracnose. The severity of symptoms varied but were generally quite heavy. Infected foliage turned brown on much of the lower two thirds of the crowns. In years when this leaf disease occurs there is always much variability from tree to tree. It's common to see one or two affected trees adjacent to twenty or more unaffected trees. Thank goodness for genetic variability! Many of these bur oaks will experience this disease each year to some extent. There is no long term impact from late season outbreaks of anthracnose, so treatment is not recommended.

Butternut wooly sawfly

The butternut wooly sawfly, *Eriocampa juglandis*, was found on black walnut in mid-August in the Brainerd area. It feeds on leaves of butternut, black walnut and hickory. It is not considered a serious pest although it sometimes becomes locally abundant. The larvae have white heads with black eyespots, and their smooth green bodies are covered with white wool-like waxy material. When full grown they are about 3/4 inch long. They overwinter in papery cocoons in the ground, then change into pupae and adults the next spring. Adults are small, black, fly-like insects with two pairs of transparent wings and eggs are laid in the midribs of leaflets.



Pine forest

The pine forest is comprised of 812,300 acres or 5.5% of the commercial forest in Minnesota. The main species are jack pine, red pine and white pine. Associated species are aspen, birch and maple.

Damaging agents and their effects:

Mortality within the red pine cover type is caused by Armillaria root rot, *Armillaria* spp., Diplodia canker, *Sphaeropsis sapinea*, Sirococcus blight, *Sirococcus conigenus*, and several species of bark beetles.

White pine blister rust, *Cronartium ribicola*, and white pine weevil, *Pissodes strobi*, are the major insect and disease problems of the white pine cover type. These problems have restricted new plantings and greatly reduced the existing commercial management of this species. On an annual basis, 9% of the volume of white pine wood produced is lost due to natural causes (FIA, 1990). White pine weevil, deer browse and white pine blister rust account for approximately 65% of those losses.

Phellinus pini causes about 90% of the decay in all ages of jack pine and it becomes more prevalent as the pines get older. The major pests causing mortality in jack pine are jack pine budworm, *Choristoneura pinus,* pine tussock moth, *Dasychira pinicola,* bark beetles, *Ips* spp., Armillaria root rot, *Armillaria* spp. and stem rusts, *Cronartium* and *Endocronartium* spp. On an annual basis, 48% of the volume of jack pine wood produced is lost due to natural causes (FIA, 1990). Seven percent was lost to insects and additional surveys showed that jack pine budworm and bark beetles were the causal agents. Diseases, such as Armillaria root rot and stem rusts, caused 27% of the mortality losses.

Included in this report:

Bark beetles
Semi-mature tissue needle blight of white pine
Jack pine budworm
Pine tussock moth
Introduced pine sawfly
Pine needle rust
White pine bark adelegids
Cone beetles in branch tips

Bark beetles

Ips pini (Say) and other species

Host: All pines
Damage: Discoloration and mortality
Area: 2,880 acres
Severity: See table
Trend: Isolated pockets of bark beetles found in Cass County. Also in St. Croix State Park where jack pine is overmature and stagnating.

Bark beetles 1998		
County	**Light to moderate discoloration**	**Heavy to severe discoloration**
Cass	345	
Pine	289	2246
Totals	**634**	**2246**

After an early and somewhat dry spring, we anticipated lots of bark beetle infestations in pine plantation thinnings and in fact some did begin to develop. The first generation adults began emerging from logs the week of June 14th in northeastern Minnesota. With the early start of the season, three generations of bark beetles were expected in northern Minnesota instead of the more usual two generations. Fortunately the rains returned and only a few locations had bark beetle buildups that required extra sanitation work. A damaging population of bark beetles was found in red and jack pines that surrounded a housing development in Beltrami County. Bark beetles were also mapped in St. Croix State Park in Pine County causing damage to the overmature and stagnating jack pines.

Bark beetle pheromone traps were deployed in Wooden Frog State Campground this year. See report in the Special Projects section.

Semi-mature tissue needle blight of white pine

Physiological problem

Host: White pine
Damage: Needle discoloration
Area: Not documented, see map
Severity: Some trees not affected to trees with > 50% of their needles discolored.
Trend: First occurrence as a widespread phenomenon.

An unknown condition affecting white pines has been observed during the summer for the last four years, primarily in the Bemidji area. The tips of the current year needles are brown or tan but the base of the needles are green and healthy. This year many white pine trees have a brownish cast to them especially in the lower and mid-crowns. See map below. The distal portions of current needles wilt and die-back either partially or completely. The new needles look chlorotic and are continually being shed. This blight is especially noticeable during mid- to late- summer. Stomates are a normal white color and no fruiting bodies or other evidence of pathogenic fungi were detected.

The July 15th, 1998 issue of Maine's Forest & Shade Tree-Insect & Disease Conditions Newsletter reports a similar condition that they call "Semi-mature tissue needle blight of white pine". The cause of this condition is uncertain but they feel it is probably weather related. They believe it is a physiogenic disease that occurs in the spring when partially hardened but still emerging young needles are damaged by rapidly changing weather conditions. As young needles emerge in the spring, the tissue at the needle tip is the oldest while that at the base in the needle sheath is the youngest. In between is a zone of semi-mature tissue. This semi-mature tissue collapses, due to some rapid weather change. Tissue death then extends towards the needle tip causing the tip burn symptom.

According to the article, this condition has been reported in the northeastern US and Canada in past years and was common over large areas in southern and central Maine this year. The symptoms are most common in the lower and mid-crowns and less common in the upper crown. They report it on about one out of ten trees with affected trees growing right next to unaffected trees.

It is not considered a serious problem and no treatments are recommended. Because it is caused by weather conditions it will only occur next year if the weather conditions occur again when the needles are in a susceptible stage of development.

Semi-mature tissue needle blight of white pine - 1998

Jack pine budworm

Choristoneura pinus Freeman

Host:	Jack pine
Damage:	Defoliation
Area:	None
Severity:	NA
Trend:	1998 was the third consecutive year of zero budworm activity in Minnesota. The outlook for next year is for continuing low activity.

Jack pine budworm larval surveys were completed in Region I in Jack pine stands that have historically had budworm-caused defoliation. Trees were sampled earlier than normal this year due to early development of male cones where young budworm larvae feed. No significant numbers of larvae were found and no defoliation had been observed by June 10, 1998. Jack pines were dropcloth sampled at seven locations in Hubbard and Wadena Counties, but none were found.

Jack pine budworm egg mass surveys were completed on August 5th in Region I. Twenty-nine egg mass plots were sampled in southwestern Beltrami, Hubbard and eastern Becker Counties. Only one egg mass was identified and it was parasitized. In Region III, three egg mass plots were sampled at St. Croix State Park which yielded zero egg masses. So next year, it's very likely that budworms will again be really hard to find in jack pines.

Pine tussock moth

Dasychira pinicola (Dyar)

Host:	Jack pine
Damage:	None
Area:	None
Severity:	NA
Trend:	Increasing sharply in Wadena and Hubbard Counties while remaining static in Pine and Crow Wing Counties.

As part of a fifteen-year cooperative study with Canadian Entomologists, pheromone traps are placed in mature jack pine stands to collect male moths and track their numbers in relation to visible defoliation and the number of larvae collected from felled trees. This year, male flight started two weeks early. Trap collection numbers remained high, but no defoliation was detected and no larvae were collected in June on trees in Hubbard and Wadena Counties. See Survey Results section.

In years past, pine tussock moth populations increased to such great numbers that they caused heavy mortality of pines in Mission Township of Crow Wing County and in Pine County around General Andrews Nursery. To control this insect in Pine County in 1979 and 1980, aerial applications of insecticides were completed. Prior to the 1979 aerial spraying, drop cloth counts of tussock moth caterpillars numbered 98, 42, 45, and 48 in one location. Since 1980, the numbers of pine tussock moth caterpillars in Pine and Crow Wing Counties have diminished or remained low.

After the 1980 spray operation, and in subsequent summers, pheromone trapping was done. A count of 30 or more male moths in a trap over a seven to fourteen day period would indicate possible need for chemical or other control the next year. Such numbers and decision to apply controls should be combined with larval surveys and defoliation assessments of the infested jack pines.

In 1996 and 1997, trapped moths in northeastern Wadena and southeastern Hubbard Counties increased sharply,

and in 1998, numbers of trapped moths increased at four of these locations, remained the same but at high numbers at one location, decreased at six locations. At three locations not previously trapped, moth catches ranged from 30 to 111 moths. During May and June of 1998 drop cloth sampling of several jack pines in areas of high numbers of male moths trapped in 1997 yielded no pine tussock moth caterpillars.

Larval surveys and defoliation assessments will be undertaken in northeastern Wadena and southeastern Hubbard Counties in 1999. Pheromone trapping should be continued in Wadena and Hubbard Counties in 1999. A few traps should be placed around General Andrews nursery in Pine County.

Introduced pine sawfly

In 1998, summer started early in northern Minnesota so three generations of sawflies were produced this year. The first generation was active in June, feeding on previous years' growth. The second and third generation larvae fed on the current year's needles as well as the previous years' growth. White pine defoliation caused by introduced pine sawflies was reported across southern Beltrami, Crow Wing and Morrison and Hubbard Counties, especially on ornamental trees.

Pine needle rust

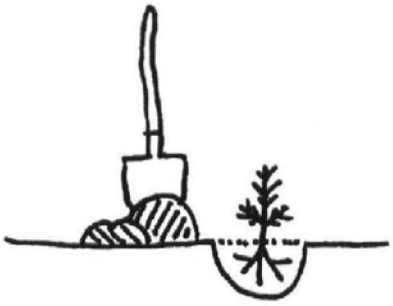
During May and June, several young red pine plantations in east central Minnesota were diagnosed with pine needle rust. Needle rust is most common on young red, jack and Scots pines up to about eight feet in height. It usually does not seriously damage the trees because only older needles are infected. Growth is slowed because the infected needles die. Only when combined with insects or other agents that attack current-year shoots and needles, can tree mortality occur.

White pine bark adelegids

White pines infested with pine bark adelgids were observed in Sherburne County on June 12th and in Beltrami County on July 24th. These insects usually feed on the undersides of limbs and on the trunk by inserting their stylets through the bark into the phloem tissues. They may be recognized by the white cottony material that collects in patches where they are feeding. Depending on the summer, several generations can be produced during the growing season. White pine bark aphids can be serious pest, causing twig and branch dieback and even tree death.

Cone beetles in branch tips

White pine cones were not abundant this year in Kanabec and Isanti Counties so the cone beetles had little choice but to attack the new shoots. Less than 1% of the new shoots were attacked, but they wilted, discolored and some fell to the ground. *Conophthorus coniperda* caused 90% of the damage



Forest Nurseries

The two DNR tree nurseries provide forest tree planting stock for Public and private use. The General Andrews and Badoura Nurseries have production capabilities of over forty million seedlings per year on their 270 acres of seedbeds. One, two, three and four year old trees are produced.

Seedlings are sold for afforestation, reforestation, wildlife habitat, windbreaks, shelterbelts, erosion control and soil and water conservation. Since the beginning of operations in 1931, state nurseries have grown and shipped over 815 million seedlings for planting in Minnesota. While manual, mechanical and chemical weed control remains the major pest management program in our Nursery operations, the following impacts were recorded in the 1998 growing season.

Nursery best management practices study

A project is currently underway at General Andrews State Forestry Nursery to develop best management practices for the continued production of low cost, high quality, native, bareroot seedlings with minimal environmental impact. Key areas of investigation include soil water management, weed control and fumigation practices related to the production of white pine and black walnut seedlings.

Soil water management tests will study sub-soiling regimes and equipment choices such as rototillers and tines, to reduce soil compaction. Irrigation techniques will be studied using new commercially available technology to determine timing and amounts of water needed for each irrigation event. The movement of water through nursery seeding and rooting zones is a critical factor in the potential impact of damping off and root rot agents.

Weed control is a primary challenge in bareroot nursery operations. All practices, sequences, and timings of organic management, fallow, cultivation and chemicals use will be reviewed.

Fumigation using sodium methydithiocarbamate (Vapam HL or Sectagon 42) will be tested against untreated fields. Fumigation is cheap insurance for bareroot operations, but its efficacy needs to be continually reviewed in relation to cost, impact on non-target organisms and health and safety issues.

Walnut (a one year product) results will be available in the Spring of 2000 and white pine (a three year product) results are to be reported in 2002.

Forest Nurseries

An active crop protection program continues in the State Forest Nursery Program. Pesticides were used on approximately 40 acres. While the major effort is still integrated weed control, direct control actions were taken on the following insect and disease agents:

Control Activities in Forest Nurseries - 1998			
Location	Target pest	Product	Comments
Greenhouse	*Botrytis cinerea*	Clearys 3336	Backpack sprayer used to apply fungicide to approx. 400 potted trees: two applications; preliminary indications suggest good control of this grey mold problem on grafted stock.
Greenhouse	*Cinara* spp.	Diazinon	Backpack sprayer Two applications Good control
Badoura	Cutworms in 1-0 conifers, Cottony aphids in 2-3 white pine, Spruce sawfly in windbreak	Diazinon	Tractor spray rig. Good control
General Andrews	Cutworms in 1-0 conifers, Cottony aphids in conifers, White grubs in 1-0 hardwoods	Diazinon	Tractor spray rig. Good control
General Andrews	Diplodia blight prevention in red pine seedlings	Thalonil	Tractor spray rig. Good control.
General Andrews	Phomopsis blight in red cedar, Leaf curl and spot in red and white oaks	Clearys 3336	Tractor spray rig. Good control.
Both Nurseries	General fumigation of seed beds	Metam-sodium	Tractor with 2 level liquid injection then water sealed

Weather-related

Included in this report:
El Nino and winter weather
Windstorms
Tornadoes
Straight-line winds, thunderstorms and hail
Storm damage hazard tree survey
St. Peter hazard tree inspection
High-low water table maladies
Fall coloration

El Niño and winter weather

The winter of 1997-1998 was one of the warmest on record. Winter is often defined by climatologists as the months of December, January, and February ("meteorological winter"). Minnesota experienced unusually mild temperatures in each of these months. The state-wide average temperature for December, 1997 was 23.6 degrees F, which is 10. 8 degrees above normal. January's average
temperature was a mild 14. 0, above the norm by 7.1 degrees. The month of February was extraordinarily warm, averaging 28.0 degrees, exceeding the normal by 14.9 degrees. The temperature for the 1997-1998 meteorological winter (December - February) averaged 21.9 statewide, which places this Winter second only to 1877-1878. The Winter of 1877-1878 is far and away the warmest Minnesota winter of the post-settlement era.

The warmest December - February temperatures in Minnesota's state-wide record are:

Rank	Temp. (F)	Year
1	26.0 est.	1877-78 *
2	21.9	1997-98 *
3T	21.7	1930-31 *
3T	21.7	1986-87 *
5	19.8 est.	1881-82
6	19.6	1991-92 *
7	19.5	1982-83 *

An asterisk (*) indicates an El Niño winter. Note that six of the seven warmest winters in Minnesota's recorded history occurred during El Niño episodes.

Windstorms

Minnesota saw some exceptional weather activity in 1998. The spring and summer of 1998 were fraught with several major storm events that swept across the Minnesota landscape causing tremendous damage to property and the loss of thousands of trees. These storms included tornadoes, straight-line winds, heavy rains, and hail. The magnitude of the economic and ecological losses incurred from these storms is still being assessed but preliminary results of many surveys indicate that the total losses are staggering. Five major storm events occurred between March 29th, 1998 and July 20th, 1998. These storms impacted some 79 cities throughout the southern half of the State. At the end of July some reports put the total incurred losses (preliminary estimates of the damage) at $16,550,000. In late December 1998 the Insurance Federation of Minnesota reported that the total damage claims for the year resulting from these storms had reached at least $1.51 billion, exceeding the sum of all insurance losses recorded in the state from 1948 to 1997.

Tornadoes

On March 29th, 1998 violent tornados swept across several south central counties leaving a swath of massive destruction to property and landscapes. Thousands of trees in the communities of Jeffers, Comfrey, Hanska, Courtland, Cambria, Judson, St. Peter and Le Center were lost or severely damaged.
A hazard tree assessment crew made up of personnel previously trained in hazard tree detection and assessment was organized. This crew assessed in excess of 3,000 trees in the communities of St. Peter and Le Center during a two-day period in early April. In St. Peter, 1,085 trees were marked as hazardous; all were to be removed except for 460 that were marked for corrective pruning. Of the 625 trees recommended for removal, severe crown damage was the major defect. Trees that had not failed due to weak unions or windthrow had their crowns ripped apart. The only trees that survived the storm averaged 6 to 8 inches in diameter. Larger trees were either destroyed by the storm or were marked for removal. In all some

On May 15th, 1998 a tornado also ripped through parts of Shoreview destroying homes and uprooting and damaging more than 5,000 trees on public and private lands.

Straight-Line Winds, Thunderstorms, and Hail

One of the earliest of the terrible wind storm events that we experienced in Minnesota this year was the straight-line wind of May 15th in Sherburne and Anoka Counties. Unfortunately, the timing was perfect for the spread of oak wilt to the newly wounded trees. In July and August, local foresters observed new infection centers and rapid enlargement of old infection centers due to storm damage.

Much of 1998's storm damage occurred May 15, when high straight-line winds and hail pummeled the Twin Cities resulting in more than $933 million in damage claims to property, some of which was caused by large numbers of tree failures. Hail caused a large portion of the damage from this storm.

On May 30th, 1998 heavy thunderstorms created more straight-line winds in excess of 80 mph that caused considerable property damage and loss of more trees. During this storm 2,700 trees were lost in St. Paul; 2,000 in Minneapolis; 1,000 in Apple Valley; 1,000 in Eagan; 300-400 in Hastings and perhaps thousands in Cottage Grove and Inver Grove Heights.

On June 27th, 1998 heavy thunderstorms again generated straight-line winds that wreaked more devastation on new areas as well as many that were recovering from damage sustained in the previous storms. The final storm during this period occurred on July 20th, 1998. This storm impacted New Ulm and hit St. Peter adding more damage on top of what had already occurred during the tornado of March 29.

Two different surveys follow. The first is a survey that was initiated by the DNR to obtain information from communities that were affected by the storms described above. This survey was sent to 321 communities. To date 175 communities have responded to the survey. This represents 54% of the number of surveys that were sent out to the communities. This survey covers the time period from 7/1/97/through 9/1/98 and therefore, includes data from the previous year. There were two major storm events in 1997 for which data is included in this survey. This survey is included here to give a sense of the magnitude of the damage and losses of trees that these types of catastrophic weather events can have on forest resources.

Storm Survey Results for 7/1/97 through 9/1/98

(These results are based on 175 of 321 Surveys that have been returned to date representing 54% of the communities that were sent a survey)

County	Public Trees Lost	Private Trees Lost	Damaged Trees	Total Cost	FEMA Cost
Anoka	17679	25896	9341	$1,475,275	$785,680
Benton	117	343	399	$16,000	$0
Blue Earth	107	33	485	$90,158	$11,744
Brown	0	10	0	$3,000	$0
Carver	935	2475	1804	$665,841	277,852
Chisago	0	0	0	$0	$0
Dakota	4686	10394	20366	$3,088,280	$1,856,394
Dodge	0	0	0	$0	$0
Goodhue	320	873	825	$84,591	$56,420
Hennepin	5260	9725	8700	$4,767,790	$3,615,900
Isanti	0	0	0	$0	$0
Kandiyohi	0	0	0	$0	$0
Le Sueur	59	96	84	$16,700	$0
Meeker	6	0	15	$700	$0
Mower	14,500	1,500	300	$0	$0
Nicollet	2390	4000	560	$0	$0
Ramsey	483	5243	4578	$958,977	$810,377
Redwood	0	0	0	$0	$0
Rice	0	0	0	$0	$0
Scott	2005	5000	50	$343,392	$263,251
Sibley	13	22	27	$0	$0
Stearns	20	0	20	$2,000	$0
Wabasha	170	448	250	$68,000	$7,500
Waseca	0	0	0	$0	$0

Washington	328	350	736	$106,484	$20,000
Winona	117	100	265	$21,715	$10,587
Wright	932	1164	227	$69,440	$44,676
TOTALS	**50127**	**67672**	**49032**	**$11,778,343**	**$7,760,381**

Storm damage: Hazard tree survey

The second damage survey was conducted by Gary Johnson, Associate Professor of Urban and Community Forestry from the University of Minnesota Department of Forest Resources and Lorrie Stromme, Tree Care Advisor, University of Minnesota Extension Service Department of Forest Resources. This survey was based on the examination of individual trees that were damaged or lost during the various storms. The results from the data compiled suggest that much of the damage was due to more than just forceful winds.

In all, forty-two (42) tree species were documented as damaged by these storms. Five hundred sixty-four (564) individual trees were examined and the following data was collected from each tree examined: date damaged, location (community/address), siting (lawn, blvd., etc.), species, size, type of storm, type of damage, any preexisting conditions that were associated with the failure/damage, and other comments. The data was collected from March through July of 1998.

The types of damaged observed were collapsed into three general categories. Category one was total failure of a tree, defined as failing at or below the ground line. Category two was a stem failure, defined as failing at the stem between the ground line and the first set of true branches. Category three was canopy damage, defined as damage that affected the area between the first set of true branches and the terminus of the canopy.

Most commonly damaged species (all storms, all types of damage)	
Species	**% of Total**
Green Ash	16.0
Colorado Blue Spruce	11.0
Littleleaf Linden	10.0
American Elm	8.0
Hackberry	6.0
Sugar Maple	6.0

Most common preexisting conditions (for all damage, separate conditions	
Condition	**% of Total**
Decay Only	13.3
Stem Girdling Roots	10.1
Included Bark Only	4.1
Root Problems	3.2
Codominant Leaders Only	3.0
Construction Damage Only	0.2

Most common type of damage (all storms)	
Damage	**% of Total**
Total Failure	56.9
Canopy Failure	27.3
Stem Failure	15.1
Multiple Failure/Damage	0.7

Most common preexisting conditions (for all damage, combined preexisting conditions)	
Condition	**% of Total**
Decay + Codominance + Inclusion	16.0
Codominance + Inclusion , Inclusion and Codominance	13.3

Most commonly damaged size (d.b.h.) Ranges (all storms, all damage	
Size (d.b.h.) Range	% of Total
10-15 inches	23.6
>25inches	23.4
6-10 inches	17.0
20-25 inches	16.8
15-20 inches	16.5
< 6 inches	2.7

Most common sites (for all storms, all types of damage)	
Site	% of Total
Park*	46.1
Lawn*	28.9
Boulevard*	24.5

* Park sites included parks, schools, campuses, and golf courses.
*lawns included residential and commercial private greenspaces.
*Boulevards, a.k.a. tree lawns, included those with and without sidewalks.

