Manitoba Conservation and Water Stewardship
Forest Practices Guidebook

FOREST PEST MANAGEMENT GUIDELINES

Part of:
TOMORROW NOW
Manitoba's GREEN Plan

Manitoba

Manitoba Conservation and Water Stewardship
Forest Practices
Guidebook

FOREST PEST MANAGEMENT GUIDELINES

Developed by Manitoba Conservation and Water Stewardship in co-operation with:
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PREFACE

MANITOBA FOREST PRACTICES

This guidebook has been developed as part of Manitoba Conservation and Water Stewardship Forest Practices Initiative. It is led by the Forestry Branch and is intended to provide consistent operational direction for resource managers, timber operators, natural resource officers and auditors to conduct or assess forestry activities.

One of the primary goals of the initiative is to advance best practices using guidelines and standards for sustainable forest management activities in Manitoba. Guidelines present alternative procedures or standards that can be applied to satisfy the principle on which the guidelines are based. Guidelines are used to develop prescriptions in the annual operating plan and are enforceable by a work permit. Forest practice guidebooks ensure all forest resource values are appropriately addressed during the full range of forest activities.

Forest practices guidebooks are references for resource managers, timber operators, natural resource officers and auditors. Other references include provincial guidelines, forest management plans, annual operating plans and standard operating procedures developed by each forest company.

Representatives from several branches of Manitoba Conservation and Water Stewardship (Forestry, Wildlife and Ecosystem Protection, Parks and Natural Areas, Environmental Assessment and Licensing, Fisheries, Water Quality), the two major forest management licensees in Manitoba (LP Canada Ltd. and Tolko Industries Ltd.), and the Forest Industry Association of Manitoba (representing timber quota holders) co-operate in a consensus-seeking manner to develop forest practice guidebooks. Regional specialists participate when meetings are held in their regions.

All guidelines for a specific forest practice are contained in a single guidebook. Each guidebook also contains pertinent references to science, legislation, policy, agreements and licences. Recommendations for the planning, implementation, monitoring and enforcement of the specific forest practice in question are included.

As much as possible, the recommendations within each forest practice guidebook are:

- based on scientific evidence and traditional knowledge
- measurable
- practical
- flexible and applicable in a variety of ecological conditions
- clearly presented for consistent interpretation and application
- contain accepted terminology and definitions

Forestry practices within Manitoba will be continuously monitored and appropriately amended when necessary. Guidebooks will be reviewed after five years or a shorter period if required.

Guidebooks can be found on the Manitoba Conservation and Water Stewardship Forestry Branch website: www.manitoba.ca/conservation/forestry/forest-practices/practices/fpp-guideline-pdfs.html.
The public is encouraged to submit comments and recommendations to Manitoba Conservation and Water Stewardship, Forestry Branch.

FOREST PEST MANAGEMENT GUIDELINES

Purpose

This guidebook will provide government and forest industry planners with pest management prescriptions for major forest pests that are currently known to cause significant damage or economic loss in Manitoba's forests.

Background

For the long-term viability of the forest industry, pest problems need to be identified and mitigated. As a component of forest management (harvesting and silviculture), integrated pest management should be practised to offset pest-related volume losses to the forest land base. Many jurisdictions have adopted this concept as a standard practice to ensure a sustainable forest resource for all users (economic and recreational).

Over the long-term, the most effective control of forest pests is prevention. This is achieved through the application of management practices that create a less vulnerable forest in which losses and control costs are reduced. Preventative management strategies can be developed that will:

- mitigate the impact of pests
- reduce the cost of pest control in the future
- maintain or improve the health of the forest

Appendix 3 summarizes the major pests currently found in Manitoba.

The forest health information obtained from pre-harvest surveys (PHS) (*Manitoba Conservation and Water Stewardship Forest Practices Guidebook* revised January 2008) and pest specific surveys can be used to set harvesting priorities, on both an area and a stand basis, to reduce current losses or to take a preventative approach for chronic pests of the site. Due to the large areas of even-aged fire origin stands in the boreal forest, stands having high levels of stem decay, stem cankers, root and butt rot and wood borers are often representative of a more extensive condition. When the PHS and subsequent follow-up assessments detect these pest problems, recommendations are made to harvest as much of the area as possible at, or near, the pathological rotation age (before net losses become economically significant). As well, stands having these pests suffer substantial, immediate losses from snow loading, ice storms and high winds. To reduce further losses and potential fire hazard, stands in this condition are given a very high priority for immediate harvest.

Forest health information collected in the PHS and pest-specific surveys can be used to identify areas, in and around a harvest block, of significant pest severity for inclusion in harvest designs. Consequently, areas in a healthy state (pest free or of low hazard), or those of non-host species, may be selected to remain after harvest as leave trees, and treed patches for a number of biodiversity values. These selected remnants will remain intact ensuring the fulfillment of their function and reducing pest damage in the adjacent or next generation forest. Appendix 4 is the pre-harvest survey table. It lists pest problems causing significant economic losses in mature forests and their associated pest management recommendations for harvesting, renewal and leave areas in and around a harvest

block. These strategies may contribute to the objectives of both wildlife and forestry, such as wildlife corridors and line of sight.

MAJOR FOREST PESTS — OCCURANCE AND MANAGEMENT

The Occurrence and Management section describes each major forest pest, its distribution, its importance in forestry and the recommended pest management prescriptions for reducing their long-term impact. Insects and diseases are grouped by softwood or hardwood, then by the tree part that is damaged.

Insects - Softwood

Foliage

Eastern spruce budworm

Eastern spruce budworm, C*horistoneura fumiferana*, is the most destructive and widely distributed forest defoliator in North America ranging from Newfoundland to Alaska. The destructive phase of this pest is the larval or caterpillar stage. In Manitoba, the budworm feeds on white spruce, balsam fir and to a lesser extent black spruce.

Figure 1: Larval frass and clipped needles webbed to partially consumed shoots

Figure 2: Severe spruce budworm defoliation – scorched appearance

Management prescriptions

When spruce budworm outbreaks are relatively small, redirecting harvest to budworm-damaged stands can be an effective means of managing spruce budworm and minimizing timber volume losses. Other measures to be considered include maximizing balsam fir use on the site when harvesting and renewing to a less vulnerable tree species or species mix to reduce budworm impact in the regenerated stand. A white spruce/black spruce mix will suffer less damage than stands with a high balsam fir component.

