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Effects of Stand Density Management on Forest Insects and Diseases

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Strategic Importance

As the dependence on second-growth forest increases for a wide variety of objectives, stand management is becoming increasingly important in British Columbia and Canada. Forest managers must not only choose methods that are economically, silviculturally and environmentally sound, they must also be aware of the implications of stand manipulation on incidence of diseases and insects. For example, some pests thrive under more open conditions and some will only become harmful when crown closure is complete. Depending on the biology of the pest, changes in the stand environment may increase, or decrease or not substantially affect the damage the pest causes.

Thinning may favor rusts, reducing the number of crop trees – Sweetfern blister rust

Stand Density Management

Stand density management is based on the process of natural mortality. Most forest sites are capable of supporting thousands of seedlings per hectare, but relatively few (150 - 400) mature trees. As crown closure occurs, increased competition results in reduced growth and eventual mortality of some trees. However, properly timed stand density management can be effective in capturing fibre which might otherwise be lost. Stand density management can also affect wildlife habitat, range, recreation and hydrologic values, as well as the ability of the remaining trees to resist insect and disease attack.

The manipulation of stand density is one of the most powerful tools available to foresters to achieve a broad range of silvicultural objectives. Stand density manipulation consists of removing some or all trees in a crown class or by removing all trees except those at a prescribed inter-tree distance. Usually, this entails one or more thinnings to reduce the number of trees to the final crop density. The thinning treatments may also be combined with other treatments such as brushing, fertilization, or pruning. Stand density management can be used to achieve a number of silvicultural objectives including:

1) Improving crop tree attributes such as crown size, height/diameter ratios, branch/knot ratios, and tree vigour;
2) Increasing wood quality, quantity, and value of the remaining trees;
3) Selecting final crop trees on the basis of species and desired silvicultural characteristics;
4) Maximizing stand vitalization by using trees that would be lost due to natural stand mortality (This may represent 25 - 35 % of gross productivity);
5) Reducing the rotation age when the rotation is determined by attainment of a certain tree diameter; and,

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6) Directing the composition of natural regeneration in subsequent stand.

Manipulation of stand density usually results in increased inter-tree distance and thereby reduces competition and increases the vigour of the remaining trees. This in turn may affect insects and diseases positively or negatively through changes in stand climate, the quantity and quality of the food base, and spread and colonization patterns. By reducing the number of trees on the site and opening up the stand, more light, water and nutrients are made available to crop trees.

Increasing the inter-tree distance between residual trees changes the microclimate of the stand by:

1) Increasing air movement;
2) Increasing the precipitation reaching the forest floor; and,
3) Increasing the amount of solar radiation that penetrates the stand.

Of the climatic factors, temperature, light and wind are most important to insect pests, whereas temperature and moisture may be especially important for diseases.

Effects of density on Insects and Diseases

Generally, residual trees have increased vigour. The more vigorous trees remaining after a thinning tend to produce more resin, enabling the trees to more readily repel bark beetle attack. While increased vigour may assist the trees in resisting many pests, thinnings also provide a food source for others. Thinning produces a large number of stumps and debris suitable for colonization by primary and secondary bark beetles and other bark and wood-boring species.

Thinning may also have negative impacts including initial thinning shock and a higher incidence of windfall, providing opportunities for pests. Moreover, mechanical entry into a stand may create wounds to the residual trees and thereby create infection courts for decay organisms and increase susceptibility to disease and insects.

Large pest populations can change stand density, age, size distribution, species composition and aesthetic values. They also increase fuel loading and hasten succession to the climax forest types. The commercial value of losses during epidemics is usually considerably greater than that indicated by the volume loss because grade is significantly reduced and, with primary bark beetles, most mortality is among the larger diameter trees.

Table 1. Insect pests affected by thinning.