Types of damage with species ranking:	
Total Failure	**%**
Colorado Blue Spruce	18.4
Green ash	17.1
Littleleaf Linden	13.7
Red Pine	6.0
Silver Maple/Crabapple	3.4
Canopy Damage	**%**
Green ash	17.1
White Oak	13.0
Sugar Maple	12.3
American Elm	11.7
Stem Damage	**%**
Hackberry	20.0
Norway Maple	9.4
Littleleaf Linden	7.1

The sorted statistics for this survey follow:

Commonly damaged species with chronic problems:

1. **Green Ash:** 73% of those that suffered stem and canopy damage had included bark and decay as preexisting conditions for failure.
2. **Littleleaf Linden:** 73% of those that suffered total failure were planted too deep and had stem girdling roots causing stem compression.
3. **Colorado Blue Spruce:** 82% of those suffering any type of damage had no preexisting conditions for failure.

Common preexisting conditions associated with failures:

4. For all trees that failed totally, 17.8% were planted too deep and had stem compression from stem girdling roots.
5. For all trees that failed totally, and were located outside of the storms' centers, 30.1% were planted too deep and had stem compression from stem girdling roots.
6. For all trees that suffered canopy damage, 78% of the trees had included bark, codominant leaders, codominant leaders with included bark, and/or decay associated with the inclusion and codominance.

St. Peter Hazard Tree Inspection Of 623 Storm Damaged Trees, Following The March 29, 1998 Tornado

On Sunday March 29, 1998 an F-3 class tornado ripped through St. Peter, Minnesota, population 9,420, devastating the community and destroying an extensive nearly mature urban forest. See Special Projects section for more information about the storm.

It was estimated by the city of St. Peter that 8,406 blew down at the time the storm struck the community. Those toppled trees were removed in the first five days after the storm, by an army of contractors, Department of Natural Resources crews, and volunteers. On Friday, April 3, a tree inspection began to evaluate the safety and defect status of all the remaining standing trees throughout the hardest hit areas of the city. Ten trained DNR tree inspectors working in pairs, inspected an estimated 3500 trees in the following three days. Of these trees, 1,083 were stormed damaged, 623 were marked for removal and 460 were saved and marked for pruning.

Criteria use for tree removal were based on the Minnesota DNR's Hazard Tree Assessment guidelines.

Five criteria for defect assessment were given to the trained inspectors. The inspectors were instructed to record the reason for all tree removals and estimate the tree size in dbh, (diameter at breast height). Trees with more than one defect category were recorded as multiple defects. All standing trees were inspected on both public and private property. On private property, attempts were made to contact the homeowner for their input.

The six failure categories used for tree removal decisions were:

1. Wind-throw; Leaning trees with evidence of recent root lifting or soil movement.
2. Crown Damage; If greater than 1/3 of the crown was damaged consider removal, if greater than ½ of the crown was damaged, remove tree. (Tree removal is preferred over severe pruning or topping for cultural, aesthetics, long term maintenance, and future safety).
3. Branch union failure; Failed weak unions on the main stem or a forked tree that compromised more than ½ of the stem circumference.
4. Main Stem Failure; New cracks associated with an existing defect that what would otherwise be considered less than threshold level, (moderate risk potential), defects. These are decay columns, or and canker and decay defects with new cracks, that affect 1/3 to ½ the stem circumference.
5. Main Stem Failure; New cracks that compromise greater than ½ the stem circumference.
6. Multiple Defects; If more than one of the above contributed to the tree failure, the multiple defect category was used.

Summary

Of the 1, 083 storm damaged, still standing trees surveyed in St. Peter following the March 29, 1998 tornado, 623 or (57.5%) were recommended for removal and 460 or (42.5%) were salvaged by recommending pruning and or removing lodged and hanging branches. See Tables 1-4. In addition to the trees that were salvaged, it is estimated that another 1800 trees located on both boulevards and private land survived. Their average size is estimated to be 9 to 10 inches in diameter.

Table 1. Number Of Trees Removed by Defect Category.		
Defect Category	**# Trees**	**% of Total**
1. Crown Damage	324	52
2. Wind-throw.	123	19.8
3. Failed Unions.	117	18.8
4. New Cracks w/ existing defects.	13	2.1
5. New Cracks.	9	1.4
6. Multiple defects.	37	5.9

Table 2. Number Of Trees Removed, By Percent and Size.			
Species	**# trees**	**%**	**Av. Size- dbh.**
All - Maple Sp. (Silver, & Sugar)	208	33.4	19.5
Sugar Maple	68*	-	21.5
Silver Maple	66*	-	18.8
Elm Sp.	63	10.1	19.5
Green Ash	51	8.1	15.6
Spruce Sp.	42	6.7	10.5
Black Walnut	35	5.6	18.8
Box elder	34	5.4	14.6
Hackberry	33	5.3	17.8
Locust Sp.	33	5.3	13.7
Norway Maple	21	3.3	10.8
Red & White Cedar	16	2.5	12.2
Basswood	14	2.2	15.8
Balsam Fir	11	1.7	8.0
Red Pine	11	1.7	11.2
White Pine	7	1.1	16.5
Black Willow	7	1.1	23.1
Other, 10 species	37	5.9	-
Total	623	-	-

*The number of Sugar and Silver identified to species from the total of 208 maple.

Table 3. Number Of Trees Removed By Failure Category In %.

Species	Percent Of Species Removed By Failure Category					
	Crown Damage	Wind-throw	Main Stem Failures			Multiple
			Unions	Defects	New Cracks	
Sugar Maple	54	6	21	3	4	12
Silver Maple	59	7	20	0	2	9
Elm Sp.	70	10	11	0	0	10
Green Ash	53	27	20	0	0	0
Spruce Sp.	38	60	0	0	0	2
Black Walnut	60	18	13	3	0	6
Box elder	68	9	9	6	0	9
Hackberry	18	21	43	4	7	7
Locust Sp.	33	17	42	0	0	8
Norway Maple	33	0	19	19	5	24
Red & White Cedar	40	60	0	0	0	0
Basswood	36	50	7	0	0	7
Balsam Fir	64	36	0	0	0	0
Red Pine	19	81	18	0	0	0
White Pine	0	100	0	0	0	0
Black Willow	57	28	14	0	0	0

Table 4. Number Of Trees Saved By Pruning, Percent and Size.

Species	# trees	%	Av. Size-dbh
Maple Sp. (Silver & Sugar)	158	34.3	19.5
Green Ash	46	10	14.2
Honey Locust	43	9.3	11.6
Norway Maple	43	9.3	12.9
Black Walnut	42	9.1	18.1
Elm Sp.	23	5.0	17.0
Hackberry	22	4.7	15.7
Basswood	14	3.0	14.8
Other (>dozen species)	69	17.6	-
Total	460		

High-low water table maladies

During the period from winter snow melt (which was very little) to the first part of June we were pondering the outcome of drought stresses on landscape trees and just how severe the effect would be. In mid-July we were wondering what the outcome of summer flooding might be, especially in western counties of Region I (where farmers are towing canoes and boats behind their farm equipment so they can get home from the fields).

Coupling the early drought stress with growing season root suffocation, the high-low water-table maladies may generate significant tree mortality in the next few years. Many trees can tolerate high water tables but these are not the same tree species people favor as yard trees. Trees, especially large ones, do not respond to fluctuating water levels like crops, such as, alfalfa. Tree responses are more subtle and incremental. One has to be more cognizant of past events, maybe over the past ten years or so. Trees experiencing midsummer flooding are vulnerable to trunk canker diseases and stem borers and bark beetles.

Fall coloration

As of September 23rd DNR State Parks and Forests reported that fall colors were peaking in some areas of the northeast. Most of the northern region of the state is in the range of 30% to 70% of peak fall colors. The central part of the state should reach peak in early October and the southern part of the state will probably be best in mid-October.

In the Metro area, many prairie areas, lakes and ponds are providing some of the best views of fall colors along with an abundance of the usual forms of wildlife found in these habitats. Scattered maples and sumac are providing a good contrast of reds and oranges while ash, aspen and birch are revealing bright yellows and gold. Prairie grasses and numerous flowers are contributing several shades of maroon and purple. Peak fall colors for much of the Metro area are expected in the first two weeks of October. Look for oaks to peak around October 11-17th.

Wild Rivers State Park just east of North Branch reported a 90% change in prairie grasses and flowers, 10% of the ash and birch were showing bright yellows and 90% of the sumac in open areas was showing peak fall color. Interstate State Park near Taylors Falls reported 50% change throughout the park. The St. Croix river valley will be a good place to view the colors which are expected to peak between September 28th and October 11th.

Incidental Pests

Insects

INSECTS	HOST	COUNTY	COMMENTS
Abbot's sphinx moth *Sphecodina abbottii*	Grape	Crow Wing	
Ash plant bug *Tropidosteptes amoenus*	Green ash	Crow Wing, Roseau, Beltrami, Kittson	In June, associated with anthracnose
Aspen webworm *Tetralopha aplastella*	Trembling aspen	Lake	East of Winton
Balsam twig aphids *Mindarus abietinus*	Balsam	Crow Wing	
Birch leaf aphids Unidentified	Paper birch	Beltrami	Numerous generations throughout summer. Dripping honey dew.
Blister gall mites Unknown genus	Bur oak	Beltrami, Hubbard, Becker	
Borers Unidentified	Maples, oak, white and blue spruce	Beltrami, Becker, Hubbard, Koochiching	Common in 1998. Associated with sapsucker damage. Yard oaks in Littlefork.
Borers Unidentified	Ponderosa pine	Becker	Windbreak in yard. 10-14 foot trees. Recently pruned.
Box elder bug *Leptocoris trivittatus*	Box elder	Crow Wing, Beltrami	
Bronze birch borer *Agrilus anxius*	Paper birch	Widespread in northwestern and central MN	Increased activity observed in 1998. In urban and rural forests, on stressed trees.

INSECTS	HOST	COUNTY	COMMENTS
Butternut wooly sawfly *Eriocampa juglandis*	Butternut	Crow Wing	
Carpenter ants *Camponotus* spp.	Cabin walls	Crow Wing	Scattered pest problem .
Chafer beetle *Macrodactylus subspinosus*	Various trees	Aitkin and Crow Wing	
Deep wood borer *Monochamus scutellatus*	Pines		Widespread in Central MN on stressed trees.
European fruit lecanium *Lecanium corni*	Burr Oak	Stearns	
Gall midge *Cecidomyia* spp.	Trembling aspen	Crow Wing	Leaf blade edge galls
Gouty oak gall *Callirhytis quercuspunctata*	Oak	Crow Wing	
Io moth *Automoris io*	Hardwoods	Crow Wing	
June beetles *Phyllophaga* spp.	Oak, Ash	Roseau	Twig and leaf feeding by Adults in June.
Kermes twig scale Unidentified	Bur oak	Beltrami	Less reported in 1998.
Lace bug *Corythuca* spp.	Burr oak	Morrison, Crow Wing	
Leaf blister gall mite *Eriophyes* spp.	Burr oak	Morrison, Crow Wing	
Maple leaf gall mite *Cecidomyia ocellaris*	Maple	Crow Wing	
Mite *Eriophyes tristriatus*	Black walnut	Stearns	
Northern pine weevil *Pisssodes approximatus*	Blue Spruce, Scotch Pine	Beltrami, Ottertail	Plantation trees on sandy dry soils.
Northern sphinx *Lapara bombycoides*	Jack Pine	Hubbard	Incidental. Forest trees during E.M. surveys for JPBW.
Oak twig pruner *Elaphidionoides villosus*	Bur Oak	Beltrami, Hubbard, Becker.	

INSECTS	HOST	COUNTY	COMMENTS
Oak aphids *Myzocallis* spp.	Bur oak	Beltrami, L.O.W., Becker, Hubbard.	Widespread in Region 1
Pecan leaf casebearer *Coleophora laticornella*	Black walnut	Stearns	
Pine bark adelgid *Pineus strobi*	White pine		Widespread in Central MN.
Pine aphids Genus not determined.	White pine	Cass	
Pine sawyer beetles *Monochamus* spp.	White spruce, Balsam Fir, Pine species	Beltrami, Hubbard, Becker	Frequently observed in 1998. Significant reporting.
Pine gall weevil *Podapion gallicola*	Red pine		Scattered in Central MN.
Poplar borer *Saperda calcarata*	Hybrid poplar, trembling Aspen	Aitkin, Throughout Region 1	Increased activity observed in 1998. Associated with Hypoxylon infected trees.
Red turpentine beetle *Dendroctonus valens*	Red pine		Widespread on large stressed pines.
Red pine shoot moth *Dioryctria resinocella*	Red pine	Anoka, Hubbard, Beltrami, Becker, Widespread in Central MN	Not as common as previous two years.
Red-humped oakworm *Symmerista canicosta*	Apple	Crow Wing	
Root collar weevil *Hylobius radicis*	Scotch, Red and Jackpine	Ottertail, Beltrami, Becker, Hubbard	Frequent occurrence in 1998. Associated with water stressed sites.
Scale *Toumeyella* spp.	Mugo pine	Morrison	
Spider mites *Oligonychus* spp.	Arborvitae, spruce	Beltrami, Widespread in Central MN	
Spiny ash sawfly *Euparephora parca*	Green ash	Crow Wing	

INSECTS	HOST	COUNTY	COMMENTS
Spruce gall adelgids Unidentified	White Spruce	Roseau	Chronic defoliator on ornamental spruce.
Stink bug *Elasmuche* spp.	Birch	Crow Wing	
Striped alder sawfly *Hemichroa crocea*	Birch	Morrison	
Tarnished plant bug *Lygus lineolaris*	Birch	Crow Wing	
Two-lined chestnut borer *Agrilus bilineatus*	Red oak, bur oak	Pine, L.O.W., Beltrami, Becker, Hubbard	Stressed yard oak trees.
White pine weevil *Pissodes strobi*	White pine	Crow Wing, Beltrami, Hubbard, Washington	Yard trees, small plantations. Less reported than in 1997.
White pine aphid *Cinara strobi*	White pine	Washington	Heavy infestation on several trees on one property
Yellow-headed spruce sawfly *Pristiophora alaskensis*	Spruce	Crow Wing	Yard tree defoliation June 16.
Zimmerman pine moth *Dioryctria zimmermanni*	White pine, Scots pine and spruce	Scattered pest problem in Central MN, Ottertail.	SWCD plantation 40% + of saplings in plantation.

Diseases

DISEASE	HOST	COUNTY	COMMENTS
Anthracnose *Apiognomonia errabunda*	Oaks, Ash	Ottertail, Becker, Hubbard, Beltrami	Common in June and late August.
Armillaria root rot *Armillaria* spp.	Basswood, Oaks, Red Pine	Scattered sites, throughout Region 1; Widespread in Central MN on stressed trees.	Flooded and thinned basswoods, yard oaks. Flooded Red Pine plantations.
Black knot *Apiosporina morbosa*	Plum		Scattered in Central MN

DISEASE	HOST	COUNTY	COMMENTS
Canker *Botryosphaeria dothidea*	Sumac	Crow Wing	
Cedar-apple rust *Gymnosporangium junipero-virgininae*	Red Cedar	Beltrami	Urban - neighbors with crab apples.
Cytospora canker *Cytospora kunzei*	Blue Spruce, White Spruce, Norway Spruce	L.O.W., Beltrami, Hubbard	Commonly observed in Region 1 - stressed yard windbreaks. Transplanted trees. Norway Spruce Plantation 60%.
Diplodia tip blight *Sphaeropsis sapinea*	Red Pine , Ponderosa Pine	Anoka, Becker, Hubbard	Stressed trees.
Dutch elm disease *Ophiostoma* spp.	Am. Elm	Regs. 1 & 3	
Elm wetwood Bacterial species	American elm	Todd	Scattered, on yard trees in Central MN.
Fireblight *Erwinia amylovora*	Crabapple, Plum, Apple	Crow Wing, Beltrami, Hubbard, Ottertail	
Leaf spot *Septoria musiva*	Balsam poplar		Widespread but scattered in Central MN.
Needlecast *Rhizosphaera kalkhoffii*	Blue spruce	Anoka, Widespread in Regs 1 & 3	Common on yard trees and windbreaks.
Pine needle rust *Coleosporium asterum*	Red pine	Pine	
Sapwood rot and canker *Cerrena unicolor*	Sugar maple	Todd	On young sugar maples stressed by wet soil in one stand.
Smooth patch of bark *Aleurodiscus oakesii*	White Oak	Cass	
Sooty mold *Catenuloxyphium semiovatum*	Basswood, Oak, Jackpine, White Spruce, White Pine	Widespread	Associated with Aphid and scale feeding.
Spruce needle rust *Chrysomyxa ledi* and *Chrysomyxa ledicola*	White spruce, Blue Spruce	Region II and Roseau	In July after heavy rains.
White pine blister rust *Cronartium ribicola*	White pine	Scattered in Regs 1 & 3, Washington	Yard and windbreaks.

Animals and abiotic

Animal or condition	Host	County	Comments
Commercial Development	Red Pine, Basswood	Scattered sites	Site clearing during drought conditions.
Drought - Low Water Table	Conifers, Hardwoods	Throughout Region	Yard trees, plantations, associated with Armillaria, weevils, back beetles, borers.
Excessive Watering	Arborvitae	Beltrami	Associated with Armillaria Root Rot. Large Resort yard.
High Water Table	Red Pine, Basswood	Beltrami	Associated with Armillaria, Borers, Root weevils, plantations, and yard trees.
Iron chlorosis	White spruce	Todd	Probably caused by high water table in 1997.
Landscaping	Red Pine	Beltrami	Housing development in Red Pine plantation.
Pocket Gophers	Red Pine, Jackpine, White Spruce	Clearwater, Beltrami, Hubbard, Becker	Commonly reported in 1998. SWCD plantings, off yard windbreaks.
Porcupine	Pine species	Beltrami	Off yard trees. Along Roadways, windbreaks.
Power lines	Red Pine	Beltrami	Root excavation - combined with drought conditions Armillaria.
Sapsuckers	Mountain Ash, Maples, Blue Spruce, White Spruce, Oaks	Throughout Regs. 1 & 3	Widely reported and observed in 1998. Stressed trees.
Transplanting Failures	Norway Pine, White Spruce	Beltrami, Hubbard	Machine transplanting during drought - summer periods - lacking adequate site preparations. Concrete planting jars by sidewalks, parking lots, etc.

Animal or condition	Host	County	Comments
Wetland site changes	Red Pine	Beltrami	Two SWCD plantations affected by water drainage changes. Associated with Armillaria and weevil damage.

Phenology 1998

Accumulated degree days are calculations based on daily high and low temperature readings starting on March 1st of the year with the base temperature of 32°F. Temperature readings were taken at St. Paul, Grand Rapids, Brainerd, St. Cloud, Hinckley, Duluth, Park Rapids, Aitkin, Little Falls, Hibbing and International Falls.