To prevent growth loss and mortality during widespread severe outbreaks, an aerial insecticide application should be considered if harvesting infested stands is not feasible within three years and moderate or severe defoliation is expected. Reduced risk pesticides, such as Mimic (tebufenozide), preferred by Manitoba Conservation and Water Stewardship, and biological pesticides, such as *Bacillus thuringiensis* sub-species *Kurstaki* (Btk), are used in aerial control programs.

Budworm larvae cease feeding and die when these products are ingested. Insecticides are applied when larval development has reached third to fourth instar (approximately 6 to 10 mm in length), in synchrony with the elongation and flaring open of current shoots. At this point, larvae are exposed and vulnerable to the insecticide. Successful application controls the larvae before they reach the fifth and sixth instars, when the majority of feeding takes place. The timing for control varies from year to year, but is generally late May to mid June in Manitoba. Forestry Branch has a degree-day larval development model that accurately predicts spruce budworm development in any given year. This model helps determine the appropriate timing for insecticide application.

Jack pine budworm

Jack pine budworm, C*horistoneura pinus pinus* (Freeman) is a major pest of pines in the Great Lake States of Michigan, Wisconsin and Minnesota, central and northwestern Ontario, Manitoba, and Saskatchewan. Severe outbreaks seriously affect the growth and quality of vast areas of pine. Jack pine is the favoured host, but red pine, Scots pine, lodgepole and occasionally white pine can be seriously defoliated when growing near susceptible jack pine.

Figure 3: Partially consumed needles clipped and webbed to shoot with frass and a pupal case

Figure 4: Severe jack pine budworm defoliation – scorched appearance

Management

When outbreaks are relatively small, redirecting harvest to budworm-damaged stands can be an effective means of managing jack pine budworm and minimizing timber volume losses.

During severe outbreaks, control measures may be required to protect high-value stands against top kill, volume loss and mortality. An aerial insecticide application should be considered if harvesting infested stands is not feasible within two years and moderate or severe defoliation is expected. Insecticides should be applied when larval development has reached peak fourth instar, in synchrony with full bud flush. Larvae are more exposed and vulnerable to the insecticide at this stage and have not yet reached the fifth, sixth or seventh instars, during which the majority of feeding and damage occurs.

At present, a bacterial insecticide, *Bacillus thuringiensis* sub-species *kurstaki* and tebufenozide (Mimic) are the only insecticides registered in Canada for jack pine budworm control. All insecticide products should be used in accordance with the manufacturer's label recommendations.

Similar to spruce budworm, an integrated approach is often employed involving the harvesting of budworm damaged stands in combination with aerial insecticide spraying.

Conifer sawflies

In Manitoba, there are a number of species of conifer sawflies, some native and some introduced, which attack pine, spruce, fir and tamarack. Adult sawflies are small black wasp-like insects with four membranous wings. With the exception of the yellowheaded spruce sawfly, larch sawfly and balsam fir sawfly, only small localized sawfly outbreaks have occurred to date.

Yellowheaded spruce sawfly

The yellowheaded spruce sawfly, *Pikonema alaskensis*, is native to North America. It ranges from coast to coast in Canada and into the Northwest Territories. Its hosts include all native and exotic species of spruce. In Manitoba it attacks white and black spruce and the introduced Colorado blue spruce.

Figure 5: Yellowheaded spruce sawfly larva

Figure 6: Yellowheaded spruce sawfly severe feeding damage

Management

Yellowheaded spruce sawfly larvae are very susceptible to pathogens, parasites and predators. Several fungal pathogens can cause a sudden collapse of an infestation. Shrews and mice eat large amounts of cocoons over the winter. Wet spring weather combined with snow melt causes rotting of pupae on the forest floor. However, when severe infestations persist, control is necessary in high value, open-growing plantations and tree improvement orchards. During the larval stage, sawflies can be readily controlled by ground application of low doses of chemical insecticides.

Stem and branch

Terminal weevils

White pine weevil

The white pine weevil, *Pissodes strobi* is distributed across North America. This insect attacks a number of pine and spruce species. White pine is its major host in eastern Canada**.** Jack pine and white spruce are preferred hosts in the Prairie Provinces**.** Engelmann and Sitka spruce are major hosts in British Columbia. In eastern North America, white pine weevil is a major impediment to

regenerating white pine. It is also an important pest of young spruce plantations in western Canada. It predominantly attacks trees between the ages of five to 35 years.


Figure 7: White pine weevil exit shepherd's crook


Figure 8: Late season white pine weevil symptom


Figure 9: Adult weevil holes with chip cocoons

Management

Rates of attack can be as high as 50 per cent. Populations can rise quickly due to multiple leaders, which provide more egg-laying sites and food. A risk rating decision support system survey can be employed to determine if control measures are necessary. The survey includes sampling at least 60 trees randomly within a sequential sampling grid. Survey results rate the infestation intensity as follows:

Light = < 10% of trees infested
Medium = 10 to 19%
High = > 20%

Infestation levels of 30 per cent over a 30-year period will reduce stand volume by 40 per cent.

In known weevil prone areas, spruce and pine should be planted at higher than normal densities. A denser stand can reduce populations since adults prefer open-growing vigorous leaders in full un which are more prevalent in low density stands. Growing spruce and pine under a hardwood overstorey reduces weevil attack by slowing the growth of the leader, and by reducing sunlight and temperature below that preferred by adult female weevils. However, there must be a balance, as too much shade can be detrimental to tree growth. In mid-summer, sanitation pruning of wilted infested leaders, prior to adult emergence, can reduce populations for the following year. Spraying leaders with an insecticide in early spring, during the adult feeding period, can control adults.

Lodgepole pine terminal weevil

The lodgepole pine terminal weevil, *Pissodes terminalis*, ranges from Manitoba to British Columbia and Yukon and south to California. Its hosts are lodgepole and jack pine.

Figure 10: Late season terminal weevil Symptom on current leader

Figure 11: Exit hole of emerging adult weevil

Management

Management practices are similar to white pine weevil, but timing of control, sanitation pruning of dying terminals, is late summer or fall.

Eastern Pine Shootborer

The Eastern Pine Shootborer, *Eucosma gloriola*, ranges from eastern Canada to southeastern Manitoba and in adjacent parts of the United States. Its hosts are white, Scots, red and jack pine.

