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GYPSY MOTH SILVICULTURAL CONSIDERATIONS
FOR MINNESOTA
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FIELD TATUM GUIDE

SILVICULTURAL TIP SHEET
INTRODUCTION

Gypsy moths, *Lymantria dispar*, were introduced into North America almost 150 years ago near Boston, Massachusetts. By the 1990s, gypsy moths had spread throughout the northeast and mid-Atlantic States into Michigan and Wisconsin (see Map 1). The Minnesota Department of Agriculture has been successfully detecting and eradicating spot infestations within Minnesota since 1969. However, it is just a matter of time, likely five to ten years, before gypsy moths become permanently established in this state.

In 2001 the “Strategic Plan for the Cooperative Management of Gypsy Moth in Minnesota” was developed by the Minnesota Department of Agriculture, Minnesota Department of Natural Resources (DNR), USDA Forest Service (USFS), USDA Animal and Plant Health Inspection Service (APHIS), and the University of Minnesota (UMN). The strategic plan recognized silvicultural practices as a valuable set of tools in dealing with this exotic pest. Because trees are long-lived and slow growing, forest management practices are most effective when applied well in advance of gypsy moth defoliation. Land managers can minimize the ultimate impact of gypsy moth defoliation by starting now.

Map 1. Gypsy Moth Action Zones, 2002

INTENT OF THIS DOCUMENT

The goal of this document is to enhance forest management in order to mitigate the long-term impacts associated with gypsy moth defoliation. The objective is to provide professional land managers the tools needed to make sound gypsy moth management decisions within the context of normal silvicultural practices. In recognition of the fact that gypsy moth management is only
one issue facing land managers, the intent is to present the information in a format which can be easily integrated with other management considerations.

Because the gypsy moth is not currently established in the state and won’t be for some time, this document focuses on the five to ten year period prior to infestation. Because the time needed for forests to respond to any form of management is relatively long, we encourage land managers to incorporate gypsy moth considerations into their plans now. Recommended steps include:

1) Review the risk model for areas at risk of damage.
2) Update stand inventories in areas at high to moderately-high risk.
3) Evaluate stand inventory data and prioritize stands that may benefit from active management with planning partners.
4) Incorporate gypsy moth considerations into scheduled management practices as budgets allow.

**RISK OF DAMAGE**

Gypsy moths produce two types of damage with the potential to affect land-use objectives, defoliation, and tree mortality. Different factors influence whether or not a stand is at risk of defoliation or of tree mortality and different strategies are used to minimize their impacts. Stands highly susceptible to defoliation may suffer little mortality when subjected to frequent heavy defoliation if they are growing under favorable conditions. Stands that have a low susceptibility to defoliation, may suffer heavy mortality on the unusual occasion of being defoliated, if extenuating conditions place them at risk. So understanding the distinction between susceptibility to defoliation and vulnerability to mortality is important in selecting appropriate management strategies.

**Risk of Defoliation and Species Composition**

The most important factor affecting the susceptibility to gypsy moth defoliation is the proportion of the stand comprised of gypsy moth’s preferred host species. While many species of trees and shrubs are utilized as a food source, gypsy moth caterpillars prefer some species and avoid others. Stands dominated by oaks, aspen, birch, basswood, tamarack, or other preferred species are at a higher risk of defoliation because they are fed on by all caterpillar stages (see Table 1). In Minnesota, 53% of the forests are comprised of 50% or more of these preferred host species. Susceptible stands dominated by preferred host species are defoliated at higher rates, more often, and for longer periods of time than stands composed of avoided species such as ash and silver maple.