Date	Event	Accumulated degree days	County or location
	Spring is 3 to 3.5 weeks ahead of an average year.	NA	Northern MN
2/ 19	Frost is beginning to exit the ground. Temperatures above freezing for past 5 days.	NA	Ramsey
3/ 19	Pines and spruces started to photosynthesize - you can see the green change from day to day.	6	Ramsey
3/ 20	Most small lakes are ice-free around their edges.	6	Ramsey
3/ 22	Silver maple buds are rapidly swelling.	11	Ramsey
3/ 25	Silver maples are beginning to flower.	29	Ramsey
3/ 26	This was the third straight day that afternoon temperatures broke 50° after the area is free of snow, SO, the bark beetles are presumed to be active.	56	Ramsey
4/ 03	Aspen catkins just opening. Red maple flower buds expanding 2-3X. Saw 3 mourning cloak butterflies.	107	Crow Wing
4/ 06	Silver maple blooming and aspen male catkins open.	138	Crow Wing
4/ 07	Elms blooming.	154	Crow Wing
4/ 08	Trillium and lilacs blooming.	160	Crow Wing
4/ 12	Red and white oak buds are expanding, about 2X. Mixed woods have taken on a minty green shade. Bloodroot, Virginia bluebells and Monarda are up. Poplars flowered last week. Grass fires running really well.	332	Ramsey
4/ 20	FTC hatching.	447	Todd
4/ 22	Prairie buttercup, pasque flower, and *Hepatica* blooming.	360	Crow Wing

Date	Event	Accumulated degree days	County or location
4/ 23	Red and pin oak buds are now 1.5 inches long. Some trees have mini-leaves on them. Mayapples up yesterday.	540	Ramsey
4/ 24	White spruce buds swelling. Spermatia in liquid drops on jack pine galls. Oak leaves and flowers just visible , and birch catkins well formed.	402	Crow Wing
4/ 24	Some aspen clones leafing out.	414	Itasca
4/ 27	Basswood leaves 1 ½ inches, and Juneberry trees blooming.	605	SE Todd
4/ 27	In bark beetle pheromone traps: one turpentine beetle and a few *Ips* bark beetles. Rose gall wasps emerged from mossy gall.	465	Itasca
4/ 28	Red oak shoots are 1-3 inches long, leaves 1 inch. Walnut shoots expanding, ½ inch long. Ash starting to leaf out. Red pine in short candle stage, white pine about the same. White spruce will pollinate within 2-3 days. *Trilliums* in flower.	662	Ramsey
4/ 28	Tamarack needles showing. About 80% of deciduous trees in leaf and flower.	477	Crow Wing
4/ 29	In bark beetle pheromone traps: one turpentine beetle.	507	Itasca
4/ 29	Marsh marigolds in bloom at Woodenfrog Campground.	405	St. Louis
4/ 29	Bloodroot, marsh marigolds, and Dutchman's breeches blooming.	495	Crow Wing
4/30	Quaking aspen leaves just out. Amelachier in full bloom. Bloodroot just starting to bloom. In bark beetle traps: one turpentine beetle and about a dozen other species.	533	Itasca
4/ 30	Spruce budcaps loose and a few green needles showing	518	Crow Wing
4/ 30	Quaking aspen leaves are quaking. Bur oak leaf buds broken and maple leaves just appearing. Marsh marigolds in bloom.	559,450, 559	Pine, Aitkin and Carlton
5/ 01	Pin cherry blooming.	475	Aitkin
5/ 02	Choke and pin cherries just starting to bloom.	587	Itasca
5/ 03	Bigtooth aspen starting to leaf out.	614	Itasca
5/ 04	Balsam fir buds expanded to ½ inch. Leaf lengths: red oak = 2", bigtooth aspen = 7/8", basswood = 1 ¼", birch 1 ¼" and sugar maple = 2 ¼". Purple elderberry starting to bloom. Raspberry and blueberry flower buds are just barely visible.	643	Itasca

Date	Event	Accumulated degree days	County or location
5/ 07	Gall rust galls sporulating on jack pine. Red maple in fruit (seed). Flowering crabs and apples blooming.	697	Crow Wing
5/ 07	In bark beetle traps: seventeen turpentine beetles.	720	Itasca
5/ 07	*Acrobasis* in walnut shoots now.	799	Isanti
5/ 08	Spruce budworm 1/4 inch long, 3rd instar	903	Morrison
5/ 08	FTC 3/16 to 7/16 inch long	759	Mille Lacs
5/ 08	White spruce cones turning pendant, about 60%.	930	Ramsey
5/ 08	Crab apples in full bloom. A few lilacs starting to bloom.	745	Itasca
5/ 08	Hoary puccoon blooming.	724	Crow Wing
5/ 09	Red pine candles 6" + long, beginning needle elongation. White spruce foliage indicates yellow-headed spruce sawfly oviposition.	959	Ramsey
5/ 10	Mayapple in flower.	987	Ramsey
5/ 11	Forest tent caterpillars in Father Hennepin State Park are 3/4 inches long.	829	Mille Lacs
5/ 11	Black ash breaking bud. Crab apples in full bloom. Apples and lilacs starting to bloom.	818, 804	Itasca, Cass
5/ 11	Spruce budworm 1/4 inch long. White spruce bud caps are >50% off.	990	Morrison
5/ 12	Spruce budworm 1/8 to 3/16 of an inch long. Togo.	844	Itasca
5/ 12	White spruce candles in floppy stage. Silver maple seed crop beginning to shed - very heavy this year.	1056	Ramsey
5/ 13	Starting to bloom: wood anemone, Jack in the pulpit and Ohio buckeye.	870	Itasca
5/ 14	Spruce budworm 7/8 inch long, 4th or 5th instar. Red pine sawfly 1/4 inch long, 4th or 5th instar, on jack pine. Spruce budworm in 4th and 5th instar at Barrows. Hoary puccoon blooming. Wake robins are blooming 5 miles north of Crosby.	874	Crow Wing
5/ 15	Strong, straight line winds cause wide spread tree breakage in Sherburne Co, especially on the Anoka Sand Plain. Both oak wilt fungus and picnic beetles are active.	1048	Sherburne
5/ 15	Scots and Jack pine pollen shed just starting. *Trillium* blooming. In bark beetle traps: 16 turpentine beetles. Mountain ash starting to bloom.	950	Itasca

Date	Event	Accumulated degree days	County or location
5/ 16	Red pine pollen being shed.	981	Itasca
5/ 17	Mt. ash in bloom.	1013	Itasca
5/ 18	Blue lupine blooming. Found one FTC, 1 and 1/4 inch long.	1019	Crow Wing
5/ 19	Expect first generation of bark beetles to emerge by the first week of June at the latest and by next week at the earliest.	NA	Crow Wing
5/ 19	Red pine sawfly larvae are 1/4 inch long and feeding on older foliage. Birch leaf miners averaging 3 larvae per leaf with up to 10 per leaf. FTC are 7/8 inch long.	1059	Crow Wing
5/ 19	Rosy maple moths (green-striped mapleworms) are out in great numbers. Backus, Pillager to Crosby and north shore of Mille Lacs. Also Cambridge.	1059, 976, 1200	Crow Wing, Aitkin, Isanti
5/ 19	FTC 3/4 to 1 3/4 inch long on basswood, south side of Mille Lacs.	1107	Mille Lacs
5/ 19	FTC reported on oak on north side of Gull Lake.	1073	Cass
5/ 19	FTC reported in Wright County and in SE MN.	1200, NA	Wright County and in SE MN
5/ 19	Black ash starting to leaf out.	1088	Itasca
5/ 24	Aspen in bloom	1195	Crow Wing
5/ 26	FTC 2 inches long.	1254	Crow Wing
5/ 27	Spruce budworm 5 to 10% pupated.	1287	Crow Wing
5/ 28	Spruce budworm 5/8 to 7/8 in long and into 5th instar. A few bark beetles are starting to pupate, mostly larvae, though.	1347	Itasca
5/ 29	Wild geranium blooming.	1635	Todd
5/ 30	FTC building cocoons.	1379	Crow Wing
6/ 08	Bark beetles are callow adults, no emergence of first generation. Spruce budworm about 5% pupated. Found a single FTC, 1 and 3/4 inch long.	1566	Itasca
6/ 10	Larch sawfly laying eggs. Some larvae hatching and are 1/8 to 1/4 inch long. Some larch needle rust and its sporulating. In bloom= blue flag and bunchberry.		St. Louis
6/ 12	Catalpa blooming.	1991	Morrison
6/ 15	Orange hawkweed and poke milkweed blooming.	1766, 2104	Crow Wing and Morrison

Date	Event	Accumulated degree days	County or location
6/ 15	Spruce budworm 60-70% pupated. First generation of bark beetles starting to emerge. Ely	1515	St. Louis
6/ 15	FTC 90% pupated. Greenstriped mapleworm eggs hatching.	1766	Crow Wing
6/ 16	Chafer beetle shredding leaves.	1801, 1708	Crow Wing and Aitkin
6/ 17	Yellow-headed spruce sawfly larvae are ½ inch long.	1850	Itasca
6/ 19	Many spruce budworm moths. Indian paint brush, hoary allysum and butterfly weed blooming.	2254	Morrison
6/ 24	Yellow-headed spruce sawfly larvae are 5/8 inch long.	1788	St. Louis -Duluth
6/ 24	A few 7th instar jack pine budworms found on drop-cloth samples of l4 trees.	2088	Hubbard
6/ 25	Fireweed, black-eyed susan, cow vetch, and water hemlock blooming.	2176	Pine
7/ 02	Greenstriped mapleworms 1/4 to 1 inch long.	2370	Crow Wing
7/ 06	Orangestriped oakworm 3/16 inch long, and some egg masses.	2920	Todd
7/ 06	Sunflower, lead plant, and goldenrod blooming.	2920	Todd and Morrison
7/ 09	Pinkstriped oakworm 1 1/4 inch long.	2838	Benton
7/ 10	Purple aster and wood lily blooming.	2627	Pine
7/ 15	Larch sawfly about 1 inch long.	2514	St. Louis
7/ 21	Greenstriped mapleworm pupating.	3108	Crow Wing
8/ 19	Grey willow leaf beetle adults active.	3705	St. Louis
8/19	Aspen webworm on aspen.	3705	Lake
8/ 19	Rough blazing star blooming.	3673	Pine
9/ 02	Orangestriped oakworm 95% pupated.	5280	Todd
9/ 03	Orangestriped oakworm 100% pupated.	4645	Crow Wing
9/ 17	Purple aster in full bloom. Red and white pine shedding needles. Oaks still green. Balsam poplar bare due to Septoria infection. In swamps, all black ash leaves down. Lots of wooly bear caterpillars moving across the highway today.	5194	Cass

Date	Event	Accumulated degree days	County or location
10/ 06	Peak fall color week.	5522	Itasca
10/ 12	Larches brilliant yellow.	5632	Itasca
12/ 01	Crocuses emerging, **again**.	NA	Ramsey

Special Projects

Included in this report:

Final report: Cooperative Suppression Oak Wilt Control in Minnesota, FFY1991 through FFY1997
Uncas Dunes Scientific and Natural Area - Oak wilt field trip notes
Oak wilt suppression and Mn ReLeaf grants in Region 3

Final report: Forest tent caterpillar impact in the Brookston mixed-species forest
Forest tent caterpillar: Good, bad or just ugly?

NAMP results: Are sugarbushes as healthy as other sugar maple stands?

Itasca Park: Old growth and bark beetles - Three years after the big blow

Fliers, publications and articles

White pine: How to prune for blister rust
Growing White Pine in Minnesota
White Pine Care Guide (cover only)

Risk assessment guidelines: Hazard trees, an easy to use field guide

Cooperative Suppression Program Oak Wilt Control in Minnesota
Final Report: FFY 1991 through FFY 1997

The federally assisted Cooperative Suppression Program for Oak Wilt Control (CSP) was begun in 1991 and concluded its field activities with the freezing of the ground in December of 1997. Field activities were authorized by the US Forest Service with the issuance of a Finding of No Significant Impact (FONSI) in 1991 resulting from an Environmental Assessment undertaken jointly by the Minnesota Department of Natural Resources, Division of Forestry and the U.S. Forest Service, State and Private Forestry field office in St. Paul, Minnesota. The Environmental Assessment was revised and the FONSI reissued in 1993 covering field activities through the end of "business" in 1997. This is the Report of the Final Year (FY97) of that project and constitutes the project's Final Accomplishment Report.

Accomplishments: Suppression Activity

There have been many ways to measure the accomplishments of the Oak Wilt Program that have evolved throughout the program. They have evolved for many reasons, but the most important of these are the quality of the data available and the analytical tools, particularly the EPIC GIS System. In the original pre-CSP inventory, we identified 3,006 infection centers in a 44 township area. At the end of the project, we track 8,387 centers in a 79 township area. The number of centers increased mainly because of the larger area surveyed and the more accurate on-ground survey used by the communities. Some new areas have also become infected during the seven years of the project.

During the CSP, 5164 infection centers (61.5%) were treated. The original goal of the program was to lower the incidence of centers to 1 per square mile. We now know that the pre-CSP density was actually 2.97, almost 50% more than originally thought. The final density across the entire area was lowered to 1.58. Originally, the goal was to have 75% of the area at this density by the end of the project. The final data identifies this percentage as 53%. In retrospect, 1.5 centers per square mile was a more appropriate goal and, in fact, 64% of the project area attained this level of suppression. To reach the 75% goal, the density allowance needs to be increased to 2.4 centers per square mile. Given the higher "problem severity" than originally identified, the level of accomplishment that was obtained was excellent.

Technical Accomplishment: Project Assessments

The Oak Wilt Program made heavy use of information technology, particularly GIS, to track and assess the lowering of oak wilt risk. Individual communities were required to provide an annual update to the project's inventory of oak wilt centers. Large scale maps (1:15840) were produced each year for the project area that included treatment history for each center. In this regard, over 125 custom products were produced annually for community reporting, planning, and subsequent operations.

One of the earlier measures of community accomplishment level, was the Resource Exposure Index (REI). This was based on the percentage of hardwood covertype that existed within 1500' of an active infection center. The REI became obsolete for two factors: (1) the hardwood covertype was replaced by a more biologically-appropriate "oak-dominated" covertype analysis using classified Landsat imagery and (2) the simple GIS generated buffers were inappropriate descriptors of the true danger of overland infection due to beetle-vectored spores.

The REI became obsolete when a "spore load" model was created which identified the ecological gradients created by the NUMBER of infection centers within a 1500' spore distance. This process was manually applied for this analysis, but is being automated into the EPIC GIS for future modeling work. The following visualization of this new index, is for both pre- and post-CSP. The data for this analysis is summarized in the table below for both the entire CSP Area (Metropolitan Region only) and the "core" 16 participating communities.

Technical Accomplishments: Community-Based Assessment

The 16 communities in the southeast corner of Anoka County and the north half of Ramsey County formed the core of the project area. They clearly addressed the oak wilt plague during the Federal CSP. The communities in this area (six geographical townships) lowered oak wilt damage by an amazing degree.

Risk Reduction Analysis: Spore Load Model
Acres of Oak Cover Receiving Protection

	OX Risk*	**1X Risk**	**2X Risk**	**4X Risk**	**8X Risk**	**16X Risk**	**32X Risk**	**64X Risk**	**Total**
_____	Metro	CSP	Area	____	____	____	____	____	_____
pre-CSP (acres)	40417	5741	6904	8299	8651	7722	4866	1465	84065
(%)	48%	7%	8%	10%	10%	9%	6%	2%	100%
post-CSP (acres)	46341	6503	7087	7452	6406	5850	3424	1002	84065
(%)	55%	8%	8%	9%	8%	7%	4%	1%	100%
_____	Core	CSP	Area	____	____	____	____	____	_____
pre-CSP (acres)	3189	885	1042	1498	1700	1256	504	4	10078
(%)	31.6%	8.8%	10.3%	14.9%	16.9%	12.5%	5.0%	0	100%
post-CSP (acres)	7089	1121	1035	657	98	69	1	0	10078
(%)	70.3%	11.1%	10.3%	6.5%	1.0%	0.7%	0.0%	0.0%	100%

* = Scale indicates the environmental spore load based on number of 1 acre infection centers that exist with 1500' . Each class doubles the spore load of the previous class.

Fiscal Accomplishments: Project Operations

The overall project was implemented as a cost share program designed to deliver maximum "on-the-ground" activities at the community level. Minimum cost share was defined as a 1:1 match with state, local, and private resources being summed to generate the state match. Cash matching was encouraged as communities prepared their plans, but "in-kind" matching was permitted. Volunteer contributions were encouraged and included. The State did not extract any funding for administrative or personnel overhead. These activities were used to match "cash consumptive" activities generated by the project, specifically data management and analysis activity needed by the State to prepare summaries and reports and the communities to plan and coordinate successive years of operations. In total, approximately 95% of the project funding supported "on-the-ground" control activities.
Fiscal Accomplishment: Federal Funds Overmatched

The State received $1,950,000 from the USFS during the duration of the project. This sum was overmatched by a

ratio of approximately 2:1 as follows:

Source	Amount	Comments
Cash: Community Partner	$1,107,306	mainly city and county cash
Cash: Private Landowner	$ 604,466	mainly homeowner
Cash: Other	$ 11,093	
Cash: State	$ 55,000	various State Parks, Forests, WMU
In-Kind: Community Partner	$773,090	includes inspections, vehicles, etc.
In Kind: Private Landowner	$295,913	volunteer spore tree removal
In-Kind: Other	$ 31,426	volunteer service to community, eg. Boy Scouts cleaning up spore trees
In-Kind: State	$ 165,000	inc. project coordination plus field work for control work on state land
Match Total: Cash	$1,777,865	total from all Minnesota sources
Match Total: In-Kind	$1,265,429	total from all Minnesota sources
Match: Project Total	$3,043,294	Total Minnesota Activities
Federal Cash: Total	$1,950,000	Federal CSP Grants: FY91 - FY 97
Project Total Cost	$4,993,294	Total Project Effort: All sources

Economic Analysis Of Oak Wilt Suppression in Minnesota

Cost of suppression for an "average" infection center was $966.94. Of this amount, approximately 2/3 ($589.33) was met from Minnesota sources. The federal cost per infection center treated was $377.61.During the process of treatment, 1,392,327 feet (263.7 miles) of vibratory plow line were installed and 14,193 potential spore producing trees were also removed. Of this accomplishment, 967 centers were treated in FY97, the final year of the program. In this final year, an additional 305,634 feet of plow line were installed and 4,367 spore trees were removed.

Economic analysis and overall accomplishment tracking/reporting was dramatically improved on this project through the application of the EPIC GIS, classified satellite data, and analytical models described above. Analysis identifies 84,065 acres of oak covertype within the Metropolitan Region portion of the CSP project area, not withstanding hundreds of thousands of oaks in the "urban cover". Of this total, 5,924 acres was completely protected from oak wilt by eliminating all oak wilt infection centers within 1500' (the effective spore transport distance). In addition, 8,924 acres of oak had the oak wilt spore load reduced by at least half. The median spore load was reduced from 5.9 centers (within 1500') to 4.0 centers during the program. In total, 14,848 acres or oak-dominated forest received significant (>50%) reduction in oak wilt risk as defined by "environmental spore load".

This analysis was performed on the Metropolitan Region portion of the project area because the classified satellite data identifying oak-dominated forest was only available for that area. In the total project area, this represents about 50% of the oak covertype in the total CSP area, bringing the total oak acreage to benefit from CSP activities to approximately 30,000 acres. With total CSP costs of $4,993,294, oak wilt treatments cost $166.44 / acre based on oak-dominated acreage receiving protection ranging from 50% to 100% spore load reduction. At the same time, this analysis does not include the benefit gained by individual "yard" trees (outside of identified oak covertype) or the increased security afforded oak-dominated covertype more than 1500' from an active infection center at the beginning of the project. Of this total, Federal costs were $65.00/acre protected. Minnesota costs amounted to $101.44/acre protected.

Uncas Dunes Scientific and Natural Area - Oak wilt field trip notes

The field trip on Wednesday July 8, 1998, was informative and constructive. I hope everyone was successful in washing off the poison ivy. In attendance: John Nelson, Jana Albers, Alan Jones, Mark Wurdeman, Mike Peltier, Bob Djupstrom, and Ellen Fuge

The 1996 revised management plan for the Uncas Skipper Dunes SNA addresses oak wilt management in the SNA based on the current knowledge at the time it was written. This did not take into account the high level of overland spread now known to occur. Consequently, new guidelines for oak wilt management on the SNA were considered.

The following is a record of our discussions:

Oak wilt occurs on the SNA mostly in red oaks (pin oak) but also in white oaks (bur oak). All infections will spread underground through intra species root grafts. Fungal spore mats form on infected red oak in the spring. Overland spread occurs from April through June (via insects) to freshly wounded oaks within 1500 ft. of an existing infection center.

Because of the sensitive plant communities and topography found throughout the SNA, and the overall long term management goals to return the area to a more open oak sand savanna community type (through timber harvest and prescribed burning), each infection occurrence will be assessed for control measures to be taken on a individual basis.

The timber sales of oak in the SNA and the subsequent prescribed burn regime will aid in the control efforts by removing much of the red oak and eventually creating barriers between trees left standing as root systems die and root grafts are reduced through out the site. Overland spread will always threaten to infect remaining trees and plowing around and cutting of infected trees within the plow line may be necessary when this occurs.

The occurrences currently established on the SNA were toured and the following actions will be taken:

Several patches of oak wilt were plowed (vibratory plow) in 1997. All red oaks that could potentially produce spore mats within the plow line are to be cut down. Ellen will work with Mark Wurdeman and others to identify a labor force to do this. The SNA development crews may be called upon to carry this out if no others are found. This will take place as soon as possible.

Those patches identified and not plowed will be handled in a variety of ways. Some patches are in gently rolling terrain in dense woods accessible to the vibratory plow. These will be plowed in the fall of 1998 as part of Forestry's greater effort in the State Forest. Mike and Ellen will work together to clearly identify which patches these are and routes to be adhered to by equipment and vehicles.

Some of these untreated unplowed infection points cannot be plowed because of steep slopes or their relationship to the highly sensitive remnant sand prairie/savanna communities. On these patches, alternate barriers will be attempted. A Garlon/Arsenal (?) mix will be used in cut stump treatment at choke points in the oak stands in an attempt to kill roots and disrupt root grafts thereby stopping spread underground. Several "natural" oak-free barriers will be employed to isolate these sites as well (the lake, open prairie, aspen stands, wetlands, clear-cut pine stands, etc)

All infectious trees will be cut prior to April 1 and covered with plastic. The rest of the living oak will be cut and possibly removed from the site. It is recognized that oak resprouts can be infected through root grafts and overland spread. Resprouts that are greater than 6 in. dbh can produce fungal mats contributing to overland spread. Follow-up will include cutting and treating sprouts in the barrier and cutting or burning sprouts (if part of a prescribed burn unit)inside the barrier. Jana will investigate the use of Garlon/Arsenal through a research project now being conducted in another state.

The action to be taken on the one infection occurring in bur oak on the SNA needs to be considered further. Because overland spread is not a threat from bur oak and inter species grafting does not occur, oak wilt at this point may aid in the effort to reduce oak density on the SNA. However, to what extent this is allowed to occur must be determined. Barriers may have to be established at some point if loss of the bur oak expands beyond management goals for bur oak density on the site or if it threatens oak outside the SNA.

Marking the location of barriers around infection zones was discussed. Since SNA is not growing oak, much of the oak on site is to be removed and prescribed burning will be used to keep oak resprouts down, interior patches of oak wilt do not need to have plow lines and other barrier perimeters marked. On experimental sites (Garlon/Arsenal) and those near the boundaries of the SNA, such perimeters will be marked with metal posts that can stand up to prescribed fires.

Prior to the field trip, these recommendations were developed:

Recommendations for controlling oak wilt on the Uncas Dunes SNA

For existing oak wilt infection centers:

1) already within timber sale boundaries.
   fall 1998 - install vibratory plow lines around OW perimeters.
   prior to April 15, 1999 - cut red oaks that wilted in August and Sept. of 1998. Dispose by removing from site, debarking them or cut, pile and tarp until Nov. 1, 1999.
   let logger finish sale as planned.
2) 3 sites with vibratory plow lines installed in 1995.
   prior to April 15, 1999 - cut red oaks that wilted in August and Sept. of 1998. Dispose by removing from site, debarking them or cut, pile and tarp until Nov. 1, 1999.
   It's best to clearcut the rest of the oaks inside the plow line, too. No special treatment for this wood.
3) monitor these sites for "skips" or "jumps" and retreat as in #2 , if needed. Aerial survey or ground visit in July.