Management

Management practices are similar to white pine weevil; however sanitation pruning of dying terminals should be timed for early summer. An experienced eye is required to detect an infested shoot as early symptoms of attack are difficult to identify. Advanced symptoms of shoot decline indicate the larva has girdled and exited the terminal. Pheromone trapping can be used in high value stands such as seed orchards and family tests to monitor the shootborer population.

Figure 12: Late season eastern pine shootborer symptom

Eastern larch beetle

The eastern larch beetle, *Dendroctonus simplex* occurs throughout the range of tamarack, which includes northeastern United States, much of Canada and into Alaska. In Manitoba, localized outbreaks have occurred in the past. However, an outbreak which commenced in 2001 has expanded throughout much of tamarack's range within southeastern Manitoba and the boreal plain forest. Three successive winters with above normal temperatures, resulting in increased larval and pupal survival, combined with excessive precipitation increasing tree stress, are contributing factors to this widespread outbreak.


Figure 13: Larch declining due to eastern larch beetle

Management
Sanitation involving timely use and/or removal of infested wood can reduce the risk of attack. Eastern larch beetles breed in standing trees as well as stored logs with bark intact. Adults will emerge from this material in spring and attack live healthy trees. Infested trees and logs should be used or removed from tamarack stands before the beetles emerge in spring. Tamarack fuel wood should not be stored with bark intact through spring and summer in close proximity to live, healthy tamarack trees. If it cannot be used during the winter months, it should be debarked for longer-term storage.

Root/root collar

Root collar weevils

The pine root collar weevil *Hylobius radicis* occurs in the northcentral and northeastern regions of the United States and in southeastern Canada extending as far west as southeastern Manitoba. The Warren root collar weevil, *Hylobius warreni*, occurs throughout Canada. In Manitoba, it is most common in the western and northwestern portions of the province. The pine root collar weevil's main host is Scots pine, but it also attacks jack pine and red pine usually on dry, light, sandy soils. Warren root collar weevil feeds on white spruce, jack pine and black spruce growing on moist sites.

Figure 14: Resinosis and larva - pine root collar weevil

Figure 15: Advanced symptoms in jack pine

Management prescriptions

Management options for the Warren root collar weevil include clear-cutting of infested stands, leaving no residual host trees and then scarification or a prescribed burn of the site. By following these silvicultural practices, stumps infested with root collar weevils would be removed, along with the duff layer in which the adults prefer to inhabit. Where practical, removing the duff layer around the root collar area and pruning the lower branches is beneficial as it will increase the temperature of the soil and make it less inviting to the adult weevils (both Warren and pine root collar weevil). Planting less susceptible tree species is not an option for Warren root collar weevil in Manitoba. However, for the pine root collar weevil, planting less susceptible species is probably the best management option. Infestations of this weevil is heaviest in Scots pine plantations adjoining natural jack pine forests, especially in southeastern Manitoba. However, damage to jack pine is far less than to Scots pine.

Insects –Hardwood

Foliage

Forest tent caterpillar

Forest tent caterpillar, *Malacosoma disstria*, is a serious defoliator of deciduous trees across Canada and the United States. It occurs throughout much of the range of trembling aspen. The destructive stage is the larva or caterpillar. Severe outbreaks may defoliate hundreds of thousands of hectares of deciduous trees and shrubs. The preferred host, trembling aspen, often occurs in pure stands. Monocultures of aspen contribute to the development of wide-spread outbreaks. The caterpillars also feed voraciously on foliage of various other broad-leaved trees and shrubs. When starvation threatens they may attack conifers.

Figure 16: Forest tent caterpillar defoliation

Figure 17: Forest tent caterpillar – aerial view of widespread severe defoliation

Management prescriptions

To date, management of forest tent caterpillar outbreaks has not been considered necessary for commercial forestry purposes. However, the weak, white annual ring produced in a year of severe forest tent caterpillar defoliation may be linked to white trunk rot, an important stem decay of aspen. The white rings create an internal defect that may allow decay to spread readily in the trunk of the tree. If research demonstrates this association between forest tent caterpillar and white trunk rot, management of forest tent caterpillar populations may be considered a viable option.

Stem and branch

Poplar borer

The poplar borer, a round-headed wood borer, ranges across North America wherever host species occur. Trembling aspen is a preferred host, but many other poplars and willows are susceptible to attack.

Figure 18: Poplar borer damage

Management

Brood trees are individual trees that contain a high percentage of poplar borer larvae and should be removed in urban, park and woodlot settings to prevent breakage and reduce the spread of poplar borer. High priority should be given to harvesting stands that are moderate to severely infested by

poplar borer to prevent further volume loss due to stem breakage from wind or heavy snow. Buffers, wildlife corridors and other leave areas are not recommended in severely infested aspen stands as infested trees are subject to breakage and are a source of infestation to the renewing generation.

Diseases –Softwood

Foliage

Needle casts of pine

There are many native pine needle casts and some introduced. *Lophodermium pinastri*, *Lophodermella concolor* and *Cyclaneusma minus* are pine needle casts that have caused noticeable damage on occasion in Manitoba. Field identification of the species of needle cast is difficult.

Figure 19: Pine needle cast banding

Figure 20: Pine needle cast fruiting bodies

Management

Management is not required in natural forests. In high value, tree-improvement orchards or Christmas tree plantations, repeated fungicide sprays commencing just prior to bud break and continuing every two weeks as new foliage develops in spring can be carried out. Continued application of fungicide may be required over the growing season if cool humid conditions persist.

Needle casts of spruce

Lirula, Stigmina and *Rhizosphaera* needle casts are common on spruce in Manitoba**.** The fruiting bodies produced on the needles are used for species diagnosis.

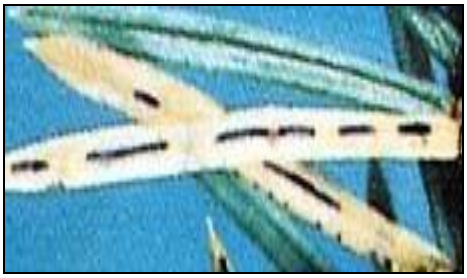


Figure 21: *Lirula* needle cast fruiting bodies

Figure 22: *Stigmina* needle cast fruiting bodies

Management
Management is not required in natural forests. In high value plantations, if warranted, a copper fungicide should be applied when new growth begins. Three to four applications should be made at 10-day intervals.