Defoliation events will occur within five to 15 years of the initial infestation of a given area. Most hardwoods will be defoliated at least once as the populations spread across the state. Subsequent outbreaks will depend on stand composition and site conditions that provide favorable gypsy moth habitat. Some stands will be 100% defoliated on a regular basis and some will be completely avoided. Most stands, however, will fall somewhere between these two extremes, with patchy, intermittent defoliation.
Table 1. Gypsy Moth Host Preferences

<table>
<thead>
<tr>
<th>Category</th>
<th>Overstory species</th>
<th>Understory species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preferred</strong></td>
<td>Species readily eaten by all caterpillar stages.</td>
<td>Hawthorn, hazelnut, hop</td>
</tr>
<tr>
<td></td>
<td>All oak, bigtooth and quaking aspen, basswood, paper and river birch, larch,</td>
<td>hornbeam, hornbeam,</td>
</tr>
<tr>
<td></td>
<td>mountain-ash, tamarack, willow, red alder, and apple.</td>
<td>serviceberry, witch-hazel.</td>
</tr>
<tr>
<td><strong>Less preferred</strong></td>
<td>Species fed upon when preferred species are unavailable and by older caterpillar stages.</td>
<td>Blueberries, pin cherry,</td>
</tr>
<tr>
<td></td>
<td>Yellow birch; box elder; butternut; black walnut; sweet and black cherry;</td>
<td>chokecherry, sweet fern.</td>
</tr>
<tr>
<td></td>
<td>eastern cottonwood; American, Siberian** and Chinese elm; hackberry; hickory;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Norway**, red and sugar maples; all pine; all spruce; buckeye*, and pear*.</td>
<td></td>
</tr>
<tr>
<td><strong>Avoided</strong></td>
<td>Species that are rarely fed upon.</td>
<td>Dogwood, elderberry,</td>
</tr>
<tr>
<td></td>
<td>All ash, E. red cedar, balsam fir, silver maple, slippery elm, N. catalpa*,</td>
<td>grape, greenbrier, juniper,</td>
</tr>
<tr>
<td></td>
<td>Kentucky coffeetree*, horse chestnut*, sycamore*, black** and honey* locusts and</td>
<td>mountain and striped maple, raspberry,</td>
</tr>
<tr>
<td></td>
<td>red mulberry**.</td>
<td>viburnum, and buckthorn**.</td>
</tr>
</tbody>
</table>

* Commonly planted urban species. Use in woodlands is not recommended.
** Species that can be invasive. Gypsy moth defoliation may increase their competitive edge if left in a managed stand.


**Site Condition**

Some stands that are otherwise susceptible will not be defoliated because they are not climatically suited for gypsy moth establishment and/or population build-up. Extreme cold temperatures (-22 F for ≥ two days) can kill the eggs. Winter mortality can keep populations low and limit or prevent defoliation, as seen in the upper peninsula of Michigan. However, egg masses survive well under snow, so population numbers can build during years of heavy snow cover. Warm winter temperatures and high solar radiation can also have an effect on winter survival, killing eggs laid in sites exposed to the sun.

Sites with a history of severe defoliation are often characterized by frequent droughts, and low foliage biomass. Harsh growing conditions and a history of disturbance are commonly associated with historically susceptible stands. The correlation isn’t clear, but may be due to an interaction between the abundance of host species and low rates of gypsy moth predation. Gypsy moths escape predation by hiding under bark flaps, in stem wounds, and on dead branches. Harsh sites often have a higher concentration of hiding places for the gypsy moth caterpillars and relatively little habitat for predators like spiders, white-footed mice, and birds.
Risk of Tree Mortality
Davidson et al. outlined a number of consistent relationships found between gypsy moth defoliation and tree mortality:

1. Preferred tree species are defoliated at higher rates and frequently suffer greater mortality than avoided species.
2. Tree mortality increases as the intensity, duration and frequency of defoliation increases.
3. Trees in the lower canopy (suppressed and intermediate crown classes) have a higher probability of being defoliated and dying, than trees in the upper canopy (dominants and co dominants).
4. Physiological condition prior to defoliation directly influences the probability of mortality of individual trees. Those in good condition are less likely to die than those in poor condition."

These factors do not act independently; rather, it is their interaction that determines the outcome in the affected stands. Actual mortality in a given situation will depend on the duration and severity of defoliation, as well as the influence of local site and environmental conditions during the outbreak.