For future occurrences of oak wilt:

In the fall (Sept. through Dec.), establish 2 plow lines around each infection center. Prior to April 15' the next year, cut red oaks that wilted in August and Sept. Dispose by removing from site, debarking them or cut, pile and tarp. It's best to clearcut the rest of the oaks inside the plow line, too. No special treatment for this wood. Utilize for firewood or just leave to rot. Monitor sites for 5 years. Aerial survey or ground visit in July.

Timber sale regulations - suggested wording for oak wilt and pine bark beetles management. All sales:

1) No harvest operations, road or trail building from April 15th to July 1st.
2) Forester will designate access, skid trails and landings.

Additional wording for pine sales:

1) The forester may require the logger to (a) halt cutting, (b) remove all cut products within three weeks of cutting, or (c) alter pine slash disposal regulations due to pine bark beetles.
2) Slash disposal regulations: Unless directed otherwise by forester, the logger will utilize pines to a 2 inch top and scatter the slash evenly on the sale. Do not lop off pine branches. Do not pile pine slash.

Oak wilt suppression and Mn ReLeaf grants in Region 3

The State legislature set aside MnReleaf monies for Forest Health, and oak wilt in particular. This program developed as an offshoot of the federally funded Oak Wilt Cost Share Program in the Metro counties that ended in 1997. With this funding, the DNR can pass funds through counties, communities and agencies for oak wilt control on public or private lands. Sherburne, Isanti, and Chisago Counties have already been granted oak wilt control monies through the Federal CSP.

Sherburne, Isanti and Chisago Counties were granted $20,000 , $10,000 and $10,000 respectively, for the 1998 growing season.

In anticipation of state funding, we aerially photographed 15 townships in Stearns, Benton and Mille Lacs Counties to find the northern and western extent of oak wilt spread. Wright County was not photographed due to the windstorm that occurred fifteen days before the survey. Only twenty-two sites were located. We are in an excellent position to "nip oak wilt in the bud" with current funding by setting up community/ county cost share programs through the Soil and Water Conservation Districts in those counties. The City of St. Cloud also participated in the program, receiving $12,000 for the 1998 growing season.

On September 11th in St. Cloud, there was an informational meeting about oak wilt control in Stearns, Wright, Benton and Mille Lacs Counties. At that meeting Jana Albers discussed oak wilt spread and control and the successes of the federal cost suppression program. Ken Holman, DNR Urban Forestry, talked about Technical Assistance Grants for the SWCD and MnReleaf Cost Share funding and granting procedures. Tim Edgeton, Tree Board in Sherburne Co., talked about the mechanics of running an oak wilt program with monies from the DNR.

Subsequent meetings were held with the Mille Lacs SWCD and the Wright County Board for further information on the local threat of oak wilt and possibilities of program participation. In early December of 1998, Mille Lacs is proposing to request $10,000 and Wright County will wait until an accurate aerial survey is done before committing themselves.

Here is the proposed annual plan of work for the DNR, LMIC and cooperating agencies in Region 3.

MN RELEAF-FOREST HEALTH-OAK WILT SUPPRESSION
Suggested procedures:

1. DNR does aerial survey community/ county for oak wilt (OW) and creates digital map of infection centers. See #7 below.
2. Community / agency applies for MN Releaf Forest Health Grant based on survey and expected workload for OW suppression program. Needs Determination form filled out by DNR Area Forester in cooperation with community/ agency.

3. If needed, community / agency applies for Technical Assistance Grant. These grants can be used to hire qualified, consultant foresters who perform some of the fieldwork.
4. Community / agency advertises availability of monies for cost sharing OW suppression & makes applications available to homeowners and landowners.
5. For individuals wishing to participate:
   a. Evaluate oak mortality and/or verify by lab samples that OW is the cause of death.
      11. Homeowner applies to participate in cost share program.
      22. Evaluation may be done by trained agency staff forester or trained in OW forestry consultant.
   b. Where OW is probable or verified, the homeowner calls in the OW contactor for a preliminary visit (usually $25 inspection fee).
   c. Contractor does OW control work and homeowner pays in full to vendor. Home-owner needs receipt to be able to get MN Releaf cost share dollars.
   d. Community / agency inspects the site to see if OW work has been correctly completed.
      If not, homeowner is not eligible for reimbursement.
      If yes, homeowners' application can be processed and reimbursed.
6. Community / agency processes the homeowner applications and uses own accounting system for bookkeeping.
7. Community / agency keeps records of all OW control actions taken: owner, total cost, action(s) taken, date of action and location.
   a. Use base map provided by DNR (see # 9 below).
   b. Geographical information on actions include: map of OW control line suitable for digital records.
   c. Newly found infection centers are mapped onto the base map.
8. DNR Area Forester does Compliance Check to ascertain MnReleaf Grants and Technical Assistance Grants have been properly used.
9. DNR will provide 2 maps / year of community/county showing OW active and OW treated along with attached list of all OW and control taken by S-T-R.
   a. After the treatments are done for the year, DNR will send "new information" to LMIC for digitization. LMIC will create a new set of maps for the next growing season / biennium.
   b. LMIC is paid ($12,000 statewide) against project dollars.
10. Community/ agency receives reimbursement.
11. DNR accumulates all annual records and maps from communities and agencies in order to create a final report.

Final report: Forest tent caterpillar impact in the Brookston mixed-species forest

In Minnesota, the forest tent caterpillar (FTC) is a native defoliator with outbreaks occurring at cyclic intervals of six to sixteen years. Defoliation generally lasts only three to six years in any one area or part of the state (Witter et al., 1975), but on a statewide basis an outbreak can last many more years. Reports of aspen mortality during and following outbreaks varies from stand to stand and outbreak to outbreak. Batzer and Morris (1978) reported that defoliation, during typical outbreaks in the Lake States, kills few trees except for ones that are suppressed. However, diameter growth may be reduced by as much as 90 percent.

Following the 1933-1938 outbreak in Minnesota, Duncan and Hodson (1958) estimated tree mortality varied from zero to as high as 80 percent in some stands. This outbreak coincided with the mid-thirties drought. Mortality may have been higher during this outbreak because of the combined effects of drought and defoliation.

In studies conducted during the course of the 1948 to 1959 outbreak, Duncan and Hodson (1958) found no tree mortality resulted from defoliation. During the second year and again during the third year of heavy defoliation, growth losses as high as 90 percent were found. Growth was reduced about 15 percent the year after defoliation ceased in a stand. Churchill et al., (1964) later studied the same plots to document long term impact. Six to ten years after defoliation ceased on a plot, they found up to 49% tree mortality caused, at least indirectly, by FTC defoliation. Mortality was directly related to the intensity of defoliation and the number of years of defoliation. Increased mortality occurred in the intermediate, co-dominant and dominant trees classes but not in suppressed trees. The incidence of additional insects and diseases also increased with the intensity of defoliation.

The 1964-1971 outbreak was studied by Witter et al., (1975). On study plots with an unusually long defoliation history (five to seven consecutive years of heavy defoliation), live stem densities were reduced by 41 percent and basal areas were reduced by 27 percent. Mortality among plots varied from two to 59 percent. They stated that the mortality varied with plot elevation, and therefore, the water table. As plot elevation increased, tree mortality due to defoliation decreased. The highest levels of mortality occurred where the aspen were growing at low elevations and on a high water table.

Near Brookston in southern St. Louis County, FTC caused defoliation for thirteen consecutive years starting in 1978 and continuing through 1990. During this time period, other areas in the state experienced two separate FTC outbreaks of much shorter duration. The first outbreak occurred from 1977-1983 and the second occurred from 1987-1993.

During the extended outbreak near Brookston, defoliation varied from very light to heavy and varied from stand to stand. Not all stands were defoliated in each of the thirteen years but defoliation occurred over much of this area for the entire thirteen years. Dead aspen trees began to be observed in 1981 in the affected area. Mortality continued to increase during the course of the outbreak. All size and age classes were involved, including regeneration.

In 1987, Minnesota Forest Health Specialists asked a simple question: "How much mortality occurred in this area that experienced prolonged FTC defoliation?". The original intent was to use aerial photography and a double sampling approach to document the FTC losses in the Brookston study area. Field observations in 1988 documented that this approach could not be utilized. Large numbers of trees had already died, fallen over, and started to rot. Many of these trees were already covered by grass and brush and would not be observable on aerial photographs. In fact, it would be almost impossible to accurately determine mortality even for the planned field sample points.

Since Forest Inventory and Analysis (FIA) plots had been established just prior to the start of the outbreak and were being remeasured in 1987, Forest Health specialists decided to evaluate whether the FIA could be used to quantify forest pest impacts in the documented outbreak area.

Forest Inventory and Analysis data from the study area and a similar adjacent area in Carlton County were used to quantify the relative growth and mortality of trembling aspen, big tooth aspen and balsam poplar growing stock and determine whether they were significantly different between the two areas. If the differences were significant, then the results could be extrapolated to quantify actual growth loss to aspen that has been subjected to repeated and prolonged defoliation by FTC. The extrapolated growth loss thus calculated would be the loss assessment.

A cooperative project between Minnesota, Division of Forestry, Forest Health and Resource Assessment staff and the USDA Forest Service NC Station FIA unit and NA S&PF Forest Health group was initiated. Funding was provided by the St. Paul, State and Private Forestry Office. The forest tent caterpillar outbreak near Brookston, MN in southern St. Louis County was the study focus. This paper also contains speculation as to why the outbreak lasted so long in this area.

Study Areas

The Brookston study area included parts of Townships 50 and 51 Range 16, 17, 18, and 19 and Township 52 Range 17 and 18 in southern St Louis County. A total of one hundred sixty four sections were involved (map 1A). The ownership within the Brookston study area is primarily small private landowners, Bureau of Indian Affairs and St Louis County.

This area experiences a shorter growing season than anywhere in the region. The average last spring frost (June 6) and average first fall frost (Sept 1) both occur in this area of St Louis County (maps 1B & 1C). This might adversely affect tree growth by shortening the growing season and may also cause frost damage to trees.

A severe drought occurred in Minnesota in 1976 and 1977. Another drought occurred in 1987 and 1988. A report in the Minnesota Department of Natural Resources, Forest Insect and Disease Report-1988 noted that the aspen

Aspen defoliation 1978 -1989

Aerial sketch-mapped by Minnesota DNR- Forestry

1978

1979

1980

1981

1982

1983

1984

1985

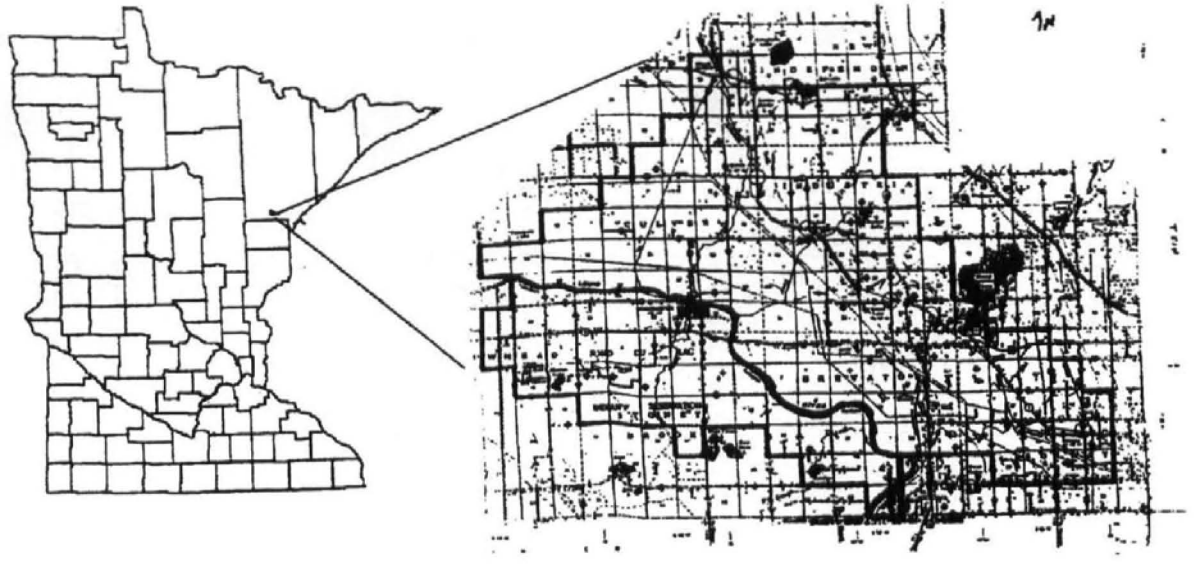
1986

1987

1988

1989

Map 1. Brookston Study Area



A. Section map of study area

B. Average last spring frost is after June 6th

C. Average first fall frost Sept. 1st to 6th

defoliation in the Brookston area looked dramatic because most of the trees did not refoliate after being defoliated by FTC and remained leafless through the summer. These droughts in combination with the FTC defoliation may have increased the losses.

The study area contains two distinct landform/soils types. The Culver end moraine has 16-36 inches of loamy material over clayey material. The Highland moraine is loamy but has a dense hardpan at 12 to 26 inches. They both act in similar ways, the clayey material and hardpan both perch water above them. Witter et al., (1975) found that aspen tree mortality following defoliation was more severe on plots having higher water tables. Fralish (1972) stated that high water tables had an adverse impact on aspen growth because the root systems did not develop normally.

FIA plots in Carlton County were used as the control and became the comparison for the Brookston study area. Carlton County was chosen because it is adjacent to the Brookston study area and has similar climate, landform and soils, but did not receive continued and heavy defoliation by the forest tent caterpillar like the study area. Aspen in Carlton County was defoliated during the 1977-1983 and 1987-1993 outbreaks but did not experience the prolonged outbreak that occurred in the study area.

Methods

FIA Data Base: The FIA data base and plot system were chosen for this study because the FIA plots were established just prior to the start of the outbreak and were being remeasured when this loss assessment was originally proposed in 1987. The FIA accounts for every tree on the plot and what happens to each of them between inventory dates. FIA plots are remeasured approximately every ten years (Jakes; 1977, and Miles et al., 1990).

Study period: Trees in the Brookston study area were defoliated by FTC from 1978 through 1990. Depending on the plot, the loss assessment using the FIA data covers the period of September 1974 through May 1989. FIA plots were all initially established one to three years prior to the start of noticeable defoliation in the area. Defoliation continued, depending on the plot, for two to four growing seasons after the plots were remeasured. Mortality can be expected to occur for a number of years following cessation of the outbreak.

Study area delineation: Map 2 shows the history of aspen defoliation in Minnesota from 1978-1989. Aerial sketch maps were used to delineate the area that experienced 12 consecutive years of defoliation (map 1A). This area became the Brookston study area.

Data base from the study area: We selected FIA plots within the Brookston and Carlton County areas that met the following criteria:

> All plots must have been measured during both the 1977 and 1990 survey. Plots in both areas must have been classified as timberland during both time periods, showed no evidence of harvesting during the intervening years and must have contained quaking aspen, big tooth aspen or balsam poplar growing stock trees in 1977. Thirty six plots in the Brookston study area and seventy plots in Carlton County met these criteria.

The specific cause(s) of the death and volume reduction on the Brookston study area plots were not determined on a tree by tree basis. For the purposes of this study the losses as a whole were assumed to be either a direct or indirect result of the prolonged FTC defoliation. Soils, fire history, climate, weather, and other insect and diseases may also have played a part in the mortality and growth loss of the aspen in the Brookston study area. Some of these will be discussed later in the paper.

Data Analysis and Results

Forest Inventory and Analysis (FIA) data from two adjacent geographic areas were used to quantify the relative growth and mortality of aspen and balsam poplar growing stock trees and to determine whether the growth and mortality estimates from the two areas were significantly different. Beyond this, computations were used to

develop a volume loss for the Brookston study area due to the prolonged FTC outbreak.

The plots in the Brookston study contained 211 growing stock trees in 1977. When remeasured, it was found that 84 of these trees had died. The plots in Carlton County contained 334 growing trees at the first measurement. When remeasured, it was found that 66 of these trees had died.

Since the time periods between measurements of individual FIA plots can vary significantly, we computed annualized estimates of growth and mortality and expressed them as a percentage of the aspen and balsam poplar growing stock that were present in 1977. These three computations are annual rates of mortality or growth based on plot measurements at two different times and calculated as an annualized percentage of the growing stock that existed at the first measurement.

For each plot, we computed the following:

(1) Relative Annual Tree Mortality

Expresses tree mortality that occured during the period. It is the average annual growing stock mortality (trees/acre) calculated from the 1990 measurement divided by the number of growing stock trees/acre that existed in 1977.

To be included, trees must have been growing stock trees in 1990 and at least 5" DBH in 1977. Trees not present in 1977 (ingrowth and ongrowth trees) were excluded.

(2) Relative Annual Volume Mortality

Expresses volume mortality that occurred during the period. It is the average annual growing stock mortality (cubic feet/acre) calculated from the 1990 measurement divided by the volume of growing stock trees (cubic feet/acre) that existed in 1977.

To be included, trees must have been growing stock trees in 1990 and at least 5" DBH in 1977. Trees not present in 1977 (ingrowth and ongrowth trees) were excluded.

(3) Relative Net Annual Growth

Expresses net annual growth that occurred during the time period. It is the average annual growing stock growth (cubic feet/acre) calculated from the 1990 measurement divided by the volume of growing stock trees that existed in 1977.

Net annual growth includes growth contributions from ingrowth and ongrowth trees and volume decreases (mortality) from natural causes.

We performed a t-test on the means of our three estimates. Results are as follows:

		Brookston Study Area	Carlton County
Relative Annual Tree Mortality			
	Mean[1]	3.8	2.0
	Variance[1]	0.09	0.07
	N (plots)	36	70
t-value: 2.99			
df: 104			
Relative Annual Volume Mortality			
	Mean[1]	4.3	2.7
	Variance[1]	0.11	0.13
	N (plots)	36	70
t-value: 2.14			
df: 104			
Relative Net Annual Growth			
	Mean[1]	0.34	8.3
	Variance[1]	0.41	3.1
	N (plots)	36	70
t-value: 2.635			
df: 104			

1/ Values expressed are an annualized percentage of the growing stock present at the first measurement.

The means of our three estimates in the Brookston study area were significantly different at the 95% confidence level from those found in Carlton County.

The relative annual tree mortality for the Brookston study area was 3.8% versus 2.0% in Carlton County (Table 1). Relative annual volume mortality within the Brookston study area was 4.3% versus 2.7% for Carlton County and relative net annual growth within the Brookston study area was 0.34% versus 8.3% for Carlton County. Relative annual tree mortality calculated for the Brookston study area was nearly twice that of Carlton County while relative annual volume mortality was 1.6 times greater in the Brookston study area than in Carlton County. Relative net annual growth in the Brookston study area was 24.3 times less than in Carlton County.

Table 1.

	Brookston	Carlton Co.	Difference
Relative annual tree mortality	3.8%	2.0%	+1.9x
Relative annual volume mortality	4.3%	2.7%	+1.6x
Relative net annual growth	0.34%	8.3%	-24.3x

If we assumed that the differences in relative net annual growth and relative annual mortality between the two areas were due, either directly or indirectly, to the prolonged FTC defoliation history within the Brookston study area and that, had this not occurred, the relative annual mortality and growth rates within the Brookston study area

would have approached those found in Carlton County, then:

the relative annual tree mortality within the Brookston study area would have been 2.0%;

the relative annual volume mortality would have been 2.7%; and

the relative net annual growth would have been 8.3% or 24.3 times greater.

So far, the estimates of relative net annual growth have been based on a comparison of growth and mortality observed in two geographic areas. These results need to be extrapolated to compute the volume of Populus spp. that was lost due to the prolonged outbreak in the Brookston study area.

Our comparison has indicated that the relative net annual growth of aspen species within the Brookston study area would be expected to increase by a factor of 24.3 without the influence of the prolonged forest tent caterpillar outbreak. If we further assume that the actual growth within the Brookston area would increase by the same proportion as the relative growth, we can then estimate actual growth loss by extrapolating the expected growth increase as shown below.

The net annual actual growth of aspen growing stock, based on all plots that were timberland in both 1977 and 1990 and contained aspen growing stock in 1990 and expanded to the entire Brookston study area was 13,920 ft^3/year (176 cords/year).

If the prolonged FTC outbreak had not occurred, we would have expected the net annual actual growth estimated from these plots to have increased by a factor of 24.3.

Multiplying the 13,920 ft^3 /year net annual growth in the Brookston study area by 24.3 would increase net annual actual growth to 338,256 ft^3/year (4,281 cords/year). This is an increase of 324,336 ft^3 /year (4,105 cords/year).

Therefore, the estimated loss of net annual growth for aspen species in the Brookston study area was 324,336 ft^3/yr or 4,105 cords/yr.

Discussion

In the Brookston study area, the duration of the FTC outbreak was unprecedented and so was its impact.

In this study, aspen volume losses far exceed those reported in any of the other studies during previous outbreaks in Minnesota (Witter et al.,1975; Duncan and Hodson, 1958; Churchill et al., 1964). Mortality and growth losses of aspen species in the study area were so extreme that only a minute quantity of net annual growth was observed, 176 cords/yr, during the 12 years of the study. This was 24.3 times less growth than would normally have been expected. As a comparison, data of Duncan and Hodson (1958) indicates that an average 3 year long FTC outbreak could be expected to result in 2.5 times less growth during each year of the outbreak than would be produced without the outbreak.

Factors contributing to higher volume losses found in previous studies, namely, coincidence with drought, presence of a high water table and increasing growth losses and mortality as the intensity and duration of defoliation increased were also observed in the Brookston study area.

The losses were estimated by comparing the differences in mortality and growth between the Brookston study area and a similar adjacent area in Carlton County. The main difference between the two areas appears to be the duration of the FTC caused defoliation. Both areas experienced FTC defoliation during the outbreaks of 1977-1983 and 1987-1993 but the outbreak continued for an unusually prolonged time only in the Brookston study area.