Needle rusts of pine

Pine needle rusts, similar to most rusts, have a complex life cycle that involves two host species and the production of several kinds of spores and fruiting bodies. These rusts require both a pine host, plus an alternate host, which is aster and goldenrod.

Management
Avoid planting in areas where the alternate hosts are prevalent or, alternatively, control the populations of nearby goldenrods and asters.

Needle rusts of spruce

Chrysomyxa ledi and *C. ledicola* are common spruce needle rusts in Manitoba.


Figure 23: Spruce needle rust symptoms on spruce


Figure 24: Spruce needle rust, sporulation on spruce

Management
If necessary, repeated fungicide sprays on new foliage as it develops in spring can help control the problem. However, it is difficult to get spray timing right. Colorado spruce is very susceptible and should not be planted in close proximity to the alternate hosts.

Table 1: Comparison of needle casts and rusts

Needle casts	**Needle rusts**
Infection — occurs on current year needles	Infection — occurs on current year needles
Symptoms — on 2nd year and older needles Banding pattern Fruiting bodies of various shapes	Symptoms — on current year needles on spruce and 2nd needles on pine Yellow/orange fruiting bodies on conifer needles
Host — conifer only	Host — conifer plus broadleaf alternate
Needle loss — second year and older	Needle loss — current year on spruce and 2nd year on pine

Stem and branch

Dwarf mistletoe of conifers

Dwarf mistletoes, *Arceuthobium* spp., are parasitic plants that attack conifers. Two species of dwarf mistletoe are found in Manitoba. The eastern dwarf mistletoe, *Arceuthobium pusillum,* is a parasite of black spruce, white spruce and to a lesser degree, tamarack larch. The lodgepole pine dwarf mistletoe, *Arceuthobium americanum,* is a parasite of jack pine in Manitoba.

Range

Dwarf mistletoe on jack pine is widespread in the Interlake, northwestern Manitoba and Belair Provincial Forest. It also occurs in western Manitoba in the Cowan area and Porcupine Provincial Forest. Dwarf mistletoe on spruce occurs in southeastern Manitoba, east of Lake Winnipeg, in the Interlake, Spruce Woods, western and northwestern Manitoba.

Figure 25: Witches broom on black spruce

Figure 26: Dwarf mistletoe aerial shoots on spruce

Figure 27: Dwarf mistletoe aerial shoots on pine

Figure 28: Deformed dwarf mistletoe infested pine

Management

A dwarf mistletoe loss simulator model was developed for Manitoba Conservation and Water Stewardship by F.A. Baker of Utah State University. This model can be used for both species mistletoe. The model is used at the stand level to predict losses due to dwarf mistletoe over time and to help in making the best management decision for the stand given the predicted losses.

In the field, dwarf mistletoe distribution is mapped by GPS co-ordinates along parallel survey lines. The model calculates by 10-year increments:

- the infested area
- stand volume at rotation if the stand were treated for dwarf mistletoe
- stand volume in absence of dwarf mistletoe
- stand volume with dwarf mistletoe
- volume lost to dwarf mistletoe to that point in time
- the area of the stand necessary for treatment at that point in time

The information provided by the model allows decisions to be made such as when to treat the stand and at what age to harvest the stand, if losses to dwarf mistletoe exceed volume increment.

The survey to map dwarf mistletoe distribution can be done as a ground survey or aerial survey by helicopter. The aerial survey method uses a GPS unit and a video camcorder. The video camcorder is front mounted on the helicopter to record a view of mistletoe infection centres.

Dwarf mistletoe left on site following harvest will infect the renewed forest if left untreated. Sanitation at time of harvest is the most cost-effective method to deal with this disease. When harvesting infested stands, the management objective is to eliminate all sources of infection for the next generation. This objective can be achieved through sanitation and modification of harvesting and silvicultural practices. Although the management prescription is site specific, there are some basic practices to consider. Where possible, cut block boundaries should be laid out so as to avoid leaving edge infections along the periphery of the cut block. The design of the cut block should be such that the ratio of perimeter to area is kept to a minimum. Wildlife corridors and leave areas should be free of dwarf mistletoe infection. All merchantable material should be harvested. Non-merchantable host trees should be felled or killed to ensure the death of the parasite. Advance regeneration (young stems in the understorey) should also be removed. Following the harvest, any remaining edge infections should be removed or killed, where feasible. Where it is not feasible to remove edge infections, an alternate, resistant tree species may be planted in a 20-metre buffer around the periphery of the cut block. This buffer should be cleared of host trees periodically to prevent encroachment of the disease.

In addition to the obvious need for sanitation to protect the next generation, the severity of mistletoe on site has a major impact on the available seed source for natural regeneration. Seed production is significantly less on sites with large mortality pockets and severe infection (heavily infected trees produce very little viable seed). Planting is often required on these sites.

Western gall rust

Western gall rust is caused by a rust fungus (*Endocronartium harknessii*). This disease ranges throughout Canada and the north central United States. Lodgepole and jack pine are the major hosts. Some ornamental exotic pines such as Scots pine are also susceptible. It is the most common pine stem rust in Manitoba. Although the disease is common throughout the province, it is most serious in Duck and Porcupine mountains.

Figure 29: Galls on infected pine branches

Management

Western gall rust cannot be eradicated, but managing the disease can reduce its impact. Sanitation (removal of live infected jack pine) at time of harvest is the most cost-effective method to protect the next generation. Small harvest blocks surrounded by infected jack pine stands can promote the rapid spread of the disease through the young plantation, if the distance involved is less than 300 metres. When harvesting in heavily infested stands, clear cutting of jack pine is recommended. Western gall rust remains on-site and re-infects new seedlings, causing mortality and growth loss if left untreated. Buffers, wildlife corridors, edge infections or unmerchantable residuals and other leave areas of heavily infected jack pine are not recommended if regenerating to jack pine.

When regenerating to jack pine in areas of heavy infestation, ensure stocking is well over 2,000 stems per hectare. Dense stands promote self-thinning and self-pruning, removing galled trees and limbs. Increased stocking will:

- allow a pre-commercial thinning to cull diseased trees
- allow for selection of disease-free crop trees
- increase the level of disease resistance in the stand

When thinning in infected young stands, the presence of main stem galls should be a thinning criterion. Removing trees heavily infected with main stem galls can reduce losses significantly. If western gall rust is not a criterion for thinning, a reduction in volume yield may result. Thinning operations should be carried out when a plantation is 12-to-17 years old. This will delay the progress of infection therefore decreasing the future incidence of the disease and its negative effect on volume. Cutting of infected trees should not occur from late spring to midsummer as this may help spread spore and contribute to the spread of infection.