Intensity and Duration of Defoliation
Species composition is the primary factor determining the risk of defoliation. The primary factor determining the risk of mortality is the intensity and duration of defoliation. Light defoliation (less than 30%) usually causes little damage to trees. Trees with moderate defoliation (30% to 60%) may experience some growth loss, but are unlikely to die. When heavy defoliation occurs (greater than 60%), refoliation places a demand on the tree’s food reserves. The stress of refoliation can leave trees weakened and vulnerable to secondary pests, such as two-lined chestnut borer on oak and Armillaria root rot on all species. As the number of consecutive episodes of defoliation increases, the probability of tree mortality rises. Multiple stress events can have an additive effect and can result in significant loss of trees. For example, tree mortality in Michigan has been observed primarily in oak-dominated stands where gypsy moth defoliation coincided with late spring frosts or drought.

Gypsy moth outbreaks commonly last one to five years in eastern North America. However, the initial outbreak in a newly infested area is generally longer and more severe. In eastern states, initial outbreaks resulted in mortality losses of 20% to 35% of the total basal area of defoliated stands. In Michigan, initial gypsy moth outbreaks lasted 2 to 4 years in oak-dominated forests and 1 year in aspen forests. Losses at the stand level among oak forest types ranged from 0% to 75% of the basal area with average losses of 6% to 10% across all forest types. Losses associated with later outbreaks are generally lower. After the initial outbreak, gypsy moths behave much like native pests with outbreaks occurring every four to twelve years.

Among Minnesota tree species, those most at risk of damage include oak, aspen, tamarack, and basswood. Among these, oak is the most likely to suffer noticeable levels of mortality that can impact community structure, wildlife habitat, and dependent industries.

Mortality rates among aspen are likely to be low. However, the nutritional value of aspen leaves means caterpillars grow rapidly and are more likely to survive to adulthood. This allows gypsy moth populations to build rapidly. Fortunately, gypsy moth outbreaks among aspen stands are
short lived. Trees are able to recover prior to the next defoliation event. In Michigan, outbreaks in stands dominated by oaks last two to four years, whereas outbreaks in aspen stands commonly collapse after one year of defoliation. The early collapse is thought to be associated with the rate of larval infection by the nucleopolyhedrosis virus (NPV) virus, a common disease of gypsy moth. The low pH of oak leaves alters the rate of protein release and thus the toxicity of the NPV virus. Tannins, which are in higher concentrations in oak leaves than in aspen leaves, actively inhibit the virus. The combination results in less disease resistance and shorter outbreaks among populations feeding on aspen.

The difference in nutrition between aspen and oak may influence the frequency of defoliation in mixed or adjacent stands. Aspens may allow a rapid buildup of gypsy moth populations, while oaks sustain them. As a result, trees in mixed or adjacent stands may see repeat defoliation and increased mortality where they otherwise might not.

Minnesota has vast acreages of aspen, birch, oak, and basswood susceptible to both forest tent caterpillar (FTC) and gypsy moths. If gypsy moth and FTC outbreaks occur concurrently, the two insects may compete with each other for food. Because FTC emerges slightly ahead of the gypsy moth, FTC may limit gypsy moth population build up. If outbreaks occur consecutively, the prolonged stress may cause heavy mortality among all species involved.

While not normally a preferred host, white pine can be at risk of damage when grown under a susceptible overstory. Where thinning isn’t sufficient to reduce the risk of defoliation, the loss in value resulting from early harvest of a susceptible overstory may have to be weighed against the cost of protecting valuable understory pine.

**Crown Condition and Class**
The greatest single indicator of the likelihood of individual tree mortality is the physiological condition of the tree prior to defoliation. Crown condition is a highly visible indicator of a tree’s level of stress and is therefore a good measure of its vulnerability to defoliation-related mortality. Mortality is highest among poor-crown trees, intermediate among fair-crowned trees, and lowest for trees in good condition (see Figure 1).

- **Poor crowns** = 50% or more of the main branches are dead; when foliage density, size, and coloration are subnormal; or when epicormic sprouting is heavy.
- **Fair crowns** = 25% to 49% of the main branches are dead; when foliage density, size, and coloration is subnormal; or when there is some epicormic sprouting.
- **Good crowns** = less than 25% of the main branches are dead; when foliage is healthy; and there is little or no epicormic sprouting.