The growth loss estimate in this study is likely conservative for a number of reasons. Only a subset of available FIA plots were used in this analysis. Only plots which were classified as timberland during both measurements and contained aspen growing stock trees in 1990 were used to calculate the actual growth loss estimate. On some plots that contained aspen growing stock during 1977, the aspen were harvested, and on others the trees were sheared and converted to other species or land uses and therefore did not contain any aspen growing stock trees during 1990. These may also have suffered growth loss but could not be included in the analysis.

Only the growth loss for aspen species were included in the analysis. Other hardwood species, such as, paper birch and basswood were defoliated during the prolonged outbreak by the FTC and certainly also suffered growth losses. These losses were not captured in this study.

Why the FTC outbreak lingered so long in this area was not determined. When FTC populations build up to extremely high levels the caterpillars run out of food and starve to death which can end an outbreak. Hodson (1977) stated that local termination of the statewide 1948-1959 outbreak was caused by starvation due to high populations. Sippell and Rose (1977) also state that the collapse of populations is usually brought on by over-population. Dr. Hodson, U of MN (personnel communication) indicated that outbreaks in the Brookston area last longer than in other part of the Minnesota. He speculated that adverse weather conditions, such as late spring frosts, were unfavorable to the FTC in the area and prevented them from building up to extremely high population levels and starving to death. Larval starvation is frequently followed by a high percentage of pupal parasitism which further reduces the population, (Hodson, 1977). Dr. Hodson (1987, personnel communication) also felt that pupal parasitism never became high enough to end the outbreak in the Brookston area. In a statewide study of FTC in 1957, Hodson (1977) found that pupal parasitism and mortality levels ranging between 76 and 90 percent were not high enough to end the outbreak. Listed below is a summary of pupal parasitism for the years 1979 through 1987 in the Brookston study area.

Year	Percent of pupae parasitized
1979	84
1980	85
1981	93
1982	NA
1983	80
1984	77
1985	NA
1986	81
1987	59

High levels of Hypoxylon canker were noted in the study area on dead and dying aspen but levels of infection were not determined. The literature suggests that increased levels of Hypoxylon canker might be expected following defoliation. Churchill et al., (1964) found that the incidence of Hypoxylon canker, Nectria canker, and other insects increased with intensity and duration of FTC defoliation. High levels of Armillaria root disease were also noted in the area but were not measured. Since there were many stressed and dying trees, increased levels of Armillaria root disease would be expected.

Since the plot work was completed in 1989, we have made many visits to the study area. The surviving Populus spp. appear to be growing slowly and rebuilding their crowns. There is little or no aspen regeneration even on sites where high levels of mortality have opened up the stands and there is more than adequate sunlight reaching the ground. Perhaps this is related to earlier observations about Armillaria root disease and the decline and death of viable root systems that would have supplied new aspen sprouts.

Conclusion

This study shows that FIA data can be used to estimate losses that cannot be easily determined in a more direct manner in loss assessment studies. However it is a fairly complicated and difficult process. In addition, there was no way to evaluate how close the loss assessment estimates were to absolute losses for the Brookston study area. In the future FIA plots will be fixed radius plots and this may simplify the use of FIA plots and data in loss assessment studies.

In our attempts to accomplish this study, we found that there were no standard methods established to determine losses from a prolonged pest outbreak on a non-persistent tree species, that is, a tree species that quickly falls over, breaks up and rots after it dies.

Our study reaffirms the need to continue developing and documenting procedures to evaluate pest impacts using FIA data.

Definitions

Growing stock tree - A live tree of commercial species that meets specified standards of size (>=5.0" DBH), quality, and merchantability.

Ingrowth - A tree previously not large enough to be tallied on the 37.5 BAF prism plot (less than 5 inches DBH) but now large enough to be tallied (greater than or equal to 5 inches DBH).

Ongrowth - A tree previously not tallied on the 37.5 BAF prism plot, even though it was of sufficient size (greater than or equal to 5 inches DBH), because it was too far from the center of the plot for it's DBH to be 'in' the prism plot but included at the remeasurement of the plot because it's increase in DBH now makes it 'in' the prism plot.

Net annual growth of growing stock - The annual change in volume of sound wood in live sawtimber and poletimber trees and the total volume of trees entering these classes through ingrowth and ongrowth, minus the volume losses resulting from natural causes.

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Forest tent caterpillar: good, bad or just ugly?

With the inevitable return of the Forest Tent Caterpillar (FTC) apparently just beginning, you might ask is this good or bad? Most people would not hesitate to say that the nuisance, mess and dramatic visual effect was just bad. But how about from the perspective of the other plants and animals in the forest ecosystem. Is it good, bad or just plain ugly? As you might expect the answer is, it depends.

Some birds and other animals benefit from an outbreak of FTC by using the caterpillars as a food source. Kind of like having a fast food kitchen in your living room. Many species of birds move north in the spring and early summer to raise their young. This is the time when the FTC caterpillars are present. During the time of mating and raising their young, most birds need a diet high in protein and rely heavily on a diet of insects. Adults birds may eat up to ⅓ of their body weight per day and young birds may eat more than ½ of their weight per day. Populations of cuckoos increase during FTC outbreaks probably as a result of the abundance of caterpillars as food. Some mammals also consume FTC. Black bears are known to break down small trees to get at the caterpillars and eat them.

But what is good for some is bad for others. To some birds, an outbreak is harmful, at least temporarily. Heavy defoliation of trees and shrubs removes the protective cover of tree leaves and changes the microclimate. Kind of like having the roof torn off your house. Nests that normally are hidden by leaves are now exposed and more visible to predators. Also during the day in a defoliated forest the temperature is higher and the humidity is lower than normal possibly reducing the survival of young birds. Defoliation of oaks reduces the production of acorns affecting animals like squirrels, turkeys and bears that rely on them as a food source.

An FTC outbreak obviously affects the trees and the most common effect of defoliation is a growth reduction. In a study of defoliated aspen, researchers found a little growth reduction during the first year of heavy defoliation, 90% growth reduction during the second year, 90% growth reduction during the third year of heavy defoliation and 15% reduction the year after the defoliation ended. So in a typical outbreak you might expect at least two years of "no growth". In the past twenty years there have been two outbreaks in Minnesota. If we assume no tree growth of

aspen for two years in each outbreak that makes four years of no growth in the past twenty years. That equals 20% less wood production.

For most host trees, a growth reduction is the only impact in a normal outbreak. Some tree mortality can also be expected if the outbreak extends for five to seven years or if other factors, such as a drought, stress the trees.

Forest tent caterpillars don't feed on all trees equally in the forest. The caterpillars prefer aspen, birch, basswood, ash and oaks, but generally don't feed on balsam fir, spruces, pines or red maples. These trees often develop in the understory beneath the canopies of aspen, increasing in numbers as the aspen stand matures. In normal years (non-FTC years) these species are shaded by the overstory trees. When FTC defoliate the overstory trees the understory non-defoliated trees receive more sunlight and are able to put on additional height and diameter growth. Also, since the overstory trees have no leaves, evapotranspiration is less. This leaves more moisture in the soil for the fir, spruce, red maples and pines to use.
Anyone who has been in the woods during a FTC outbreak knows not to eat an open faced peanut butter sandwich there. It might sound like rain but it's really insect frass (excrement). This frass serves as fertilizer just like any other manure. It adds nutrients, especially nitrogen, to the soil. So the understory conifers have more sunlight, moisture and nutrients, put on more growth and take a more dominant position in the stand. Forest tent caterpillars act as agents of change and can speed up the ecological succession of a stand.

These are just some of the consequences of a FTC outbreak. It is a natural part of the ecosystem and something we have to put up with if we want to live, play or work in the forest. It can be beneficial as well as causing damage. It depends on your perspective.

But an outbreak can still be an ugly, messy, nuisance.

NAMP results: Are sugarbushes as healthy as other sugar maple stands?

Are sugarbush trees more vulnerable to stress than untapped stands? How much dieback is "normal" for sugar maple trees? What is the "normal" mortality rate for sugar maple trees? Should unhealthy trees be salvaged? Is it important to avoid injury to tree boles and roots during logging and sugaring? Is tap hole closure important to tree health? What are the effects of insect defoliation and adverse weather conditions on tree health?

The North American Maple Project (NAMP) has found that:

- Tree health (as measured by crown condition) is similar in sugarbushes and untapped sugar maple stands.
- Sugar maple trees under both types of management responded the same to stress. Over 90% of sugar maple trees monitored in NAMP have 0 to 15% crown dieback. Most of these trees are healthy and have an excellent chance of long-term survival, barring any significant future disturbance.
- Sugar maple trees dies at a rate of 1.2% per year. There are some differences between overstory trees (0.9% die per year), and understory or suppressed trees (2.0% die per year). These results are similar to other studies on sugar maple mortality rates.
- Crown condition can be used to indicate which trees will be surviving into the future. NAMP has followed tree health and survival over a seven-year period. Trees with 20-35% crown dieback had a 90-99% chance of survival and an 80% chance of returning to a healthy condition. Trees with more than 35% crown dieback had a 65% chance of dying or remaining unhealthy. These predictions could vary according to the cause of dieback. For example, trees with thin crowns due to insect defoliation are more

likely to recover than trees stressed by poor site conditions. So, pre-salvaging would be justified where dieback exceeds 35%.

- Major bole and/or root damage may result in tree mortality. Crown dieback of 50% or greater is associated with bole and/or root damage. By avoiding injury to trees during thinning, sugaring or other entries, your opportunity for maintaining tree health is improved.
- Trees that close tapholes rapidly following the sugaring year produce more clear sapwood for future tapping.
- Trees with greater than 35% dieback close tap holes more slowly. High dieback can be used as a signal to limit the number to tap holes.
- Vigorous trees tend to have fewer than two open tapholes in the summer following tapping.
- The impact of stress from defoliation or adverse weather on trees depends on many factors, such as the condition of trees prior to the disturbance, the site where trees are growing, and the timing and duration of the disturbance. NAMP results show that trees in areas defoliated by pear thrips or forest tent caterpillar for 1-3 consecutive years, and areas experiencing drought conditions for 2 years has significantly thinner crowns, but normal foliage returned after 1-2 years. In these types of situations, where trees are exposed to a single stress agent for a short duration, tree recovery is expected to be good.
- Healthy trees translate into good growth, higher sap volume, and more resistant trees. Once a stand starts to decline it is difficult for the overstory trees to recover. There is some evidence (i.e. a Vermont study) suggesting that there is increased abundance of ferns in stands with high dieback, which makes it difficult to promote future regeneration.
- A healthy stand begins with the site. Sugar maples grow best on loamy, well-drained soils, with pH values of 5.5 to 7.3. While sugar maples grow on a variety of soils and sites, less healthy trees can be expected on less favorable sites.

Maintaining health will depend in large part on forest management practices. While tapping trees does not adversely affect health, avoid overtapping trees to maintain adequate new wood growth for future tapping. Delay thinning in woodlots with serious insect, disease or weather damage to avoid additional stress.

Itasca Park: Old growth and bark beetles Three years after the big blow

Formal projects conducted by researchers from Syracuse and Dartmouth Universities continue in Itasca State Park to track bark beetle populations, associated insects and their potential impact on old growth pine. These projects and associated trap catches for 1998 indicate beetle populations may be back to endemic levels common before the windstorms of 1995 & 1996.

A Look at Pine Bark Beetle Predators

In 1996, the first summer of pheromone trapping, bark beetle collections were high, while few predatory beetles and little woodpecker activity was noted . In 1997 bark beetle catches remained high, low levels of predatory beetles started to be collected in the traps and widespread woodpecker activity was observed especially in the areas that had been control burned. In 1998 bark beetle flights and dispersal were noted in the traps; but two to five predatory beetles were present each time traps were collected and woodpecker activity remained high while a dramatic reduction in beetle catches occurred. Overall the pine bark beetles population seems to have returned to endemic levels in response to timely rains, generally mild weather, the degrade of windthrown material in relation to potential brood success and the rise in predation.

Work continues on developing a model to determine the threat of bark beetle attack and stand susceptibility in the park. Initial work indicates that old red pine actually have more resin flow than younger plantation red pine, and therefore should be less susceptible to pine bark beetle attack. This could be due to stocking levels in the plantations or the vigor of isolated old big trees. The question remains whether the pheromone traps actually attract beetles into stands from surrounding areas or reduce numbers.

Three research projects continue in the park.

1. One research project is looking at the height of beetle flights. Preliminary results indicate beetles are flying at much higher heights than we are hanging the traps. This may be in response to dense brush layers above the forest floor or due to bark thicknesses on the large pine hosts. Many possibilities to examine, but very important for trap placement.

2. A second project is looking at the dispersal of beetles that are marked as they leave trap logs and then hopefully recaptured in the traps. Lots of trial and error, with few results at this time.

3. The third project is looking at the death of individual old trees to see if there is a relationship between time of infestation, tree death and hazard to adjacent trees. At this time, the death of isolated old trees does not seem to be a hazard.

Four less formal studies tracked by Forest Health Specialists, indicate the bark beetles were never able to fully utilize the large log materials dropped by the wind storms. Wet summer weather in 1995 and 1996 kept standing trees in an unstressed condition. In salvaged and unsalvaged areas no additional mortality to standing red and white pines could be attributed directly to bark beetles. Only mature jack pine on the study areas seemed to have been killed by beetles. Prescribed fire, however, did kill additional standing pine of all species; but within the losses deemed acceptable in the burn plan. While traditional bark beetle "pocket kill" continued on red pine in the Indian Mounds area and in overage jack pine stands, it was not observed in the diverse older pine stands that included more pine age classes, other hardwood and conifer species, and more shading of the ground surface. Hopefully, these general observations and specific research results can help us risk rate blow down events and tailor salvage and trapping programs to specific stands and locations in proximity to these point events.

Project Demobilization

Trap placement in 1999 will only be to support continuing research projects. All traps have been cleaned, fixed and boxed. They are ready for shipment with their rebar to anyone who needs them. Additional trap parts and pheromone lures may be available on request for deployment elsewhere in the state in 1999.

The Federal Emergency Management Agency money is expended and reports filed.

SILVICULTURE FIELD TIP

Field tested ideas.
Contact the author for further information.

Minnesota Department of Natural Resources
Division of Forestry

Field Tip No. 10

January 1998

White Pine: How to Prune for Blister Rust

By: Mike Albers, Region 2 Forest Development and Forest Ecosystem Health Specialist, and
Jana Albers, Region 3 Forest Ecosystem Health Specialist

White pine blister rust is a fungal disease of white pine. Live needles are the first to be infected; then the fungus grows into the twig and towards the stem of the tree. A blister rust canker is the result of an infection that has been growing under the bark of a branch or stem for several years and is cutting off the supply of food and water to parts beyond the infection. White pine blister rust causes branch death, stem cankers, and topkill and can be fatal. This disease becomes more common and more serious as you go north and east in Minnesota, but blister rust can occur anywhere in the state where late summer weather is cool and moist.

Pruning is one of the most effective ways to reduce blister rust infections and tree mortality. Pruning is beneficial on any size tree. However, it is most beneficial when started on young trees and continued until all the branches on at least the lower nine feet of the stem have been removed. Most blister rust infections occur within nine feet of the ground because cool, moist conditions favor infection. Pruning removes the lower branches that are most likely to become infected and also removes branch infections that already exist. Here is how to prune your white pines:

When

- Branches can be pruned almost anytime of year. The best time to prune live branches is during the fall and winter when the tree is dormant. Spring is the only time trees should **not** be pruned when the bark is easily damaged and the shoots are expanding.
- Begin pruning the lowest branches off the trees when they are four or five years old and two feet or more tall.

General pruning tips

- You don't have to prune every tree on your site—prune only the best ones.
- Don't remove too much crown. Leave ½ to ⅔ of the live crown. See Figure 1.
- Do not flush cut the branches. Do not leave long stubs, either. Pruning cuts should be made just outside the branch collar. Use "natural target" pruning methods. See Figure 2.
- Pruning shears work best on branches up to the thickness of your thumb. Larger branches require lopping shears or a sharp pruning saw. Shears should have bi-pass blades (like scissors) rather than the anvil type. The anvil type crushes tissue rather than leaving a clean cut.

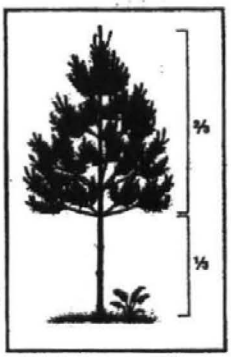


Figure 1. Leave ⅔ live crown.

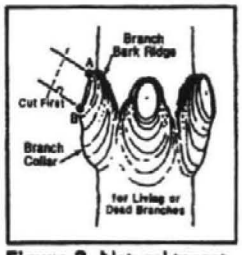


Figure 2. Natural target pruning. Make cut on line A-B.

- Do not use chain saws, Sandviks, hatchets, bow saws or clubs; this is delicate surgery.
- Do not paint or treat the pruning cuts.

Pruning to prevent blister rust infections

- Be sure to find and prune off the lowest branches. These often lay on the ground and are hidden in the grass or snow. See Figure 3.

Figure 3. Pruning branch nearest to the ground.

- Pruning should continue to a minimum height of nine feet but you may want to continue up to seventeen feet. Caution: leave ½ to ⅔ of the tree height with live branches in the upper crown.
- Frequent pruning is most effective because there's a greater chance of removing infections before they reach the main stem. Also, smaller branches are easier to prune.

Pruning already infected branches or leaders

- Pruned branches can be left on site. They won't spread the infection.
- Pruning tools do not have to be sanitized between pruning cuts. Unlike some other fungal diseases, blister rust is not carried from tree to tree on pruning tools.
- Prune off any branches higher up in the tree that show blister rust infections.
- Trees with blister rust cankers on the main stem or on a branch but within four inches of the main stem cannot be saved. See Figure 4. Do not waste your time pruning these trees. An infected tree can not infect other trees. White pines are infected by spores produced on *Ribes* species (gooseberries and currants), not on other white pines.

Figure 4. Infected branch too late to prune.

Pruning will NOT save every tree from blister rust

Some pruned trees will still be killed or topkilled by blister rust because:

- Any live needle can become infected and since the terminal leader has needles on it, the stem can be directly infected through one of these needles.
- An infection can take years to become recognizable, so the stem could already be infected but not recognized as infected at the time of pruning.
- If the leading edge of a branch canker is four inches or less from the stem, the stem is already infected even though you cut the branch off.
- In the northern and eastern parts of the state, the weather is cool and moist enough to allow infections to occur in the crown of even the tallest trees. Even here most of the infections occur within nine feet of the ground. So while pruning is an effective way to reduce blister rust infections on trees, it is not a guarantee that infection and mortality will not occur.

Graphics in Figures 1 and 2 were provided courtesy of the USDA-USFS.

Growing white pines in Minnesota

By Jana Albers and Mike Albers, Forest Health Specialists, MN DNR- Forestry

Since the last glaciation, white pines have peppered the landscape and towered above the other trees; monarchs of the forest. Contrary to popular belief, white pine stands did not blanket the state in pre-settlement times. Instead, white pines dotted the landscape, occurring in small groves with red pines and as individual super-canopy trees. White pines, beyond their beauty and size, grow across the range of forest conditions in Minnesota and fill important ecological roles.

White pines were the lure that brought loggers to Minnesota in the late 1880's. People thought that the supply would never run out and it hasn't, but the number of white pines is estimated to have decreased by 75%. Besides logging, other factors have contributed to this decrease. The forests of Minnesota have been changed by more people, more deer, changes in fire frequency and a new white pine disease. These factors have teamed up to limit both where white pines can grow and how well they do.

Many people are passionate about white pines and want to bring them back to their former glory. Planting and tending white pine seedlings involves more preparation and work than other conifers. With your help, we will see the numbers of white pine increase and restore them to their rightful place, as the "monarchs" of the forest.

Contents

PROBLEMS THAT YOU CAN HELP WHITE PINE OVERCOME

Whether you find them already growing on your land or you plant them, white pines benefit from forest management. White pines need to be planted where they can avoid diseases and insects and be protected from deer browse and plant competition. White pine seedlings can not be "stuck" in the ground and forgotten.

White pine blister rust is a fungal disease that infects needles but spreads into the branches and stem where it causes branch death, topkill, stem cankers and can be fatal. It is an exotic disease, first found in Minnesota in 1916. The major problem with this disease is that it kills white pine seedlings and saplings in certain climates and topographies.

White-tailed deer like to feed on white pine seedlings and saplings which stunts or kills them. Deer chew off twig tips, particularly the buds on the growing tip (terminal leader).

White pine weevils are insects that cause the wilting and death of the tree's leader (or terminal) in June or July. At least two years' height growth can be lost in a single attack and the damage usually causes forking of the stem. Repeated attacks cause the tree to become bushy and stunted.

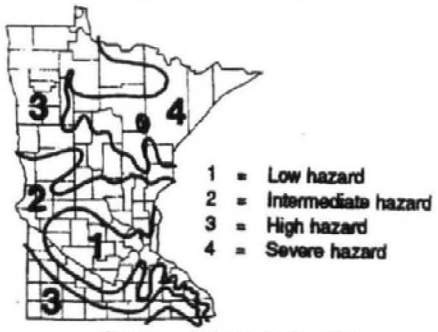
Weeds, grasses and shrubs compete for light, water, nutrients and space with the white pine seedlings. Seedlings can grow slowly, be stunted or die from competition.

WHERE TO PLANT AND GROW WHITE PINES

Site selection

White pine can and does grow in all parts of Minnesota.
White pine blister rust hazard zones (see map) indicate the general level of hazard over broad geographic areas but should not be used to determine hazard on a specific site. White pine can be grown successfully in all hazard zones, but as hazard increases, it becomes more important to carefully select planting sites (soils, topography, shade) and to implement pest management strategies (see Tending Your White Pines section).

White pine blister rust hazard zones.

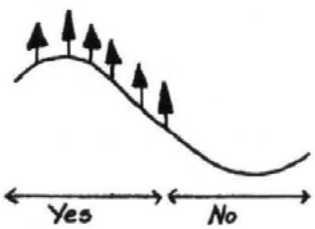


(Taken from E. P. Van Arsdel 1979.)