Western gall rust can be a serious problem in forest nurseries. Preventative measures should be taken at the nursery if western gall rust is present at, or nearby, the nursery site. Existing sources of infection in and around the nursery site should be removed by pruning or cutting. Seedlings should be grown at least 300 metres away from native pine stands. Using fungicides during the sporulation period, May to mid-July, can protect seedlings from infection.

Diplodia canker

Diplodia canker is caused by the fungus, *Sphaeropsis sapinea.* This disease is common in the pine forests of southeastern Manitoba. More than 20 pine species are susceptible to this disease. In Manitoba, red and jack pine are commonly infected.

Management
Harvest infected stands as soon as possible to prevent further volume loss from mortality or stem breakage. Trees with main stem cankers have reduced physical strength and are easily broken by high winds or heavy snow. Take precautions during harvest to minimize damage to leave trees and leave areas. The disease may enter the tree bole through insect wounds, frost cracks and other wounds.
On sites where red pine has been severely affected, jack pine, which is more drought hardy, should be considered for renewal. Where jack pine has been severely affected on nutrient-poor, drought prone sites with course soils, renewal efforts should be abandoned.

Conifer decay

Types of decay
When categorized by their effect on wood, there are two broad classes of wood-destroying fungi. There are white rots that destroy all components of the wood including carbohydrates, cellulose and lignin. The affected wood is reduced to a spongy mass, to white pockets or streaks of various sizes separated by areas of firm wood, or to a stringy fibrous condition. The decomposed wood is usually white, but may be yellow, tan or light brown.
There are also brown rots that decompose cellulose and carbohydrates, but leave the lignin more or less unaffected. The decayed wood, which is varying shades of brown, forms into a cube-like pattern. In the final stages it can be crumbled into a powder between the fingers. Brown rots are sometimes referred to dry rots.

Categories of abnormal wood
Stain: Discoloured wood that seems no softer than healthy wood when tested with the point of a sharp knife.

Incipient decay: Slight reduction of hardness in decayed wood.

Advanced decay: Decayed wood that is noticeably softer than normal healthy heartwood and useless for any product.

Description and hosts of conifer decays
Heartwood stain: Occurs on a wide variety of conifers. The affected wood becomes pink-to-red, but remains firm. The stain is often in a radiating or blotchy pattern.

Sapwood stain: Occurs in most conifers. Fungi known as blue stain fungi often cause this type of stain. A greyish-blue staining of the sapwood is the most conspicuous symptom of colonization by blue stain fungi. Sapwood stain also occurs in association with stem cankers. In this case the stain may be more of a bluish-black colour.

Incipient red rot: This decay constitutes the majority of the incipient decay found in conifers. It occurs in all of Manitoba's spruce, fir and pine species. It is predominantly red, but varies in colour from a light pink or purple to deep, reddish brown.

White (red) pocket rot: This type of decay occurs in pines and spruces. It accounts for approximately one-half of the decay found in pines and white spruce and one-third of the decay found in black spruce. It is primarily a trunk rot (*Phellinus pini*) of white and jack pine but is more common as a root and butt rot (*Inonotus tomentosus*) of red pine and white spruce. This decay appears as lens-shaped cavities parallel to the grain. These cavities are sometimes empty, but are most often filled with a white fibrous mass of almost pure cellulose, surrounded by firm light red to reddish-brown wood (Figures 30 and 31). Black, irregular-shaped zone lines are occasionally present in the decayed wood.


Figure 30: White pocket rot in stump


Figure 31: Close up of white pocket rot

Red heart rot: This type of decay is found in balsam fir. It accounts for over two-thirds of the advanced rot in this species. It is primarily a trunk rot, which in cross-section frequently occupies all or most of the heartwood. This decay is a medium to deep reddish-brown colour. It tends to remain in an intermediate stage between incipient and advanced decay for a relatively long period of time. In its later stages, it becomes stringy and crumbly in texture and tends to fade slightly in colour.

Yellow stringy (white stringy) butt rot: This decay is present in all conifers, but occurs in relatively small amounts in pines. It is primarily a butt rot. Affected wood becomes yellow or yellow-brown with the formation of pockets in the springwood. The pockets frequently coalesce causing separation of the annual rings. As the decay progresses, the wood is reduced to a loose, stringy mass of orange-yellow fibres (Figure 53). In the more advanced stages, empty cavities exist in the centre of the bole.


Figure 53: Yellow stringy butt rot

Brown cubical rot: This decay type occurs in all of the conifers. It is more common in red pine and white spruce than other conifers. For the most part, it is confined to the butt in all species. In the early stages softened wood is yellowish to light yellow-brown. It soon becomes dark brown and is separated into small, irregular, roughly cubical blocks (Figure 54) that are easily crushed to a powder between the fingers.


Figure 54: Brown cubical rot in roots

Management
Decay is assessed in terms of percentage incidence and the amount of wood volume actually destroyed. There is usually a strong correlation between age class and all three defect types (stain, incipient and advance decay). At rotation, all three defects combined are often less than 10 per cent of the total gross merchantable volume. Consequently, harvesting of conifers at their rotation age will prevent large volume losses due to decay.

Roots

Armillaria root disease

Armillaria root rot is found throughout temperate and tropical regions of the world. In Manitoba, *Armillaria ostoyae* is the most common cause of root disease. It attacks both softwood and hardwood tree species.

Armillaria spp. are complex fungi which can act as an aggressive killer of healthy trees, a secondary pathogen of stressed trees and as a beneficial saprophyte decaying dead plant material. Its role as a secondary pathogen is generally in over mature trees or in those stressed by other insects and disease or environmental conditions. Armillaria often acts as a primary pathogen on young reforested sites due to the large amount of inoculum present on the decaying root systems of the previous stand.


Figure 55: Root disease chlorosis


Figure 57: Root disease mycelial fan


Figure 58: Root disease fruiting body

Management
Armillaria fungi is indigenous in the forest soil, living on a wide variety of host plant material. Its eradication or complete exclusion is not feasible. Management should be directed toward limiting root disease build-up and reducing its impact.