Crown class has a similar correlation. As a general rule, intermediate and suppressed trees are more likely to die than dominant or codominant trees following defoliation. Small diameter trees and very large, overmature trees are also more likely to die than large, vigorous trees. In Michigan, most of the mortality has been in the suppressed- and intermediate-crown classes.

Even among the most susceptible species, dominant or codominant trees with crowns in good condition are likely to survive multi-year defoliation. On the other hand, a tree in an intermediate- or suppressed-crown class with a crown in fair to poor condition that has been defoliated is very likely to die, whether or not it is of a preferred host species.
Site Suitability
The physical capacities and limitations of the site determine to what extent trees are able to maximize their reproductive, defensive, and competitive strategies. While trees may prefer specific growing conditions (which may or may not match where they are commonly found), ultimately trees will grow where they can effectively compete. Trees growing under conditions limiting their competitive ability are often predisposed to stress because they do not have the resources needed to maintain normal functions. Growth and reproductive rates tend to be lower and mortality rates higher under these conditions. The extent to which trees are growing “off-site” is strongly correlated to the level of mortality seen after a defoliation event.

Figure 1. Effect of crown condition and position on gypsy moth defoliation-related tree mortality (taken from Gottschalk et al, 1998).

Measuring site factors, how they interact and contribute to site productivity can be a daunting task. While site index is the most common method of estimating site quality, there are many methods to use, none of which can be effectively applied in all circumstances. Instead, land managers must use all the tools at their disposal (ecological land classification system and soil maps plus tree and site measurements, as well as their own expertise) to determine the suitability of a particular site for the species in question.

Other factors associated with the site that can affect the physiological condition of a tree include: past management history, recent weather and disturbance history, stand structure, status of competitors, density, age, and the presence or absence of pests. Recreation, grazing, past harvesting, and weather extremes can alter physical site characteristics (for instance, compacted soils) and alter the status of competitors (for instance, release maples in the understory). Even thinnings done to increase tree vigor can temporarily stress residual trees, leaving them susceptible to damage if they are exposed to another stress agent prior to full recovery. Recent stand history (i.e. two to five years prior to defoliation) is important and may increase mortality levels associated with a defoliation event.

Stand composition and structure as a function of physical site characteristics determine the competitive advantage each species has over others. Because the interaction of site characteristics and the species present are unique to each site, land managers must make management decisions on a site-by-site basis.
POTENTIAL IMPACTS IN MINNESOTA

To a great extent, forest cover will determine both the risk of damage and the likelihood of secondary impacts. For instance, wildlife impacts will be directly related to the risk of forest damage. Secondary impacts associated with defoliation alone include those that affect water quality, wildlife habitat, tourism, and human quality of life. Secondary impacts associated with tree mortality include those that affect wildlife habitat, forest industries, and property values.

Risk Assessment

The risk of defoliation is almost entirely dependent on stand composition so modeling is not needed. To assess the risk of tree mortality, a risk model was developed that incorporates forest cover, soil type and evapotranspiration (Map 2). Land cover as described in the context of the National Gap program by DNR Resource Assessment using Thematic mapper satellite imagery is the source of the forest cover data. The data is at 30m resolution with a known accuracy tested by ground truthing. Soil types came from the 100m Soil Atlas data housed with Minn. Land Information Management Center. Evapotranspiration was modeled from two existing data layers available from the State Climatologist: Thornthwaite water balance and average growing season precipitation.

Values within each of the three factors were grouped by high-, moderate-, or low-risk categories. For instance, oak cover types, sandy soils, and areas with annual rainfall below average tree transpiration rates were considered high risk. The risk categories within each factor were assigned a numerical value. The values were weighted based on that factor’s contribution to the risk of tree mortality. The three values for each 30m piece of land were added together. So red oaks growing in sand in areas with little rainfall were given 65+20+15 or 100, the highest possible risk rating. The final sums were then regrouped into four risk categories, high, moderately high, moderate, and low risk.