Soil types

White pine occurs naturally on a wide range of soil types and textures. Good growth occurs on most soil textures and soil drainage classes. It is more tolerant of wetter conditions than red or jack pine but is less tolerant of droughty conditions. Best growth will occur on sites with: medium to fine soil texture, medium to high soil fertility, somewhat poor to well drained soil, constant moisture supply and rooting zone greater than 18 inches deep. Avoid the extremes of heavy, continually wet soils and coarse, drought-prone soils when selecting a planting site.

Topography



Plant white pines on steep slopes, hill tops and shoulders of hills. Avoid V-shaped valleys, potholes, bases of slopes and small openings in the forest canopy anywhere in Minnesota. A small opening is one where the spaces between the crowns are 1/4 to one times the height of the surrounding trees. These features favor the collection of cool, moist air and favor infection by the white pine blister rust fungus in both northern and southern Minnesota.

Shade

White pine grows better and has better form if growing under the shade of other trees. Unlike red pine or jack pine, white pine can easily tolerate growing under an overstory. Planting under an overstory has two benefits, namely, reduced risk of white pine blister rust infection and reduced risk of white pine weevil attack.

Aspen, birch, oak and other hardwoods are good choices for the overstory. Tree species that are intermediate or shade intolerant, such as, aspen and birch, have smaller, thinner crowns that allow

light to penetrate to the understory. Shade tolerant species, such as, sugar maple and basswood, have large, dense crowns that intercept lots of light and are likely to significantly reduce the growth of the understory white pines.

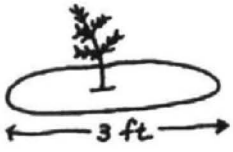
High shade (from overstory trees that are significantly taller than the white pines) is preferred to shade from brush and shorter trees that are similar in height to the white pines. High shade is beneficial; less incidence of blister rust and better growth.

Look for and choose the sites: where aspen (or birch) is mature and the stand is breaking up, where a hardwood stand just underwent thinning or where a stand was partially harvested. The overstory should be vigorous enough to survive an additional twenty to thirty years. Heavy or continuous shade can be detrimental to white pine growth, so, as a goal, maintain approximately 40 to 60 percent shade. You can tell if you're on the right track with the correct amount of shading if the white pine seedlings grow about 1 to 1 ½ feet in height per year after being established for six to eight years.

Shade or no shade. Planting white pine seedlings in the open (like in an old field) is more acceptable in Hazard Zones 1 and 2 because the climate is less favorable to white pine blister rust infection. In Zone 2, blister rust can be a problem so avoid open field planting in V-shaped valleys, potholes and the bases of slopes.

HOW TO PLANT WHITE PINES

What to plant



A variety of planting materials are available.
1. Seedlings grown from seed collected in Minnesota may be better adapted to local conditions than seedlings from seed collected in other states. Verify the seed source with your grower.
2. Container stock, bare-root seedlings, bareroot transplants or even larger trees can be selected. Being larger, bareroot transplants, may survive better when planted in the shade of an overstory canopy.
3. Currently, there are no sources of planting stock proven to be resistant to white pine blister rust. Seedlings advertised as "resistant" may cost more and have no proven benefit.

Site preparation

Although white pine seedlings can do well in partial shade of overstory trees, they can be choked out by the shade of competing grasses, weeds and shrubs. These plants can be controlled or killed prior to planting by hand cutting, herbicides or scarification of the patches where the seedlings will be planted. A recent innovation is to use a "weed control" mat for each seedling. It inhibits weed and grass growth immediately around the planted seedling. The mat may be made out of a variety of materials including mulch, cardboard,

jute or polypropylene. It should be about three feet in diameter. Solid materials need to be weighed down with soil or rocks and a few holes poked through them to allow water to soak through.

Ribes reduction

Additional site preparation and tending work may be done to improve seedling and sapling survival. Since blister rust needs both the white pine and the *Ribes* to complete its life cycle, getting rid of the *Ribes* breaks the life cycle and therefore prevents blister rust infections. To prevent or minimize white pine blister rust infections, *Ribes* (currants and gooseberries) could be eliminated in and around high value plantings. *Ribes* are most easily identified in the early spring.

1. The effectiveness of *Ribes* eradication varies by location. It's most effective in Hazard Zone 1 and least effective in Zone 4. (See map in Site Selection.) If time and energy permits, eradicate *Ribes* in a buffer around the planting area, too. In Hazard Zone 1, eradicate Ribes in a 50 foot buffer, in Zone 2 = 70 feet, Zone 3 = 600 feet, and Zone 4 = 900 feet.
2. Pull up or treat all the *Ribes* species in the planting area. This should be done prior to planting and again two or three more times at three year intervals in order to get rid of the plants germinating from seed stored in the soil.
3. Don't plant gooseberries and currants near high value plantings of white pine.

When to plant

Spring is usually the best time to plant white pine. Soil moisture is usually good and cooler conditions help prevent drying of the young seedlings. In southern Minnesota, planting season is from early April to early May, whereas, in northern Minnesota, the season is late April to mid-May.

Handling and storage of seedlings

Due to root dessication, white pine seedlings may die before they even get their roots in the ground. Care must be taken so that young, bareroot seedlings are kept cool and moist right up until the time they are planted. When you receive your tree seedlings, check to make sure the roots are moist. If they are especially dry and crackly, return them to the nursery. If they are somewhat dry, wet them down and try to plant them as quickly as possible. If you need to store them for a few days before planting, keep them inside the package they were shipped in, find a cool, well shaded spot and allow for a limited amount of air circulation around the package. The sooner you plant them, the better their chances of survival. During the planting process, make sure the tree roots are kept moist and are not expose to long periods of sunlight or drying winds. Even a few minutes of exposure to a light breeze on a sunny day will kill the roots (and the seedling).

Planting methods

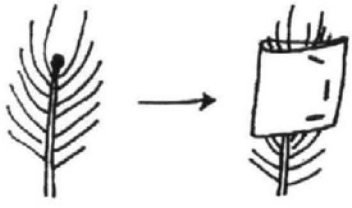
White pine seedlings can easily be planted using a shovel, hoedad or planting bar. Always plant in mineral soil, not in the duff or litter layer. Tree planting machines can be used for open field plantings, especially in southern Minnesota, where the risk of blister rust and weevil are low.

1. Make sure the hole is deep and wide enough to allow the roots to fully extend down and out to the side. Roots should assume a natural position and not be twisted, compacted or stick out of the hole.
2. Plant the seedling at the same depth it grew in the nursery. If planted too deep, roots will become curled and the seedling is more likely to be killed by insects and diseases. If planted too shallow, some roots will be exposed to the air and they will die.
3. Refill the hole with soil and pack the soil firmly around the root system. Avoid creating air pockets around the roots, creating a mound or depression near the stem or allowing large amounts of organic matter to be incorporated into the planting hole.

TENDING AND PROTECTING YOUR PINES

Deer browse

During the winter, white-tailed deer like to feed on white pine seedlings and saplings. Deer can chew off any twig tips within their reach. Serious damage is caused when the terminal (or topmost) bud is destroyed because the seedling is stunted and may be kept stunted by browsing year after year.



Bud capping for deer protection. White pines can be protected from deer browse by a number of methods including repellants, fencing, wire cages and bud capping. Bud capping is one of the cheapest and easiest methods, but must be done every year until
the terminal bud is out of the reach of deer. A bud cap is a piece of paper that is folded and stapled around the terminal (top) bud of the seedling to keep deer from chewing the buds off. This protects the terminal bud of the tree in the fall when the deer are likely to feed on it, yet allows the bud to expand and grow up through the paper sleeve during the next growing season. Deer will feed on the side branches but the bud cap usually protects the more important terminal bud. It's not necessary to remove the bud caps in the spring.
1. Bud caps should be applied in the fall before snow covers the ground, usually by November 1st .
2. Use light -weight paper such as typing or computer paper. The bud cap needs to last only a few months and should fall apart by the next growing season.
3. Cut the paper into 4" X 6" sizes. Smaller caps of 3" X 4" may be used for small trees.
4. Bud caps should be held on the tree by catching needles in at least three staples.
5. The terminal bud of the tree should be placed at least ½ inch below the top of the paper but not lower than the midpoint of the paper.
6. Bud caps should be applied every year until the tree is at least five feet tall or out of reach of the deer.

Plant competition

Weeds, grasses and shrubs compete for light, water, nutrients and space with the white pine seedlings. Seedlings can grow slowly, be stunted or die from competition

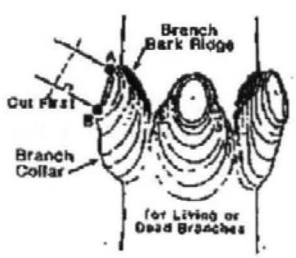
Maintaining good height growth and survival of the white pine will likely require control of competing grasses, weeds, shrubs and overstory trees. Try to maintain 1 to 1 ½ feet of height growth per year after the trees have been in the ground for six to eight years.
1. Grasses and weeds can be controlled by mowing, mulching, use of individual "weed control" mats or herbicides.
2. Competing brush and shrubs greatly reduce the survival and growth of white pine and must be controlled. This can be done by hand cutting or herbicides. Consult with a professional forester on types, timing and application methods for herbicides.
3. The shade from overstory trees should be maintained at 40 to 60 percent. Partial overstory release may be necessary to accomplish this. Overstory trees can be felled or girdled.
4. When growing pines under an overstory, maintain the overstory trees until the pines are at least twenty years old.

White pine blister rust

White pine blister rust is a fungal disease of white pine. It causes branch death, stem cankers, topkill and can be fatal. Live needles are the first to be infected then the fungus grows into the twig and towards the stem of the tree. A blister rust canker is the result of an infection that has been growing under the bark of a branch or stem for several years and is cutting off the supply of food and water to parts beyond the infection. This disease becomes more common and more serious as you go north and east in Minnesota, but blister rust can occur anywhere in the state where late summer weather is cool and moist.

Tree size can affect the severity of blister rust. Old, large trees can live a long time with blister rust. Often, these trees are topkilled because infections in the upper crown girdled and killed the main stem, yet, the lower crown can survive for decades. Infected side branches die before the fungus can grow down them, so the fungus can't reach or girdle the main stem. In contrast, young, small trees die when they are infected
with blister rust because all infections reach and girdle the main stem.

How to prune for blister rust



Careful pruning of white pine branches helps reduce the risk of damage from blister rust and white pine weevil. It also helps trees to grow straighter and produce higher quality wood products. Pruning is one of the most effective ways to reduce blister rust infections and tree mortality. Pruning is beneficial on any size tree. <u>However, pruning is most beneficial when started on young trees and continued until all the branches, on at least the lower nine feet of the stem, have been removed.</u> The "natural target" method of pruning allows the tree to quickly close the pruning wound with minimum risk of future decay.

How

1. If the branch is large or heavy, first cut it off more than six inches away from the final cut to prevent tearing of the bark when the branch falls.
2. For the final cut, locate the branch collar and the branch bark ridge.
5. Make the final cut at the line AB. Always avoid cutting into the branch collar.

When

1. Branches can be pruned almost anytime of year. The best time to prune live branches is during the fall and winter when the tree is dormant. Spring is the only time trees should NOT be pruned because the bark is easily damaged.
2. Begin pruning the lowest branches when the trees are two or three feet tall.

Pruning tips

1. You don't have to prune every tree on your site - prune only the best ones.
2. Don't remove too much crown. Do not remove more than 1/3 of the living branches at one time. Always maintain 2/3 of the tree height in live branches.
3. Do not flush cut the branches. Do not leave long stubs, either. Pruning cuts should be made just outside the branch collar. Use "natural target" pruning methods.
4. Pruning shears work best on branches up to the thickness of your thumb. Larger branches require lopping shears or a sharp pruning saw. Shears should have bi-pass blades (like scissors) rather than the anvil type. The anvil type crushes tissue rather than leaving a clean cut.
5. Do not use chain saws, Sandviks, hatchets, bow saws or clubs; this is delicate surgery.
6. Do not paint or treat the pruning cuts.

Pruning to prevent infections.

Pruning removes the lower branches that are most likely to become infected. Most blister rust infections occur within nine feet of the ground because cool, moist conditions favor infection.

1. Be sure to find and prune off the lowest branches. These often lay on the ground and are hidden in the grass.
2. Pruning should continue to a minimum height of nine feet but you may want to continue up to seventeen feet (for lumber production). Caution: try to maintain 2/3 of the tree height in live branches.
3. Frequent pruning is most effective because there's a greater chance of removing infections before they reach the main stem. Also, smaller branches are easier to prune.

Pruning already infected branches or leaders.

Pruning removes branches that are <u>already</u> infected and prevents the infection from growing down the branch into the stem.

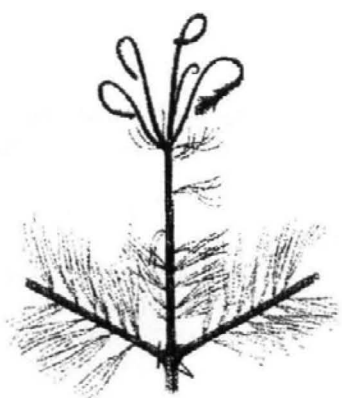
1. Prune off any infected branches higher up in the tree that you can reach.
2. Trees with blister rust cankers on the main stem or on a branch but

within four inches of the main stem cannot be saved. Do not waste your time pruning these trees.
3. Pruned branches can be left on site. They won't spread the infection.
4. Since blister rust is not carried from tree to tree on tools used in pruning, as are some fungal diseases, tools do not have to be sanitized between pruning cuts.

Pruning will NOT save every tree from blister rust
Some pruned trees will still be killed or topkilled by blister rust because:
1. Any live needle can become infected and since the terminal leader has needles on it, the stem can be directly infected through one of these needles.
2. An infection can take years to become recognizable, so the stem could already be infected but not recognized as infected at the time of pruning.

3. If the leading edge of a branch canker is four inches or less from the stem, the stem is already infected even though you cut the branch off.
4. In the northern and eastern parts of the state, the weather is cool and moist enough to allow infections to occur in the tops of even the tallest trees. Even here most of the infections occur within nine feet of the ground. So while pruning is an effective way to reduce blister rust infections on trees it is not a guarantee that infection and mortality will not occur.

White pine weevil



White pine weevils are insects that cause the wilting and death of the tree's terminal in June or July. At least two years' height growth can be lost in a single attack and the damage usually causes forking of the stem. Repeated attacks cause the tree to become bushy and stunted. Weevil damage can best be reduced by growing white pines under an overstory. The cooler temperatures and thinner diameter terminal leaders produced in the shade discourage weevil attacks. Damage from weevils can also be reduced by planting white pines at high densities, up to 1200 trees per acre, especially if the trees are open grown. The high density should be maintained until the trees are about twenty feet tall. These trees tend to produce thinner diameter terminals, which discourage weevil attack. Growing in high densities produces straighter trees. If attack does occur, a lateral branch will straighten up faster and take over for the terminal killed by weevils.

Insecticide applications can also be used to kill weevils as they try to lay eggs in the terminal leader. This method is not commonly used.

Corrective pruning for white pine weevil infestation

If a tree is attacked by weevils, a straight tree can be produced by pruning out the damaged terminal and "training" another lateral branch to take over as the new terminal leader. Also, promptly clipping and destroying the currently wilting terminal will help prevent damage next year by killing the next generation of weevils inside the wilted terminal.

1. Use a pruning shears to cut off the damaged terminal leader. Pruning off dead terminal leaders in July will remove the larvae still present inside them.
2. Be sure to remove enough of the terminal and main stem to remove the larvae. Larvae feed down the stem and will be found under the bark at the bottom edge of the damage, two or three whorls of branches down the stem.
3. Collect (bag) and destroy (burn) the infested terminals and infested stems so the larvae cannot complete their development and emerge as adults.
4. Prune the highest whorl of branches by cutting off all the side branches except one or by cutting back and shortening all side branches except one. (See figure at left.) This lateral will straighten up over a period of a few years and become the new terminal.

For additional information, please contact your local state, county or private professional forester.

Suggested Readings

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Katovich, S. And M. Mielke, 1993. How to Manage Eastern White Pine to Minimize damage from Blister Rust and White Pine Weevil. USDA Forest service NA-FR-01-93.

Nicholls, T.H. and R.L. Anderson, 1977. How to Identify White Pine Blister Rust and Remove Cankers. USDA Forest Service, N.C. For. Exp. Stn., 8p.

Robbins, K. 1984. How to select planting sites for eastern white pine in the Lake States. USDA, USFS NA-FB/M-8, 7pp.

Van Arsdel, E.P. 1979. Tree Diseases. Texas A & M University Press. pp119-134.

The last four illustrations were provided by USDS-USFS, S&PF and are taken from NA FR-01-93 by S. Katovich and M. Mielke.

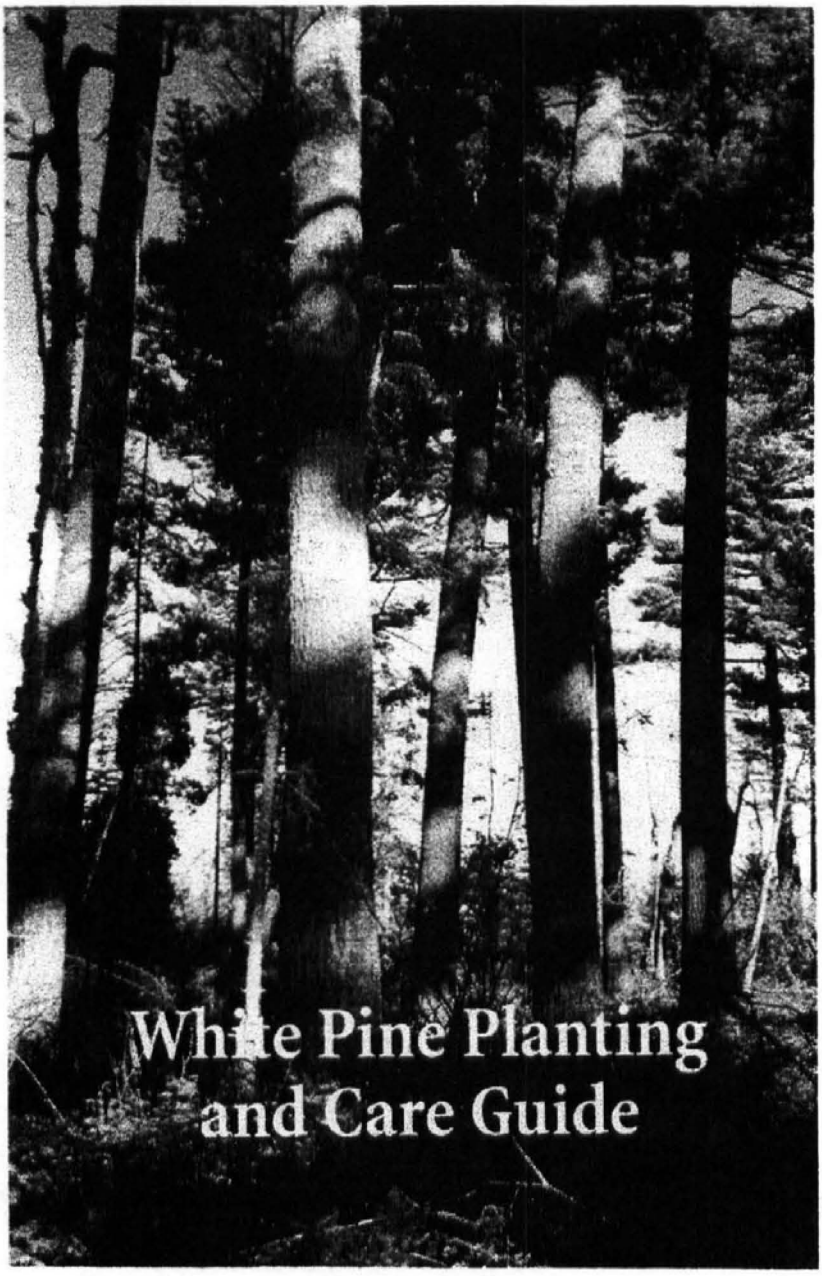
Minnesota Department of Natural Resources

Division of Forestry - Forest Health Unit

December 1997

White Pine Care Guide

This pamphlet has similar content to the previous publication, Growing White Pine in Minnesota. It is an abridged version with less forestry jargon. It was published to accompany private white pine seedling orders for the next seven years. Here is the cover.



Risk Assessment Guidelines: Hazard Trees, "An Easy to Use Field Guide"

By Ed Hayes

This article appeared in the April 1997 issue of Tree Care Industry Magazine.

Introduction:

Trees are important. They provide shade, improve air quality, wildlife habitat, soil protection, and aesthetics. People want trees, but they also want to be safe. This awareness of public safety and the increasing knowledge base of arborists and resource managers, combined in the late 80's to bring forward guidelines used to identify hazard trees.

Trees have limits. They have defined life cycles. As trees become more massive, advancing in age, the signs and symptoms of structural defects become evident to the trained eye. These are the dead wood, cracks, weak unions, decay, cankers, architectural and root problems. Guidelines can be written that describe levels of risk for each category of defect.

Trees fail in predictable patterns. Each species has a profile of tree defects. Learn the profile of defects for the species of trees that you work with. Each site develops a pattern of defects for the species found on that site. Begin to look for these patterns.

Hazard tree programs are becoming common and important in high use recreation areas and in urban and community forestry programs. Hazard tree assessment is now a tool used to regenerate urban forests. Risk assessment programs for tree hazards is good tree maintenance. The goal of a hazard tree program are not to sanitize recreation sites or urban areas but to provide reasonable public safety, and to maintain a renewable, diverse, and multi-aged tree cover. The benefits include reducing exposure to lability, reducing future storm damage and the costs of clean up, and increasing awareness for management, for what are not static, but constantly changing resources.