Growth loss due to root disease occurs throughout the life of the stand and premature mortality often occurs near rotation age. Root disease stresses trees and increases susceptibility to bark beetles. Therefore, it is important to harvest heavily-infested stands at maturity, prior to the onset of significant mortality. Live standing trees with root disease should be harvested as infection and volume loss is restricted to the butt log (generally bottom one metre). Rotation age should be based on the pathological rotation for highly susceptible forest types such as upland black spruce. When harvesting, areas heavily infested with root disease should not be preserved for buffers, wildlife corridors, or other leave areas as they are subject to windthrow due to instability of the root systems. When selective cutting in uneven aged stands, avoid wounding and minimize stress to future crop trees.

Infected stumps and roots left on the site are a large source of inoculum, which can cause significant mortality in the regenerating stand for 15-to-20 years. Site preparation techniques that uproot stumps and roots, and therefore reduce inoculum, should be employed.

Within root disease centres, less susceptible species, which are ecologically suited to the site, should be planted to reduce the impact on the renewed forest. Jack pine and white spruce are less susceptible than upland black spruce.

Diseases –Hardwood

Stem and branch

White trunk rot of aspen

White trunk rot of aspen is caused by the fungus *Phellinus tremulae*. It is the most important decay-causing fungus of aspen in the Prairie Provinces.


Figure 61: White trunk rot conks


Figure 62: White trunk rot - advanced decay

Management
No direct control measure is available to prevent or control decay of white trunk rot. However, there are procedures that will help to reduce losses due to decay.

Harvest heavily-infected stands as soon as possible to prevent further volume loss from high winds or heavy snow. Harvest heavily infected individual trees to reduce source of inoculum level for next generation. During harvest, take precautions to minimize damage to leave trees and leave areas. The disease enters the tree through wounds, frost cracks and broken branches. It is not believed to be transmitted from infected trees to new root suckers. Buffers, wildlife corridors and other leave areas, with extensive white trunk rot, are not recommended as they are subject to stem breakage.

Do not delay scarification. Delayed scarification or re-treatment is not recommended three-to-seven years after harvest to prevent damage to root suckers and creating entry points for disease spores. Select site preparation methods that initially ensure good regeneration.

There is an indication that there are clonal differences in the amount of decay in aspen. This factor may become important in future genetic improvement programs for aspen.

The following guide can be used to determine the level of white trunk rot for a forest stand:

Number of conks per tree	**Percent of tree volume with advanced decay [1]**
0	1% - 2%
1 - 2	4% - 6%
3 – 6	8% - 12%
7 - 11	14% - 18%
12+	21% - 26%

[1] Decay range is based on the mean ± 3 standard errors (99% confidence interval). The standard error is a standard deviation of an estimate, rather than an individual unit. Therefore, even though the method involves estimating advanced decay on individual trees, the results should be applied to a larger area such as a plot or stand. The higher percentage for decay in each category should be used if the tree has frost cracks, a combination of other external defect types (poplar borer damage, stem cankers, insect wounds, mechanical damage, etc.) or the number of conks is at the upper end of the range.

Hypoxylon canker

Hypoxylon canker, *Hypoxylon mammatum* (Wahl.) Mill., is present throughout the range of trembling aspen, its major host species. This disease also affects other poplars including largetooth aspen and balsam poplar. Hypoxylon canker is the most damaging disease of young and intermediate age aspen.

Figure 63: Hypoxylon canker vegetative stage

Figure 64: Hypoxylon canker conidial blisters

Figure 65: Hypoxylon canker perithecia

Management

Harvest severely-infected stands as soon as possible to prevent further volume loss from mortality, wind and snow breakage. Take precautions during harvest to minimize damage to leave trees and leave areas. The disease enters branches or the bole through insect wounds, broken branch stubs, frost cracks or other wounds. Following the harvest of severely infected sites (greater than 25 per cent infection), renewal to a mixedwood stand should be considered. In moderately infested stands, ensure initial aspen regeneration is well over 10,000 stems/ha as incidence of Hypoxylon canker increases in understocked stands.

Removal of infected trees as soon as infection is noticed, prior to spore production is a feasible management option for small scale woodlot operations. Removal of infected trees in high use recreation areas should be done for safety reasons.

Abiotic

Abiotic disturbances, disturbances caused by non living factors, are a natural and integral part of Manitoba's forest ecosystems. They can have a major impact on forestry, positive and negative. Abiotic disturbances should be a consideration when investigating a forest health inquiry. Management of these disturbances needs to be examined on a case-by-case basis as the intensity and severity of these events can vary.

Invasive Pests

Invasive pest have the ability to damage large areas of Manitoba's commercial, urban and recreational forest. Vigilance and understanding of current invasive threats to Manitoba needs to be understood by all Manitobans. The current invasive species that pose a risk to Manitoba's forest are: mountains pine beetle, pine shoot beetle, Asian longhorn beetle, emerald ash borer, gypsy moth, brown spruce longhorn beetle and Dutch elm disease. Many other invasive pests will threaten Manitoba forest in the future.