Forest Impacts

While high-risk stands occur in a scattered pattern across the state, the highest concentrations of stands at high to moderately high risk of mortality occur in a C-shaped band from southeast Minn., through the Twin Cities area, west and north along the prairie’s edge, and then east across Itasca County to Grand Portage.

In the southeast, stands are commonly even aged and dominated by oak. White and northern red oak are found on the moist sites, while bur and pin oak are found on the drier sites. The topography limits management options, so gypsy moth defoliation is likely to shift species composition toward the current understory species, i.e., maple on the moist sites and shrub or grasslands on the drier sites. Local wildlife dependent on the oaks may decline as a result of any population shifts.

Northern red oak and pin oak dominate most of the hardwood stands in the Twin Cities area, where oak wilt, buckthorn, and development pressures limit both growing conditions and the management options. Oak decline is already common on the Anoka Sand Plains after the last several drought events, so significant mortality may be a problem once the gypsy moth arrives.

Along the transition between prairie and forest ecosystems, intermittent drought and harsh growing conditions place oak-dominated stands at high risk of mortality. A heavy pine
Map 2. Risk of Tree Mortality

See the discussion of subsections under separate cover.

With Subsection Boundaries

With County Boundaries
component may lessen defoliation in some forest stands, but without active management, oak dominated stands may covert to nonforested cover types.

In northern Minnesota, the lowland conifers are at little risk of gypsy moth-related damage. However, the abundance of aspen throughout this region will support large populations of gypsy moths. Defoliation events are likely to be spectacular but are not likely to cause much tree mortality, unless FTC outbreaks compound gypsy moth-related stress.

On the other hand, many of the birch along the North Shore are at their pathological rotation age and have already begun to decline. The shallow rocky soils limit other species and the tourist industry limits management options. It may be difficult to maintain these stands in birch as the gypsy moth moves into the state.

In east-central Minnesota, forested sites are more moist with fine-textured soils. As a result, they support diverse northern hardwoods that are less susceptible to defoliation. Because of the range of management options, silvicultural practices may be useful to limit future tree loss. However, defoliation will still likely be significant and affect the tourist industry.

Wildlife Impacts
Gypsy moth infestation in Minnesota has the potential to both harm and benefit wildlife habitat and species. The degree of impact is dependent on the timing and extent of defoliation, and whether or not defoliation results in significant tree mortality. There may also be some impacts to wildlife arising from silvicultural efforts to prepare for potential moth infestation.

Many bird species may see short-term benefits from the dramatically increased food supply, increasing survival rates and fledging success. Cuckoos, which quickly adapt to intensive feeding on moth larvae, may increase in number. Mammals such as black bears, mice, and shrews are also likely to take advantage of moth larvae as a food source. Moth eggs may be used for food by wintering insectivorous bird species such as chickadees and woodpeckers. On the other hand, defoliation can reduce mast production among the oaks, which can affect bird and mammal populations dependent on acorns.

Oak (all species), aspen, basswood, and all hawthorn, hazel, and alder species provide important wildlife food, nesting sites, or cover. Significant mortality of these species can lead to long-term loss of valuable habitat. Tree mortality can benefit some species by creating additional snags with cavity potential and coarse woody debris as dying trees begin to fall.

Opening the forest canopy, whether by defoliation alone or by defoliation followed by tree mortality, increases the amount of light reaching the forest floor and subsequent temperatures. Birds susceptible to heat stress may abandon nests. They may also see an increase in egg/juvenile mortality along with forest reptiles and amphibians. An open canopy may lead to increased predation of some bird species and their nests and an increase in the incidence of nest parasitism. Conversely, opening the canopy can lead to a flush in growth of shrub, grass, and forb species that respond to increased light and temperature levels. This vegetative flush can be beneficial to many bird and mammal species that utilize them for food and cover. Increased light and temperature through the canopy may also lead to an increase in insect populations. This can be beneficial to species that utilize them for food, and to the young of species that have a critical need for insect food sources located within or near cover, such as turkeys and ruffed grouse.
**Water Quality Impacts**

Gypsy moth, like other forest defoliators, can influence the quantity and quality of water resources as well as promote changes to the aquatic animal community. Whether these perturbations have serious consequences for Minnesota’s water resources depends on the duration of the defoliation-induced change.