How to use these guidelines:

The guidelines use visual assessment of external indicators to predict potential of tree failure. There are seven categories of structural defects and two categories of risk, moderate and threshold, or high risk. These are only guidelines! Potential to fail is a measure of risk. It does not mean a particular tree will fail or not. These guidelines are only intended to provide information needed to evaluate potential to fail. Every tree is different, every site is different. Site, tree condition, and past history all play a roll in development of tree defects. Common sense, experience, and professional judgement are required of

the trained tree inspector. It is up to the trained inspector to determine the risk potential. These guidelines were developed for field people and intended to be easy to use.
These guidelines do not rate targets. There are many methods available for rating targets. Target ratings should be based on intensity of exposure to people.
Definitions:

Hazard tree- Defective tree with a target.

Target- Generally defined areas where people are invited to move through, linger, or stay. Includes facilities and personal property.

Moderate Risk Potential - Non-threshold, discretionary, defects. They may or may not result in eventual tree failure. Moderate weak unions and moderate poor architecture defects will eventually fail increasing in risk over time. Moderate cankers and decays can decrease in risk as additional wound free sound wood is added. However, moderate cankers and decays on exposed sites, and with full crowns (sails) may fail with significant loads (wind). Moderate defects are considered individually and in combinations. Combinations of moderate defects may or may not increase the risk of failure. For example, moderate cankers and decay in contact with one or more cracks would indicate the tree is failing (high risk). While a moderate root loss in contact with a stem decay or canker can remain a moderate risk.

High Risk Potential- Threshold level defects that indicate the tree has failed, is failing, or is in eminent danger of failing. Action must be taken as soon as possible.

The seven categories of defect;
Dead Wood: Dead trees and dead branches can fail at any time. Dead branches or dead tops that have all ready broken off and "lodged" are especially dangerous.

Cracks: Cracks are actual physical separations of the wood fibers. Cracks indicate the tree has failed or is failing. Cracks are the component killers of defective trees. Wood fibers can separate in two basic ways. Cracks can form across the grain, in the up and down, or axial plane of the tree (radial cracks), and between the growth increments (ring shakes). These guidelines evaluate to some extent internal but for the most park external cracks evident to the outside of the tree. Cracks are evaluated for the extent of compromise to the stem circumference. Any time the that one half or more of the tree circumference is structurally compromised the tree can fail. Cracks are evaluated for their extent into the tree and with what other defects they are associated. Branches with cracks are high risk. In addition it is useful to understand the difference between seams, propagating rib cracks, shear cracks, and tension cracks.

Seam- Seams can be indicators of internal defect or radial cracks but are covered by several layers

of annual growth. They are in effect a repair of an internal defect or radial crack.

Propagating rib crack- Radial cracks that are opening and closing and forming a rib or a nose rising off the tree surface. Propagating rib cracks can generally be assumed to be radial cracks to the center of the tree. Propagating rib cracks on opposite sides of the tree can generally be assumed to be radial cracks completely through the tree.

Shear crack- Serious radial cracks that generally form in the center of leaning trees. Shear cracks form in what are called the neutral fibers, where the shear forces are the greatest between wood that is under compression on underside of the lean and wood that is under tension on the upper side of the lean. A shear crack would indicate the tree is failing.

Tension crack- Fiber separation in the horizontal of tangential plane of the tree. The wood fibers are pulled apart by tension forces (the mass above is moving). Tension cracks are dangerous and catastrophic. The tree is failing!

Weak Unions: Weak unions are unions that have included or ingrown bark between two or more stems. There is no fiber attachment between the co-dominant stems. Weak unions are common in species with an opposite bud set, Maples and Ash. All weak unions will eventually fail, it is only a matter of time. Weak unions are easy to evaluate. Weak unions with a crack, canker face, or signs of decay in the union are high risk. Young trees with weak unions can be corrected.
In weak unions the included bark within the union forms a wedge which leads to an internal crack. Where cracked unions continue to open and close and not fail, a propagating rib crack will form. Eventually one stem becomes sufficiently overloaded enough to fail. Unfortunately, trees that fail from a weak unions leave the remaining stem with one half of the stem circumference compromised or high risk.

Decay: Decay is wood that is decayed or missing (cavity). The extent of tree decay in many instances can be the most difficult category to evaluate for risk of failure. Understanding how the process of decay works is vital to evaluating trees for defects. The objective is to determine if their is enough sound wood in the outer shell of the tree to support the tree. Studies have shown that tree failures resulting from decay occur when the sound wood in the outer shell is less than 30% of the stem radius. This works out to be a need for approximately one inch of sound wood for each six inches of stem diameter or root collar. In addition the cavity can be 1/3 open and the tree can have a full crown. Branches with decay are high risk.

There are many signs of decay, including cavities, holes, canker faces, branch stubs, and fruiting structures (conks). There is only one symptom of decay that is the addition of extra wood, a stem bulge, or swelling. Visual assessment of the extent of internal decay can be a reliable means of predicting potential risk. There are several types of decay. There are brown rots, white rots, soft rots, discolored wood and

wetwood. The brown rots are particularly nasty as they can fool the tree into acting as if it is still structurally sound. Brown rots may not produce any external signs or symptoms. In addition there are several problems that can result in continually expanding decay columns, repeated annual wounds, in rolling bark (rams-horning) at the edge of wounds and cavities, propagating rib cracks, and canker rot fungi.

Invasive techniques such as increment cores or drilling may be used to qualify the extent of sound wood or decayed wood. This must be done carefully and with several considerations. Use an increment borer only when there are no other means to estimate the extent of decay. Make the whole where the symptom is most pronounced. This is where the outer shell will be the thinnest.
It is helpful to know something about the resistance to decay of each species. Some species are very resistant to decay while others decay very quickly.

Learn from tree failures that result from decay or from tree removals. The patterns and extent of decay will be similar for each species of similar ages, condition, and history of past disturbance.

Canker: Cankers are areas of missing, dead, or sunken bark. They can be caused by mechanical injuries or diseases. In all cases the wood below the canker is affected to some extant. Cankers are evaluated for the extent of compromise to the stem circumference. Any time one half or more of the tree circumference is structurally compromised the tree can fail. A moderate canker or canker and decay where one third to one half of the stem circumference is compromised may or may not fail depending on the size of the crown and the exposure.

Poor Architecture: Poor tree architecture problems arise from patterns of structural weakness or imbalance. They can occur when individual trees are opened up from stands of trees, when large poorly tapered branches grow into openings, or they can be created. Mistreatment's such as topping, flush cutting, or disturbance that results in tree decline can all lead to architectural problems. Large epicormic branches poorly attached to decay columns are the result of topping. As trees become over mature for the site conditions, large old branches can begin to relax or subside. Epicormic branches that form on these branches result in trees on branches, or harp trees. These will eventually fail as the load increases over time. As large over mature trees begin to shed branches, it is a clear sign for the need to regenerate the tree.

All trees lean to some extent. When trees lean excessively they may become high risk. Leaning trees with signs of failure are quite different. Leaning tree's with compressed or buckling fibers on the lower or compression side would indicate the tree is starting to fail. This is one of the bio-mechanical warning

signals that can be seen in the bark. A tension crack on the upper or tension side would indicate very high risk and a failing tree. Leaning trees without signs of failure but with other moderate defects can place the tree in the high risk category.

Root Problems: When roots are severed from any number of reasons there can be a significant loss of structural support. Leaning trees with recent soil-lifting, soil movement or soil mounding would indicate the tree is failing. Where tap roots exist they can help anchor or support the tree. However it is the small diameter lateral roots under tension that provide a greatest anchoring support for the tree. The tensile (tension-pulling strength) of small 2 inch diameter roots is very dramatic.
Forty percent (40%) is only suggested as a guideline. If even one major supporting lateral root is severed a tree with a large crown may fail in a storm. In Mattheck's work there is a model for predicting windthrow.

The concepts of tree failure include; Defensive Dieback, Compartmentalization, and Adaptive Growth.

Defense Dieback: Trees react to energy stress! Trees can live for long periods of time by storing massive quantities of food, water, and meristematic tissue, (epicormic buds). As long a these energy resources are in good supply and replaced each year the tree does fine. However, with low energy reserves and under stress a tree may dieback defensively, shedding parts (dead wood) in order to survive. What the tree can no longer feed or defend is cut off. Trees can dieback to defined thresholds for that species on that site, beyond which the tree dies. If the stress is removed before the threshold is reached the tree can recover.

Compartmentalization: Trees react to wounds! Decay is caused by wounds. Decay is the highly ordered process described in Shigo's model Compartmentalization. Decay is confined to the wood present at the time of wounding. The tree reacts to the wound by creating a barrier zone separating the wood present at the time of wounding from the wood that will form after wounding. The wood present at the time of wounding will eventually be lost to a succession of micro-organisms. The wood that follows remains free of decay. This is how decay columns form!

Adaptive Growth: Trees react to mechanical stress! A tree is a self optimized bio-mechanical load bearing structure. It's mass is evenly distributed over it's entire surface. No single part is overloaded or under loaded in a self optimized tree. No part is made to fail more than any other. Loads must be transferred uniformly from the crown through the stem into the ground. Trees will fail where there is a weak link. A tree is an chain of links of equal strengths. To understand this is to begin to understand the mechanics of tree failure. Wood is preferentially added to overloaded areas measured by the tree in order to restore a state of uniform stress. This is adaptive growth. The only symptom of tree defect is the addition of extra wood! This in effect is the repair response. The objective of the inspector is to determine

if the repair has been made. If it has leave the tree.

Other considerations;

Exposure and crown size: Trees obviously in the open with full crowns have a higher exposure than trees in stands (groups) of trees. The guidelines given for tree failure are generally for full crown trees as they exist in their natural setting.

Inspections: Inspections for structural defects are best done in the leaf off seasons. Inspecting individual trees needs to be a systematic and complete process. Inspections should be done once a year and after serious storms. The first time through is the most time consuming.

Documentation: Always document your evaluations and actions. Use a standard form that records the species, defects, and treatment recommendations.

Treatment: Correcting hazardous trees can be as creative as your imagination and resources allow and include; moving the target, rerouting the traffic, pruning the tree, reducing the crown, fencing or closing the area, or removing the tree.

Training: Training is essential. A good training session can be completed in one day and must include a field session to evaluate trees. Learning can take several years.

The most important piece of information is a tree failure that does not have to cost you an arm and a leg. Investigate and learn from tree failures. If you want to see how trees fail take a walk in the woods.

Papers and posters presented

Included in this report:

History of a 45 year outbreak of spruce budworm in Minnesota
Interagency oak wilt working group
Integrated pest management activities to improve timber productivity concepts and actions
Assessing Gypsy Moth Damage Potential At The Landscape Level: A Predictive GIS-based Model

Poster: History of a 45 year outbreak of spruce budworm in Minnesota

By Mike Albers

Abstract:

Throughout North America, spruce budworm usually exists at low, endemic levels but periodically develops into large scale outbreaks. The population stays in an outbreak state until much of its food source, mature and overmature balsam fir and white spruce, are killed. The outbreaks in the past have generally lasted for eight to fifteen years. Northeastern Minnesota is experiencing it's 45th consecutive of spruce budworm outbreak. This outbreak is unusual and possibly unprecedented in length. This poster documents the geographic location of spruce budworm defoliation and the number of acres defoliated, during this outbreak , on a year by year basis.

This poster was presented at the "Improving Forest Productivity for Timber...A Key to Sustainability" conference held in Duluth December 1-3, 1998.

Poster: Interagency Oak Wilt Working Group.

By Dwight Scarbrough

Abstract:

The Interagency Oak Wilt Working Group is a cooperative working group of public agencies dedicated to preventing and controlling oak wilt through awareness and education. Current member agencies include: -
Hennepin County Parks
- Minnesota Department of Agriculture
- Minnesota Department of Natural Resources
- Minnesota Department of Transportation
- MnSTAC Forest Health Subcommittee
- University of Minnesota Extension Service
- USDA Forest Service

This poster was displayed at the 2nd Annual Vegetation Management Association of Minnesota (VMAM) Conference held July 20-21, 1998, at St. John's University. The conference was sponsored by the Minnesota Department of Transportation.

This poster was displayed at the 1998 North Central Forest Pest Workshop held September 14-17, 1998, in Dubuque, Iowa. The workshop was sponsored by the USDA Forest Service and the Iowa Department of Agriculture and the Department of Natural Resources.

Paper: Integrated pest management activities to improve timber productivity concepts and actions

By Michael R. Carroll, Alan Jones, Jana Albers and Michael Albers

Abstract:

Pest management actions are a critical portion of any efforts to improve forest productivity for timber. For most managers, pest management involves managing the host (tree) rather than the pest. Managers need to have practical understanding of the importance of selecting the proper site for a given planting project and maintaining crop tree vigor. The key ingredient is tree and stand vigor. The DNR Division of Forestry has specific pest considerations and management recommendations for the major cover types in Minnesota. The objective of the recommendations is to increase the available wood volume and quality available for harvest. If timber productivity is the goal, clearly defined management objectives are needed which include articulating specific volume and grade goals to support a defined economic return on investment. Given these specific targets and dollar guidelines, an integrated pest management plan should be put in place that includes establishing several crop species of proven genetics on the properly selected and prepared site. With the stand's basal area and species composition rigorously controlled, survey and evaluation actions can be scheduled and carried out. This will lead to implementing a crop protection plan which is supported by real dollars and staff so that timely actions to reduce pest impacts can be initiated. Cooperation with adjacent landowners would be critical for the effective implementation of control actions as part of sustainable forest management operations on designated landscape units.

This paper was presented at the "Improving Forest Productivity for Timber...A Key to Sustainability" conference held in Duluth December 1-3, 1998.

Paper: Assessing Gypsy Moth Damage Potential At The Landscape Level: A Predictive GIS-based Model

By Thomas G. Eiber

Abstract:

Foresters have been modeling damage caused by gypsy moth for decades. These models normally assess damage potential over either (1) a large area in a non-spatial context with a graphic output showing a map created by coding counties or (2) a small area utilizing spatially-identified, stand level data which is more intense and accurate. Minnesota has prepared a statewide damage potential model based on four factors that operate across all landscapes using spatial data. This model overcomes many of the spatial and scale problems associated with previous models. It also includes an environmental stress component derived from climatological data.

Our model predicts susceptibility to damage (ie. mortality) based on (1) cover type (AVHRR satellite-based data), (2) cover density (AVHRR satellite-based data), (3) soil type (Minnesota Soil Atlas), and (4) environmental stress moisture shortfall: EVM. The result is a model of where and how forest health is likely to decline when defoliation by the exotic gypsy moth occurs. Areas of the state likely to suffer significant mortality can be identified with spatial definition previously unavailable.

Presented at the GIS '98/RT '98 Conference in Toronto, April 6-9, 1998.

Survey Results

Survey information included in this report:
Aerial survey methods
Oak wilt, in selected townships in southeastern counties
Gypsy moth trap catches in Region 3
Spruce budworm
Pine tussock moth

Aerial survey methods

Good communications are essential between the appropriate Region Forest Health Specialists and the aerial survey mappers before and during the survey period because it is not possible to completely describe survey methods and also needs, timing, and methods change due to weather, current pest problems, current projects.

Pre-flight meeting:

On an annual basis, the mappers from Resource Assessment and Region Forest Health Specialists meet to discuss expected pest locations, ground check results and other topics of concern.

Preferred flight parameters:

1500 feet above ground level
3 mile flight lines
east-west flight lines

Timing:

In general, the main flight window is the last 2 weeks in June and the first 3 weeks in July. Since every year is just a bit different due to insect and tree phenologies, surveys should not start until the Region Forest Health Specialist (RFHS) gives the go ahead. The RFHS will be doing some pre-flight ground checks of insect phenology and damage to determine survey windows in each Region.

In addition, surveys may be flown at other times, for example, fall defoliators in mid-August. This will be determined on an annual basis.

The windows for specific pests are different temporally and geographically. Depending on the problems we're likely to encounter in a given year, the RFHS could indicate which pests are best viewed at which times. For example, spruce budworm is most visible during the last week of June and first week of July. There are additional limitations on flying for SBW; need to look for the color change in webbed needles before wind and rain knock them off the tree, low haze and shadows from clouds interfere with seeing the discolored needles. Since SBW has such a small window, it may be advisable to use more than one airplane in order to accomplish the acreage on a timely basis. Also, if clouds or haze occur in Region 2 or 3, interfering with SBW detection, then use that day to survey elsewhere.

For 1996, we suggested starting in the south (Rochester) in early to mid-June to pick up early defoliators which show up in the south first. Because of the short window for optimun viewing of spruce budworm damage, northern Region 2 should be mapped during the last week of june

and/or first week of July. Finish the remainder of the state by the 3rd week of July.

Time of day:

Generally, mapping can begin around 9 am and continue until haze, clouds, rain, etc. limit detection. For budworm, because the sun angle may limit the ability to pick up the slight color change we have historically surveyed from about 10 am to about 3 pm.

Weather:

Optimum = clear, blue sky, sunny days. Can't survey with a general overcast. As a rule, it is difficult to pick up color changes due to budworm feeding in both jack pine and spruce-fir in the shadow of a cloud. If cloud cover is patchy, you may be able to fly aspen defoliation detection as long as you can reliably distinguish cover type and defoliation.

If there's a question, fly over a ground checked area and be sure you can see the damage. Don't go into unknown territory under questionable conditions.

Maps:

1:100,000 scale. Use purchased maps in the plane, not photocopied maps.

On the maps:

1. Draw polygons delimiting the damage.
2. Make notations as to what type of damage it is (defoliation, mortality, stem breakage,etc.).
3. Make notations as to what tree species or cover type is affected OR if known, the causal agent.
4. Determine damage class. It is here that we can come up with many differing ways of describing damage. Yet, it's best to have as few "rules" as possible. We feel we can meet Federal standards and satisfy our own needs with these rules.

a. Map any damage type in stands surrounding FHM plots. The observer should judge how large an area to include. The ideal would be a 1,000 acre polygon (oligon) around the plot.

b. Do not map water-killed trees (beaver flooding) not associated with FHM plots (oligons).

c. **Defoliation alternative 1.** For defoliation, class 5 is NOT optional. Use classes 3,4 and 5 on the maps.

General definitions:
Class 3 = Heavy defoliation, scattered
Class 4 = Heavy defoliation, more or less contiguous
Class 5 = Light or moderate defoliation, scattered or contiguous.

Heavy = > 50% defoliation. Light and moderate = < 50%

Defoliation alternative 2. Map defoliation as light, moderate, or heavy and as scattered or contiguous and forget about classes during maping. When the maps are prepared for digitizing we would then add the classes. Light = 1 to 24%, moderate = 26 to 49%, heavy =>50% defoliation.

d. Map any occurrence of damage; there is no minimum size of damage. If you fly over something and it looks significant to you, then map it. Make any other notations, descriptions that you want directly on the map.

Exception to d. Map broad polygons (with appropriate damage classes noted) for pests

that cover many thousands of acres. Do not map individual stands in these situations:
SBW in northern St. Louis, Lake or Cook Cos.
aspen defoliation that covers many thousands of acres (FTC or LAT)

Post flight meeting:

As soon as the aerial survey is finished or as parts of it are finished the mapper should meet with the appropriate RFHS to review the map and together prepare the final version of the map. This will allow the RFHS to augment the aerial survey with knowledge acquired in ground surveys and also try to clear up any questions the mapper may have , etc. The RFHS will send the final version of the map to be digitized.

Coop agreements:

The USFS will fly Superior Natl. Forest, Chippewa Natl. Forest, Voyageur Natl. Forest and the Grand Portage Indian Reservation, and the Red Lake Indian Reservation. See map prepared by Bill Befort. (Resource Assessment will make final agreement with USFS regarding areas of survey coverage). The USFS should send us a digital file for the areas they survey in the state for merging with the state data.

Oak wilt survey, in selected townships in southeastern counties

These are the 1998 ground survey results from field checks of 100 of the 380 possible oak wilt sites identified in the September, 1997 aerial photography. Refer back to the Oak forest section of this report for more details.

Seventeen sites on state land in Wabasha County remain to be checked, as well as many more in the other counties surveyed. Multiple sites were checked in Olmsted County and are yet to be added to the survey results. Many of the Olmsted County sites are where the bulk of the control work took place in 1998.