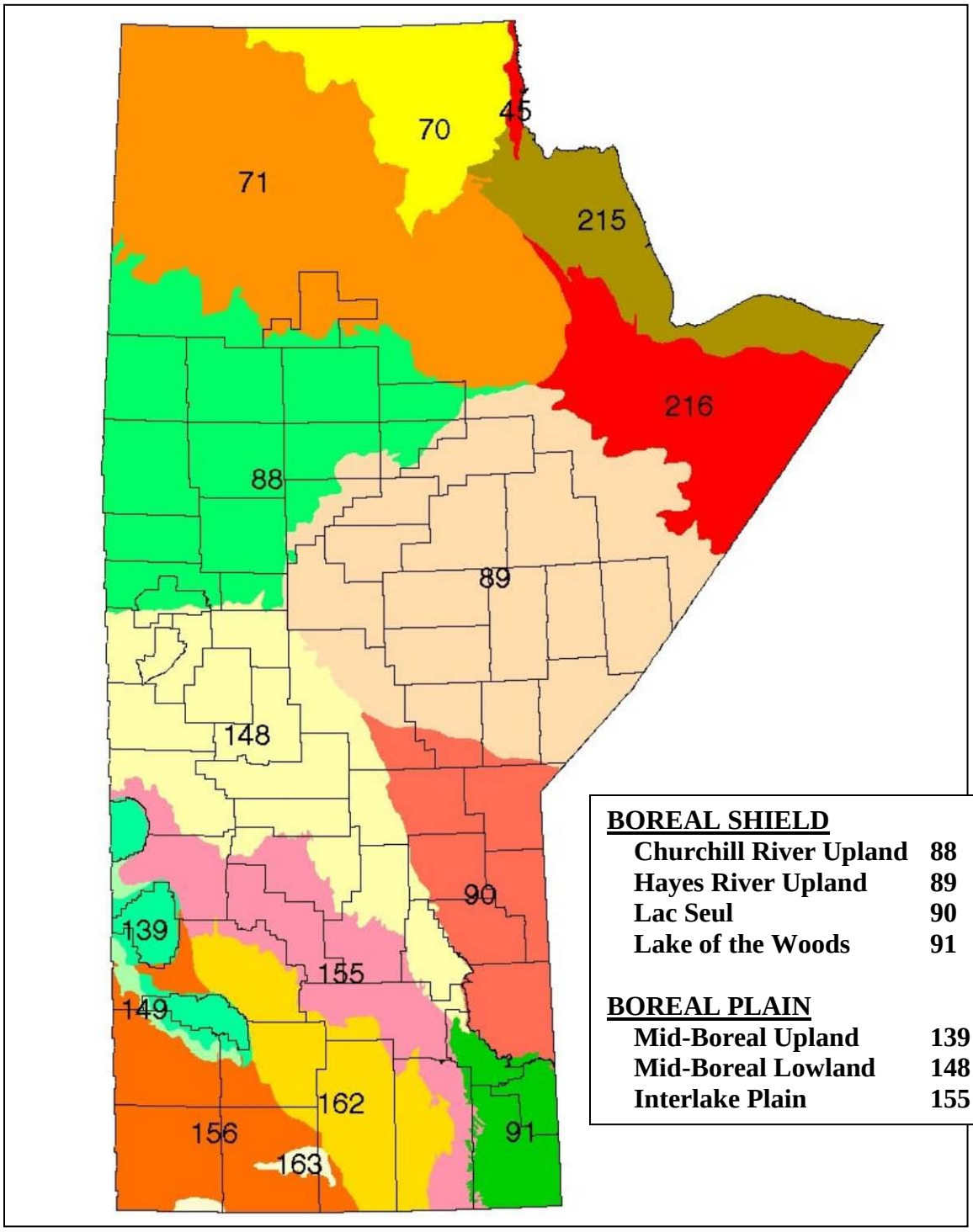
Management

Invasive species management and monitoring is done through a partnership between Manitoba Conservation and Water Stewardship and the Canadian Food Inspection Agency. Suspect insect and disease samples should be sent to:

Manitoba Conservation and Water Stewardship
Forestry Branch
200 Saulteaux Crescent, Box 70
Winnipeg, Manitoba, R3J 3W3

Brochures on forest pests found in Manitoba can be obtained online at:
http://www.gov.mb.ca/conservation/forestry/health/index.html

Appendix 1: Manitoba's Ecozones and Ecoregions



Appendix 2: Major forest pests by Ecozone and Ecoregion

Ecozone	Ecoregion	Forest Pest
Boreal Shield	88 Churchill River Upland	**Spruce Budworm** on white and black spruce **Western Gall Rust** on jack pine **Armillaria and other Root and Butt Rots** on conifers **Stem Cankers** on conifers **Root Collar Weevil** on pine and spruce **Hypoxylon Canker** on aspen **Dwarf Mistletoe** on jack pine
	89 Hayes River Upland	**Armillaria and other Root and Butt Rots** on conifers **Hypoxylon Canker** on aspen **Western Gall Rust** on jack pine **Stem Cankers** on conifers **Root Collar Weevil** on pine and spruce **Dwarf Mistletoe** on jack pine
	90 Lac Seul	**Spruce Budworm** on balsam fir, white and black spruce **Armillaria and other Root and Butt Rots** on conifers **Jack Pine Budworm** on pine **Dwarf Mistletoe** on jack pine and spruce **Western Gall Rust** on jack pine **Stem Cankers** on conifers **White Pine Weevil** on pine and spruce
	91 Lake of the Woods	**Dwarf Mistletoe** on jack pine and spruce **Armillaria and other Root and Butt Rots** on conifers **Jack Pine Budworm** on pine **Western Gall Rust** on jack pine **Root Collar Weevil** on pine and spruce **Spruce Budworm** on balsam fir, white and black spruce **Hypoxylon Canker** on aspen **Stem Cankers** on conifers **White Pine Weevil** on pine and spruce
Boreal Plain	139 Mid Boreal Upland	**Armillaria and other Root and Butt Rots** on upland black spruce **Western Gall Rust** on jack pine **Root Collar Weevil** on jack pine and black spruce **Hypoxylon Canker** on aspen **Spruce Budworm** on balsam fir, white spruce and black spruce growing in conjunction with white spruce and/or balsam fir **Dwarf Mistletoe** on jack pine and spruce **Stem Cankers** on conifers
	148 Mid Boreal Lowland	**Dwarf Mistletoe** on jack pine **Armillaria and other Root and Butt Rots** on conifers **Root Collar Weevil** on jack pine and black spruce **Western Gall Rust** on jack pine **White Pine Weevil** on pine and spruce **Stem Cankers** on conifers
	155 Interlake Plain	**Dwarf Mistletoe** on spruce and pine **Armillaria and other Root and Butt Rots** on conifers **White Pine Weevil** on pine and spruce **Hypoxylon Canker** on aspen

Appendix 3: Pre-harvest forest health recommendations by pest

PEST	PEST SEVERITY *(As determined by Pre-Harvest Survey)*	HARVEST PRIORITY	REGENERATION TREATMENT	HARVEST METHOD	INFESTED TREES MAY REMAIN IN LEAVE AREAS	PEST MANAGEMENT PRESCRIPTION
Spruce Budworm	Moderate Severe	*See Pest Management Prescription* *(page 7)*	Consider a less vulnerable tree species mix	Maximize balsam fir use Identify stands for treatment if harvest is delayed >3 years		Consider control treatment for spruce budworm if harvesting is delayed for more than three years to prevent growth loss and mortality (particularly in multi-year harvest blocks). Maximize balsam fir use on the site when harvesting. Consider renewing to a less vulnerable tree species or species mix to reduce budworm impact in regenerating stand. A white spruce/black spruce mix will suffer less damage than stands with a high balsam fir component
Jack Pine Budworm	Moderate Severe	*See Pest Management Prescription* *(page 8)*				Consider control treatment for jack pine budworm if harvesting is delayed for more than two years to prevent growth loss, top kill and mortality (particularly in multi-year harvest blocks).
Poplar Borer	Moderate Severe	High		Harvest severely-infested brood trees	No	Harvest stands moderate to severely infested by poplar borer as soon as possible to prevent further volume loss due to stem breakage from high winds or heavy snow. Buffers, wildlife corridors and other leave areas not recommended in severely infested hardwood stands as attacked trees are subject to breakage and are a source of infestation to the regenerating stand.