While Minnesota is renown for lake resources, the state also hosts a number of valuable stream resources that are more likely to be impacted by defoliation. These streams contain diverse animal communities and complex food webs. Some streams harbor rare or endangered biota, while others include important recreational species such as trout. Due to the complex interaction of stream communities, changes in any one component of the animal community can have rippling effects throughout the entire aquatic system. And undoubtedly, these changes will be judged to be “beneficial” or “undesirable” depending on how recreationally important or ecologically sensitive species respond.

Reduction in the amount of foliage in a forest stand reduces the rate of evapotranspiration. Water that normally moves through the leaves of trees remains in the soil. Rainfall energy, normally dissipated by leaves, can result in increased runoff during periods of defoliation. This runoff can lead to increased turbidity, channel instability, and risk of flooding. Later, increases in herbaceous plants due to increased available light may increase soil water-holding capacity and help absorb rain impact.

Any changes in leaf deposition volume or timing from riparian trees (whether from defoliation-induced forest community changes or active forest management) could disrupt stream productivity and cause shifts in the aquatic invertebrate community if occurring over a long period of time. The stream invertebrate community could shift from one specialized on shredding of leaf material to one specialized on filtering particulate matter or algae. However no studies have been identified which quantify this response.

Extensive stand mortality can increase the amount of coarse woody debris in the riparian corridor. Coarse woody debris is recognized as an important habitat component in the littoral area of lakes and greatly enhances habitat complexity in streams. Woody debris provides a substrate for algae and aquatic insect fauna, which are the base of the aquatic food chain. Numerous fish species utilize woody debris for overhead cover in streams and spawning substrate in lake environments. Woody debris in the riparian zone also contributes wildlife benefits as loafing habitat for waterfowl, turtles, and small mammals.

Leaf bits and frass produced during larval feeding drop into streams causing the nutrient content, primarily nitrogen and phosphorus, to increase. In karst groundwater recharge areas, these sources of pollution as well as contamination due to inappropriate application of pesticides, may severely impact sensitive fish, wildlife, and water resources. Turbidity as well as fecal streptococci and coliform counts can also increase in response to increased frass production. A study of water quality before and during gypsy moth defoliation events in an Appalachian stream watershed suggested that acidification can occur due to the large amount of nitrate entering the system. Nitrate, acting like sulfate in acid rain, can overwhelm the capacity of the watershed to neutralize it, resulting in a decrease in stream pH. The detrimental effect of stream acidification on aquatic communities is well documented in the scientific literature. Stream resources in northeastern Minnesota likely would be most vulnerable to acidification.
Stream water temperature can increase because of reduced cover and increased solar radiation. A reduction in the forest canopy and beneficial shading of streams can cause an elevation in stream temperature. This is particularly a concern for trout streams in central Minnesota that approach the upper thermal tolerance limit for trout.

**Recreational Impacts**

Losses in tourism are influenced by the perceived scenic beauty of forests and by the direct impact of gypsy moths in high-use areas. Light defoliation opens forest stands and increases flowering among understory plants. This tends to increase public appeal. However, heavy defoliation and the resultant tree mortality decreases both drive-by and in-the-woods appeal.

In high-use areas, losses in tourism occur primarily during May, June, and early July. This is when feeding caterpillars become such a nuisance that tourists either shorten their visits or completely avoid recreational, historical, and tourist facilities located in infested areas. For example, public use of the Allegheny National Forest declined 20% during periods of defoliation. Wood-lot owners in New Jersey reported they lost recreational use of their land for an average of 108 person-days annually. This is because of the downpour of caterpillar droppings, irritating effects of larval hairs and lack of appeal created by large numbers of caterpillars and defoliated trees.