County	Twp./Range/Sec./1/4	What Was Found
Houston	101-5-15-SE	DED(Dutch elm disease)
	104-8-21-NW	DED
	104-8-27-NW	DED
	103-4-11-SE	DED
	103-6-6-NE	DED
	103-6-4-SW	DED
	104-6-29-NE	DED
	104-6-28-NW	DED
	103-4-10-SE	OW(oak wilt)
	103-4-23-SW	OW-Landowner controlled
	103-4-11-SE	OW-Landowner controlled

	101-4-31-NW	OW-Landowner controlled
Fillmore	104-8-24-NW	OW
	104-8-24-SE	OW
	104-8-21-SW	OW
Winona	109-10-23-NWSE	OW
	109-10-23-NESW	OW
	107-10-27-SENE	OW
	107-10-27SENE	OW
	106-10-27-SWNE	OW
	106-10-20NESE	OW
	106-10-20-SWSE	OW
	106-10-20-SWSE	OW
	106-10-20-SWSE	OW
	105-10-1-NESW	OW
	105-10-1-NESW	OW
	106-10-35-NENW	OW
	106-10-35-NENW	OW
	106-10-35-NWNW	OW
	107-10-26-SWNW	OW
	107-10-26-SWNW	OW
	107-10-26-SWNW	OW
	107-10-26-NWNW	OW
	107-8-26-SENW	OW
	107-8-16-NENW	OW
	107-8-10-SWSW	OW
	107-8-36-SESE	DED
	107-8-25-NWSW	DED
	107-8-7-SENE	DED
	107-8-28-SWSE	DED
	107-8-33-SENE	DED
	107-8-22-NESW	DED
	107-8-9-SESE	DED
	106-10-20-NESW	Hickory Engraver
	106-10-35-NESE	Hickory Engraver

	106-10-35-NESE	Hickory Engraver
	106-10-35-SWNW	Hickory Engraver
	106-10-35-SWNW	Hickory Engraver
	107-8-9-NWNW	Not Field Checked
	107-8-9-SENE	Not Field Checked
	107-8-15-SESW	Not Field Checked
	107-8-15-SESW	Not Field Checked
	107-8-15-SESW	Not Field Checked
	107-8-32-SENW	Not Field Checked
	107-8-32-NENE	Not Field Checked
	109-10-24-NWNW	Not Field Checked
Goodhue	112-14-7-SESE	DED
	112-15-10-NW	DED
	112-15-3-SWSE	DGA,dead green ash-feed lot
	112-14-6-NW	OW, to be cleared-developed
	112-14-6-NW	OW, to be cleared-developed
	112-14-6-NW	OW, to be cleared-developed
	112-14-6-NW	OW
	11315-27-SW	OW
	112-14-6-NW	OW
	113-15-27-SW	OW
	112-15-1-NE	OW
	113-15-27-NE	OW
	112-15-1-NENW	OW
	112-15-12-NE	OW
	112-14-6-NW	OW
	112-14-5-SW	OW
	112-14-6-NWSW	OW
	113-14-6-SW	OW
	112-14-6-SW	OW
	112-14-1-SE	OW
	112-14-6-SW	OW
	112-14-6-NW	OW
	112-14-5-SW	OW

	112-15-2-SE	OW, State, sale, post-TSI
	112-14-7-SWSW	OW, State, sale, post-TSI
	112-14-7-NESW	OW, State, sale, post-TSI
Wabasha	110-11-28-NE	DED
	109-10-10-NW	DED
	110-11-12-SE	OW, State, sale, post-TSI
	110-10-7-SW	OW, State, sale, post-TSI
	110-10-7-SW	OW, State, sale, post-TSI
	110-10-7-SW	OW, State, sale, post-TSI
	110-11-29-SE	OW, State, sale, post-TSI
	110-10-7-SW	OW, State, sale, post-TSI
	110-11-28-NW	OW, State, sale, post-TSI
	110-11-29-NE	OW, State, sale, post-TSI
	110-11-22-NW	OW, State, sale, post-TSI
	110-11-21-NE	OW, State, sale, post-TSI
	110-11-15-SE	OW, State, sale, post-TSI
	110-11-15-SE	OW, State, sale, post-TSI
	110-11-15-NW	OW, State, sale, post-TSI
	110-11015-NE	OW, State, sale, post-TSI
	109-10-10-SE	OW, State, sale, post-TSI
	109-10-10-SE	OW, State, sale, post-TSI

1998 Gypsy Moth Trap Catches in Region 3

County	Township	Address	Township	Range	Section	1/4 Section	Num
Crow Wing	PLATTE LK	NONE04	3	29	07	NE	1
Crow Wing	DAGGETT BROOK	OG 97 FIRE	043	30	02	SE	1
Morrison	BELLEVUE	NOT GIVEN	039	32	10	NE	1
Stearns	AVON	18703 TWO RIVERS RD	125	30	06	NE	1
Stearns	ROCKVILLE	HOUSE #121	123	29	16	NW	1
Stearns	ST. JOSEPH	NOT GIVEN	124	29	10	SW	1
Stearns	ST. WENDEL	012976 CO. RD. 4	125	29	06	SW	1
Stearns	BROCKWAY	NONE	126	29	35	SE	1
Wright	WOODLAND TWP	8356 ELDER AVE.	118	26	16	SW	1
Wright	FRANKEN TWP	11781 DALTON AVE.	118	25	33	SW	1
Wright	FRANKEN TWP	AHERN AVE. SE	118	25	20	SW	1
Wright	OSTEGO	NW CORNER OF 37 AND 42	120	23	25	SW	1

Spruce budworm

Larval survey and defoliation estimates

Percent buds infested is derived from a 15 inch branch sample. The number of larvae found is divided by the number of buds on the sample and the resulting number is multiplied by 100. If the number is greater than 10 percent, heavy defoliation can be expected. Actual defoliation is the average value for nine 15 inch branch samples per plot. Actual defoliation is a visual estimate of the percentage of needles consumed during the feeding period. Percent buds eaten is the average value computed for nine 15 inch branch samples per plot. The number of consumed buds is divided by the number of remaining buds plus the number of buds eaten and the resulting number is multiplied by 100.

Egg mass survey

For each plot, three branches are clipped from the mid-crown of each of three co-dominant trees. The number of egg masses per 15 inch branch tip is tallied. The following scheme is used to predict next year's defoliation by spruce budworm.

Spruce budworm defoliation prediction		
Average number of egg masses per branch	**Expected defoliation next year**	**Expected percentages of new foliage consumed**
0 - 0.1	None to light	0 - 20 %
0.2 - 1.7	Moderate	21 - 50 %
1.8 or more	Heavy	51 - 100 %

Spruce budworm survey - 1998											
Location	**Species**	**1996**		**1997**		**1998**					**1999**
						Larval survey		**Egg mass survey**		**Notes**	
		Defolia-tion	**Ave # egg mass**	**Defolia-tion**	**Ave # egg mass**	**% of buds on twig**	**Ave # of larvae on twig**	**Actual defolia-tion**	**Ave. # egg masses**		**Pre-dicted defolia-tion**
Atkin Co.											
NENE 7-51-23	WS		0.1		0.55			58	0.44	Vigorous	Mode-rate
NENE 17-52-24	WS		0.1		0.11			9	0	Vigorous	O-Very Light

Spruce budworm survey - 1998

Location	Species	1996		1997		1998					1999
						Larval survey		Egg mass survey		Notes	
		Defoliation	Ave # egg mass	Defoliation	Ave# egg mass	% of buds on twig	Ave # of larvae on twig	Actual defoliation	Ave. # egg masses		Predicted defoliation
Becker Co.											
NWNE 21-141-36	WS				1.33			Heavy-Moderate	0.77		M
Beltrami Co.											
NESE 26-149-30	WS		1.5								
NWSW 12-147-30	WS				1.55			Heavy	1.33		M
SWSW 12-147-30	WS				0.33			VL	.01		L
NENE 26-149-30	WS				1.0			H	0.88		M
SESE 2-147-31	WS				2.1			H	0.55		M
NESW 1-148-31	WS		0.33								
Cass Co.											
NENE 1-139-26	WS				0						
NWNE 1-139-26	WS				0.66						
NWNW 11-139-26	BF		0.2		0.44			14	0.11	Vigorous	VL
NENE17-140-27	BF		0								
SENW 21-145-30	WS				.077			H	0.1		L
NWSE 9-145-30	WS				3.0			H	2.22		H

Spruce budworm survey - 1998

Location	Species	1996		1997		1998					1999
						Larval survey		Egg mass survey		Notes	
		Defoliation	Ave # egg mass	Defoliation	Ave # egg mass	% of buds on twig	Ave # of larvae on twig	Actual defoliation	Ave. # egg masses		Predicted defoliation
SWSE13-136-31	WS		1.3		0.33			24	0	Vigorous	VL
SWSE 13-136-31	"		0.5					21	0.11	Vigorous	VL
SWSE 22-138-31	BF		0								
SWNE 30-139-25	WS							58	0.1	Some trees have 40% of buds eaten. No dead tops	Light
NWNE 30-139-25	WS							52	0.1	No dead tops	L
NWSE 8-145-30	WS										
Chisago Co.											
SESE 36-36-21	WS		0								
Cook Co.											
NWNW 33-63-4E	WS,BF	M	0.22								
NESW 35-64-3E	BF	O	0								
NWSE 3-61-1E	BF	L	0	L	0.0						
SWNE 22-63-1E	BF	O	0								
NESW 10-64-1W	BF	O	0								
SENE 4-61-1E	BF, WS			L	0.0	<10	2.1	1	0	Vigorous	0
Crow Wing Co.											

Spruce budworm survey - 1998											
Location	Species	1996		1997		1998					1999
						Larval survey		Egg mass survey		Notes	
		Defoliation	Ave # egg mass	Defoliation	Ave# egg mass	% of buds on twig	Ave # of larvae on twig	Actual defoliation	Ave. # egg masses		Predicted defoliation
SENE 19-44-31	WS		0.8		0.33			3	0	Vigorous, recovered	O-VL
Hubbard Co.											
SE 13-141-32	WS		0.55								
SWSE 13-141-32	WS				0.33			H	0.0		L
SESE 1-143-33	WS		1.99		0.44			M	0.22		L
SE 1-142-33	WS		1.66								
NWSE 23-145-33	WS		1.66								
NENE 24-139-34	WS				NA			VL	0.11		L
NWNE 21-141-36	WS		2.1								
Itasca Co.											
NESE 2-61-22	BF			M	0.33	80	7.8	88	0.66	In campground small stands , over mature SW & BF	M
NENW 34-62-22	BF	L	0.44	VL	0.77	55	5.7	29	0.22	Good vigor	M
NWSE 26-62-23	BF	L	0	L	0.55	20	3.1	32	0.22	Mix Pines, Aspen Birch	M
NWSW 3-58-24	WS	L	0	O	0.0	<1	0	<1	0	Vigorous	O
SWNE 3-58-24	WS	O	0	O	0.0	<10	.1	<1	0	Vigorous	O

Spruce budworm survey - 1998

Location	Species	1996		1997		1998					1999
						Larval survey		Egg mass survey		Notes	
		Defoliation	Ave # egg mass	Defoliation	Ave # egg mass	% of buds on twig	Ave # of larvae on twig	Actual defoliation	Ave. # egg masses		Predicted defoliation
SWSW 35-58-24	WS			M	1.22						
NENW 23-59-24	BF					<10	0	<1	0	Vigorous	O
SWSE 36-62-24	BF WS	H	0.77	H	1.0	95	16.3	9	0.33	Many trees on south edge are newly 90% defol. Few live branches on lower 3/4 of crown.	
NENE 17-53-25	WS			M	1.99						
NWSW 35-58-24	WS	L	1.1	M	1.22	90	15.6	40	0.44	No dead tops	M
NWNE 7-60-25	WS	O	0								
NW 9-56-25	WS	O	0.44								
NWNE 4-60-26	WS	O	0								
SENW 12-53-26	WS	VL	0.1		0.11	25	1.11	3	0.11	Vigorous	L
SESW 11-53-26	WS	VL	0.1	VL	0.55	40	3.1	17	0	Vigorous	O-VL
SWSE 17-60-26	BF	VL	0			<10	0	1	0	Vigorous	O
Koochi-ching Co.											
NWNW 4-65-22	BF			H	1.2	90	5.7	98	1.33	Natural stand	Modrate -Heavy
NWNW 19-65-22	WS,BF	M	2.0	L	1.1	80	6.7	74	0.77	Good vigor, mixed stand	M
NENE 24-65-23	BF			M	0.55						

Spruce budworm survey - 1998

Location	Species	1996		1997		1998					1999
						Larval survey		Egg mass survey		Notes	
		Defoliation	Ave # egg mass	Defoliation	Ave # egg mass	% of buds on twig	Ave # of larvae on twig	Actual defoliation	Ave. # egg masses		Predicted defoliation
10-67-22	WS							H	0.55	WS short for their age. Lots of buds set. Quite a few overstory WS & BF	M-H
SENE 23-67-22	BF	L	1.2								
NESW 31-70-26	WS				0.1	60	9.3	60	0.22	Gen. def of stand is light	M
SENW 4-71-22	BFWS				0.44	80	7.8	82	0.55	L-M def in 1998	M
SESE 35-71-24	WS	L	0.11								
SESE 8-69-23	BF				0.11	35	6.0	57	0.44	Mixed stand, natural-stands around show light, defoliation to pockets of mod. Def.	M
SESE 16-69-23	BF	L	0								
NWNE 22-65-23	BF			M	0.55	90	8.5	83	0.88	BF stands along Hwy 65 have mod.-light def.	M
SWSW 25-69-23	WS					12	5.3	41	0.44	Yard trees-range crowns. Light def observed from ground	M
NWSE 5-70-23	BF							95	0.77	Poor vigor	M
SWSE 36-62-24	BF WS	M	0.77	H	1.0	95	16.3	99	0.33	Many trees on South edge are 90% def. Trees are newly def-few live branches in lower 3/4 of crown.	M

Spruce budworm survey - 1998

Location	Species	1996		1997		1998					1999
						Larval survey		Egg mass survey		Notes	
		Defoliation	Ave # egg mass	Defoliation	Ave# egg mass	% of buds on twig	Ave # of larvae on twig	Actual defoliation	Ave. # egg masses		Predicted defoliation
SENE 27-70-25	WS					70	16.8	80	0.44	Mixed pine, spruce hwds. Good vigor	M
NWNE 27-158-26	WS		0			<10	.22				
Lake Co.											
SWNE 11-55-8	BF		0	O	0.0	<10	0	<1	0	Vigorous	0
SWSE 5-59-8	BFWS		0	O	0.0	<10	.1	0	0	Vigorous	0
NESE 28-61-10	WS		0								
SENE 11-61-11	WS,BF		0								
SENW 31-62-11	WS,BF		0.11								
Mille Lacs											
SWSE 1-35-27					1.0						
Morrison Co.											
NENE 1-41-29	WS		1.66		0.33			6	0	Vigorous, recovered	O-VL
NESW 11-42-32	WS		0		0.44						
Sherburne Co.											
NWNW 33-34-27	WS		0.55		0.22			31	0.1	Vigorous	L
St. Louis Co.											
NESE 22-62-12	WS,BF		0.55	L	0.33	30	3.3	12	0	10% Dead fir	O-VL

Spruce budworm survey - 1998

Location	Species	1996		1997		1998					1999
						Larval survey		Egg mass survey		Notes	
		Defoliation	Ave # egg mass	Defoliation	Ave # egg mass	% of buds on twig	Ave # of larvae on twig	Actual defoliation	Ave. # egg masses		Predicted defoliation
NWNE 6-63-12	BF		0.11								
SESE 31-58-13	WS,BF		0	O	0.0	0	0	<1	0	Vigorous	O
NWNE 4-62-13	BF		0.22								
NESE 6-63-17	BFWS		0.11	M	1.55	70	9.3	35	0.77	A very few dead, old balsam firs	M
SWNW 2-64-17	BF		0								
NENE 8-51-18	WS		0								
SWSW 33-61-18	WS,BF		1.33	L	2.11	40	9.6	41	1.22	Tofted branches, no dead tops	M
NWNW 33-65-18	BF		2.55	H	3.33	85	11.0	86	1.22	20% Dead top	M
SWSW 26-61-20	WS							<1	0	Trees growing on rocky outcrop	O
NWNE 25-63-20	BF							82	1.33	Second year of def.	M
NENE 12-68-20	WS,BF		0.33								
SWNW 33-60-21	WS			M	1.66	90	14.3	82	0.33	Mature trees, mixed cedar, White pine, wind break natural	M
SWSW 2-60-21	WS		0.88	M	2.77	90	19.6	87	2.0	Poor vigor-open spacing between trees	Heavy
NWSW 12-64-21	BF		0.22		0.66						

Spruce budworm survey - 1998

Location	Species	1996		1997		1998					1999
						Larval survey		Egg mass survey		Notes	
		Defoliation	Ave # egg mass	Defoliation	Ave# egg mass	% of buds on twig	Ave # of larvae on twig	Actual defoliation	Ave. # egg masses		Predicted defoliation
NESW 12-64-21	BF	H	.022		.066	90	10.9	95	1.55	Adjacant stand at Balsam saplings in area show mod-heavy def. (Ripro saplings)	M
SENE 16-67-21	WS							H	0.44	Trees 30+ years old. Much current year shoot mortality. Some branches w/lots of new bulbs. Others few.	M
SENE 16-67-21	WS							H	0	Trees 20 years old. Lots of new buds set for next year	O
16-67-21	WS							L	0.3	Trees are 10-18' tall	L
30-67-21	WS							L	0.44	All EM are only 1/4 normal size	M
30-67-21	WS							H	0.44	Trees 12-25' tall	M
SESW 12-68-21	WS		0.77	H	1.55	100	14	83	1.22	Severe def.- many along edge with less then 10% of original crowning. Should be harvested	M
SESE 13-64-21	BF			L	0.66	80	11.2	96	0.33	Poor vigor-mature trees mixed stand along road	M

Pine Tussock Moth

Pheromone trapping

The following data represents an annual effort to monitor the populations of the pine tussock moth, an insect that has, in years past, increased in such great numbers that it caused heavy mortality of pines in Mission Township of Crow Wing County and in Pine County around General Andrews Nursery. Since l980, the numbers of pine tussock moth caterpillars in Pine and Crow Wing Counties have diminished or remained low. In 1996 and 1997, trap catches increased sharply in Wadena and Hubbard Counties and had variable trends in 1998.

A count of 30 or more male moths in a trap over a 7-l4 day period would indicate possible need for chemical or other control the next year. Such numbers and decision to apply controls should be combined with larval surveys and defoliation assessments of the infested jack pines.

COUNTY	LOCATION	DATE TRAP PLACED	TRAP NO. OR NAME	DATE TRAP CHECKED	MALE P.T. MOTHS IN TRAP	COMMENTS
Crow Wing	SWSE 30-134-28	6-8		7-8 7-13 7-31 8-11	0 2 5 0	Trap at Paul Bunyan Nature Learning Center
Crow Wing	NENW 9-136-27	6-8	1	6-25 7-10 7-3l 8-19 9-8	4 8 4 9 0	
Crow Wing	SWNE 9-136-27	6-8	2	6-25 7-10 7-31 8-19 9-8	1 1 10 3 0	
Crow Wing	SWSW 9-136-27	6-8	5	6-25 7-10 7-31 8-19 9-8	7 3 4 14 0	
Crow Wing	NWSW 11-136-27	6-8	3	6-25 7-10 7-31 8-19 9-8	8 8 6 8 0	
Crow Wing	NENE 23-136-27	6-8	4	6-25 7-10 7-31 8-19 9-8	6 2 0 3 0	
Hubbard	16-139-32		C Nursery	6-26 7-2 7-9 7-25 9-3	28 11 14 3 0	

COUNTY	LOCATION	DATE TRAP PLACED	TRAP NO. OR NAME	DATE TRAP CHECKED	MALE P.T. MOTHS IN TRAP	COMMENTS
Hubbard	10-139-32		Cutover Rd	6-1 6-26 7-2 7-9 7-25 9-3	27 42 31 20 6 3	
Hubbard	35-139-33		Game Farm	6-16 6-26 7-2 7-9 7-31 9-3	24 26 15 22 13 6	
Hubbard	16-139-32		F Nursery	6-26 7-2 7-9 7-25 9-3	31 7 18 5 2	
Hubbard	9-139-32		Woodland Tour	6-16 6-26 7-2 7-9 7-25 9-3	8 29 21 15 6 2	
Hubbard	15-139-32		Potlatch 64	6-16 6-26 7-2 7-9 7-25 9-3	8 30 27 18 7 17	
Hubbard	34-139-33		Short Cut Road	6-16 6-26 7-2 7-9 7-31 9-3	12 22 2 3 6 0	
Hubbard	17-139-32		Tripp Lake Road N.	6-16 6-26 7-2 7-9 7-31 9-3	4 14 8 3 4 0	
Hubbard	29-139-32		110-109 Jct.	6-16 6-26 7-2 7-9 7-31 9-3	26 31 19 16 2 1	

COUNTY	LOCATION	DATE TRAP PLACED	TRAP NO. OR NAME	DATE TRAP CHECKED	MALE P.T. MOTHS IN TRAP	COMMENTS
Hubbard	31-139-32		109 South Cr.	6-16 6-26 7-2 7-9 7-31 9-3	24 34 21 18 12 2	
Hubbard	12-139-32		Chimney Rd.	6-16 6-26 7-2 7-9 7-25 9-3	14 20 4 2 1 4	
Hubbard	25-139-33		Old Landing	6-16 6-26 7-2 7-9 7-31 9-3	20 23 18 9 5 2	
Hubbard	26-139-33		Mid R. Hill	6-16 6-26 7-2 7-9 7-31 9-3	24 38 17 9 5 3	
Hubbard	26-139-35		St. River 1	6-16 6-26 7-2 7-9 7-31 9-3	4 13 6 7 12 13	
Hubbard	25-139-35		St. River 2	6-16 6-26 7-2 7-9 7-31 9-3	1 14 12 6 13 8	
Pine	SENW 6-44-19	6-9	7	6-25 7-10 7-31 8-19 9-8	0 0 7 4 0	

COUNTY	LOCATION	DATE TRAP PLACED	TRAP NO. OR NAME	DATE TRAP CHECKED	MALE P.T. MOTHS IN TRAP	COMMENTS
Pine	SESE 30-45-19	6-9	8	6-25 7-10 7-31 7-19 9-8	1 1 7 0 0	
Pine	SWSW 36-45-20	6-9	11	6-25 7-10 7-31 8-19 9-8	3 1 0 0 0	
Pine	NESW 26-45-20	6-9	9	6-25 7-10 7-31 8-19 9-8	0 0 8 4 0	
Pine	NENW 36-45-20	6-9	10	6-25 7-10 7-31 8-19 9-8	2 2 2 0 0	
Wadena	14-138-33		Huntersville Imp.	6-16 6-26 7-2 7-9 7-31 9-3	9 19 6 2 5 0	
Wadena	10-138-33		Roadsign 1	6-16 6-26 7-2 7-9 7-31 9-3	27 19 19 4 1 1	
Wadena	3-138-33		Duck Hole	6-16 6-26 7-2 7-9 7-31 9	33 29 15 3 0 1	

COUNTY	LOCATION	DATE TRAP PLACED	TRAP NO. OR NAME	DATE TRAP CHECKED	MALE P.T. MOTHS IN TRAP	COMMENTS
Wadena	7-138-33		Shell River	6-16 6-26 7-9 7-31 9-3	9 15 11 12 5	
Wadena	8-138-33		Tree Farm 1	6-16 6-16 7-9 7-31 9-3	0 15 11 12 5	
Wadena	11-138-33		Road Sign II	6-16 6-26 7-2 7-9 7-31 9-3	22 15 8 4 5 0	
Wadena	9-138-33		Tree Farm 2	6-16 6-26 7-2 7-9 7-31 9-3	10 20 9 12 0 4	
Wadena	27-138-33		Nimrod S	6-16 6-26 7-2 7-9 7-31 9-3	9 25 10 13 8 1	
Wadena	22-138-33		Nimrod North	6-16 6-26 7-2 7-9 7-31 9-3	19 17 8 3 2 1	