PEST	PEST SEVERITY *(As determined by Pre-Harvest Survey)*	HARVEST PRIORITY	REGENERATION TREATMENT	HARVEST METHOD	INFESTED TREES MAY REMAIN IN LEAVE AREAS	PEST MANAGEMENT PRESCRIPTION
Dwarf Mistletoe	Low Moderate Severe →	*See Pest Management Prescription (page 16)*	Sanitize site. Natural regeneration may be low and planting may be required	Clearcut	No, unless buffered	Clearcutting in a pattern that minimizes edge infections is recommended followed by sanitation (removal of all advanced regeneration and unmerchantable trees for 20 metre past last visible infection). Ensure stand boundaries and leave areas are free of dwarf mistletoe infection or a 20 metre wide buffer of no trees/non-host species is maintained inside regenerating block. Mistletoe infections reduce a tree's ability to produce viable cones and seeds. Planting may be required if large mortality pockets of dwarf mistletoe infected trees occur in the stand.
Western Gall Rust	Severe	*See Pest Management Prescription (page 18)*	>2,000 stems/ha	Clearcut	No, if regenerating to pine	Clearcutting of jack pine is recommended since gall rust remains on site to infect new seedlings, causing mortality and growth loss if left untreated. Buffers, wildlife corridors and other leave areas with heavily galled jack pine are not recommended if regenerating to jack pine. Ensure stocking density of pine is well over 2,000 stems per hectare. Increased density will allow self-thinning to remove galled trees, allow for selection of disease-free crop trees, and increase the level of disease resistance in the stand.

PEST	PEST SEVERITY (*As determined by Pre-Harvest Survey)*	HARVEST PRIORITY	REGENERATION TREATMENT	HARVEST METHOD	INFESTED TREES MAY REMAIN IN LEAVE AREAS	PEST MANAGEMENT PRESCRIPTION
Conifer Stem Canker	Severe	High	Plant non-host or less vulnerable tree species		No	Harvest as soon as possible to prevent further volume loss from stem breakage as trees with main stem cankers have reduced physical strength and are easily broken by high winds or heavy snow. Main stem canker diseases often kill entire trees or that portion above the canker. With Diplodia stem canker on red pine, a more drought hardy species such as jack pine should be considered for renewal. Diplodia has been associated with drought stress.
White Pocket Rot **1)** *Tomentosus* Root Rot **2)** *Phellinus pini*	Moderate Severe	High			No	**1)** Harvest as soon as possible to prevent further volume loss from windthrow. Buffers, wildlife corridors, and other leave areas are not recommended in stands with extensive root and butt decay as the trees are subject to windthrow. Live standing trees infected with *Tomentosus* root and butt decay should still be harvested, as decay is restricted to the butt log, generally bottom one metre. **2)** Harvest as soon as possible to prevent further volume loss from advanced decay and stem breakage as trees with *Phellinus pini* stem decay have reduced physical strength and are broken by high winds or heavy snow.

PEST	PEST SEVERITY (*As determined by Pre-Harvest Survey)*	HARVEST PRIORITY	REGENERATION TREATMENT	HARVEST METHOD	INFESTED TREES MAY REMAIN IN LEAVE AREAS	PEST MANAGEMENT PRESCRIPTION
Brown Cubical Rot	Moderate Severe	High			No	Harvest as soon as possible to prevent further volume loss from windthrow. Buffers, wildlife corridors, and other leave areas are not recommended in stands with extensive butt decay, as the infected trees are subject to windthrow. Live standing trees infected with brown cubical rot should still be harvested as decay is restricted to the butt log (bottom one-to-two metre).
Armillaria Root Rot and Yellow Stringy Rot	Moderate Severe	High	Push over logging OR Use stump and root removal site prep treatments OR Expect losses to continue in the next generation		No	Harvest heavily-infected stands as soon as possible to prevent further volume loss from windthrow. Buffers, wildlife corridors and other leave areas not recommended in conifers with extensive root and butt decay due to instability of roots. Live standing trees infected with Armillaria root disease should still be harvested as decay is restricted to the butt log (generally bottom one metre). Push over logging of conifers could be attempted to determine operational and environmental feasibility to control Armillaria root disease.

PEST	PEST SEVERITY (*As determined by Pre-Harvest Survey)*	HARVEST PRIORITY	REGENERATION TREATMENT	HARVEST METHOD	INFESTED TREES MAY REMAIN IN LEAVE AREAS	PEST MANAGEMENT PRESCRIPTION
Hardwood Stem Decay, White Trunk Rot of Aspen	Severe	High	Carry out prescribed site preparation immediately after harvest	Harvest severely-infected trees	No	Harvest heavily-infected stands as soon as possible to prevent further volume loss from stem breakage due to high winds or heavy snow. Leave areas not recommended in hardwoods (buffers, wildlife corridors, etc) due to instability. Harvest heavily-infected trees to reduce source of inoculum for next generation. Decay enters the above ground portion of trees often through insect wounds, branch stubs, frost cracks or other wounds. Decay is not believed to be transmitted from infected trees to new root suckers. Do not delay scarification if prescribed. Delaying scarification or retreatment is not recommended from three-to-seven years after cutting to prevent injuring the saplings thereby providing entry points for spores
Hypoxylon Canker	Moderate →		>10,000 stems/ha	Harvest infected trees and burn or remove from site	No	In moderately infested stands, ensure initial aspen regeneration is well over 10,000 stems/ha as Hypoxylon incidence increases in understocked stands. Infection enters the above ground portion of trees often through insect wounds, branch stubs, frost cracks or other wounds. Harvest severely-infected stands as soon as possible to prevent further volume loss from wind and snow breakage. Renewal to a mixedwood stand should be considered for sites containing severe levels of infection (≥25%).
	Severe →	High →	Consider mixed wood			