An additional cost is the creation of a large number of hazardous trees in high-use and urban areas. Hazard trees combined with multiple targets (people, structures, and vehicles) greatly increase public liability. Associated management costs can be prohibitive particularly for government agencies and small communities dependent on the tourist trade.

**GENERAL SILVICULTURAL CONSIDERATIONS**

There are two silvicultural strategies in forest management that can help mitigate future damage due to gypsy moth defoliation. The first involves reducing the likelihood of defoliation by reducing the percent of preferred host species found in a stand. This strategy is appropriate where the importance of nonhost species can be increased, while still maintaining adequate stocking levels of important preferred host species. Doing so reduces the severity and frequency of gypsy moth population outbreaks, which in turn lessens the impact on recreation and aesthetic values. In stands with a 50% or more preferred host species compositions, or in stands where site conditions or land use limit silvicultural options, diversifying the stand may not be an option.

The second strategy is to reduce the vulnerability to mortality associated with gypsy moth defoliation-related stress by increasing stand vigor. Generally, damaged and suppressed trees are removed. Crop trees are favored. Nonpreferred host species are encouraged where appropriate and healthy preferred host species are maintained as an important component of the stand.

An added approach is the use of biopesticides. It may be necessary to protect high-value stands or stand components under certain circumstances, even when silvicultural practices are being utilized. For instance, understory white pine may be at high risk if growing under an overstory of oak. If the silvicultural options are limited due to site conditions or other factors, biopesticides may be the only means to limit damage to high-risk stands.
How and where these strategies apply depends on site-level risks and the values and land use that may be affected. Recreation managers may not be concerned with tree mortality, but may be very concerned about defoliation levels affecting tourism. While growth loses may be noticeable, timber production isn’t severely affected until tree mortality begins to reduce merchantable stand volumes. The management threshold for aesthetic and wildlife values tends to fall somewhere between tourism and timber needs. Once the risk of damage has been determined, these values provide the basis for determining which silvicultural practices are appropriate for a particular stand.

**Site-Level Silvicultural Considerations**

**Diversifying stand composition:**
- Where site conditions allow, use thinning or regeneration systems to increase the proportion of less-preferred and avoided tree species, such as ash, conifers, and maples, to 50% or more of stand stocking.
- When regenerating a stand using shelterwood systems, special protection of the understory may be warranted through the use of biopesticides. The overstory may support high gypsy moth populations and the resulting defoliation can kill young seedlings.
- When managing stands on severe sites, such as sandy outwash plains or dry ridges, focus on regeneration of more suitable species or consider shift in community type based on the appropriate Subsection Forest Resource Management Plan (SFRMP).
- Where underplanting is needed to maintain oak in the stand, plant a 50% mix of oak and avoided tree species, such as ash or balsam fir. Always plant species appropriate for the site.

**Intermediate timber stand improvement techniques to improve health and vigor of existing stands:**
- Thinning should be used to increase the size and vigor of residual crowns, i.e., best trees in the dominant and codominant crown classes.
- Reduce stocking to an appropriate level.
- Early in the rotation, thin stump sprouts of gypsy moth preferred tree species, such as oak, or birch, to one stem per stump.
- Harvest stands within five years of maturity to encourage advanced regeneration and preserve stump sprouting.
- If there is insufficient advanced regeneration present, use a shelterwood harvest. Undesirable vegetation may need to be controlled and desirable seedlings may need to be protected to ensure regeneration of the stand.

**Maintain stand structure and composition to provide multiple benefits:**
- Where healthy individuals are present, retain large-diameter, preferred-host species as seed and timber sources and for wildlife habitat.
- Where appropriate, provide wildlife habitat in nearby moderate- to low-risk stands.
- Although the creation and retention of coarse woody debris can enhance gypsy moth habitat by providing larval hiding places, the gypsy moth is not yet established in Minnesota. Until the moth becomes established in Minn., follow site-level guidelines for the volume of snags, culls, and coarse woody debris. At that time, remove larval hiding places in high-risk stands.
REFERENCES