These insects	affect these hosts	and cause this type of damage	and may be affected by thinning because	so forest managers should
Mountain pine beetle (*Dendroctonus ponderosae*)	Pine spp.	*Primary bark beetles*: these beetles can kill apparently healthy trees, even during non-outbreak years. Infestations tend to be persistant and often spread over large areas.	Major impact: Thinning affects host vigour, food base, stand climate, and spacing. With the exception of mountain pine beetle, beetles may build up in stumps, windfall, and injured trees, especially 1-3 years after thinng. Increased stand vigour may reduce subsequent beetle activity.	• Not thin stands during years of high stress (e.g. drought, defoliation). • Not thin stands that are prone to windthrow or have a high incidence of disease. • Thin stands during late summer and early fall after the main beetle attack. The inner bark of stumps and slash loses most of its attractiveness to beetles the following year. • Reduce the density of skid trails, and prevent injury to residual trees. • Cut low stumps. • Not pile or burn slash inside the stand. • Remove diseased, decadent and severly weakended trees which may be susceptible to attack.
Douglas-fir beetle (*D. pseudotsugae*)	Douglas-fir			
Spruce beetle (*D. rufipennis*)	Spruce spp.			
Lodgepole pine beetle (*D. murrayanae*)	Pine spp.	*Secondary bark beetles*: these beetles mainly breed in injured or otherwise weakened trees, slash and stumps, but may attack and kill healthy trees during outbreaks. In healthy trees infestations are normally limited in size and decline within 1-3 years.		
Red turpentine beetle (*D. valens*)				
Pine engraver (*Ips pini*)				
Spruce weevil (*Pissodes strobi*)	Spruce spp.	Terminals are attacked. Adult weevils feed and oviposit in elongating leaders. The larvae mine the phloem, sapwood and pith of the current year's terminal leader.	Major impact: Thinning affects host vigour, shading, spacing, and stand climate. Thinning increases inter-tree distance allowing adult weevils to more easily locate terminal leaders. Conversely, high stand density reduces attacks as both weevil species are adversely affected by shade and lower stand temperature. Greater inter-tree distance results in increased stand temperature which promotes greater brood survival.	• Survey stands for pest conditions before thinning. • Consult the Terminal Weevils Management Guidebook for thresholds for weevil attack. • Not thin mechanically as this may leave damaged trees and favor weevils by making hosts easier to find. • Maintain high stand density and do not brush until trees are of sufficient size. • Remove seriously damaged trees once trees are of sufficient size.
Lodgepole pine terminal weevil (*P. terminalis*)	Lodgepole pine Jack pine	Infestation causes reduced height growth and permanent crooks in stems. The spruce weevil generally attacks trees 1.5-9.0 m tall while the lodgepole pine weevil attacks trees 1.5-5.0 m		

Table 2. Forest diseases affected by thinning.

These diseases	affect these hosts	and cause this type of damage	and may be affected by thinning because	so forest managers should
Armillaria root rot (*Armillaria ostoyae*)	most conifers; larch becomes tolerant after 20 years of age.	decreased growth and mortality in infected stands. In mature stands, over 50% of the trees may have *Armillaria*-infected roots. This disease reduces leader growth, and causes discoloration and thinning of the crown. Basal resinosis is often present.	Major impact: Thinning affects the food base. The fungus survives from one rotation to the next in colonized stumps. The fungus spreads from stumps and infected trees by root contact, root grafts, and shoestring-like mycelium called "rhizomorphs". Stumps remaining after thinning provide additional food for the fungus and upset the equilibrium between host and fungus in favor of the fungus. Mechanical thinning methods without stump removal favor the fungus by leaving stumps in root contact with most of the remaining crop trees.	Survey stands for pest conditions before thinning. Action thresholds are included in the Root Disease Management Guidebook. Deny the fungus any additional food base during thinning by: - removal of stumps, - pop-up spacing, and - whole tree logging. Use low thinning methods without stump removal. This will leave the smallest stumps, and so leave less food for the fungus.
Dwarf mistletoe: *Arceuthobium* spp.	Many economically important conifers including pines, western larch, western hemlock, and Douglas-fir.	Dwarf mistletoes are parasitic plants which infect many conifers. Infection causes growth loss and tree mortality. This disease causes distortion of annual rings and swellings and reduces wood quality. This disease may provide entrance points for stain and decay producing fungi.	Major impact: Thinning affects light, and inter-tree distance. Mistletoe seed production is stimulated by increased light. The rates of vertical spread by mistletoe within a tree crown and horizontal spread between trees is more rapid in open stands than in dense stands. Infected residual trees carryover dwarf mistletoe from rotation to rotation.	Survey stands for pest conditions before thinning. Action thresholds are included in the Dwarf Mistletoe Management Guidebook. Cut or girdle infected overstory. Remove severely infected trees during thinning operations. Prefer non-host and uninfected trees as crop trees. Leave deciduous trees during thinning; they provide buffers. Not thin in stands where minimum stocking standards cannot be met with non-host, non-infected, or lightly infected trees. Remember than selection methods favor mistletoe by leaving infected trees.
Western gall rust (*Endocronartium harknessii*) Comandra blister rust (*Cronartium comandrae coleosporioides*) Stalactiform blister rust (*Cronartium coleosporioides*) White pine blister rust (*Cronartium ribicola*)	Lodgepole pine and western white pine.	Western gall rust produces swellings or galls on branches and stems while the Cronartium rusts cause cankers. Stems galls or cankers cause stem deformities which result in decreased lumber volume and value. Mortality occurs when the galls or cankers girdle the stems.	Thinning affects light, space, and stand climate Thinning provides space for herbaceous alternate hosts required by Cronartium rusts to complete their life-cycle. Both western gall rust and Cronartium rusts are spread by spores. Increased inter-tree distance allows wind to disperse spores for greater distances within the stand. Increased air circulation and temperature may be unfavorable for spore germination.	Survey stands for pest conditions before thinning. Action thresholds are included in the Pine Stem Rust Management Guidebook. Mechanical thinning methods favors rusts by leaving infected trees. Thin rust infected stands in late spring when stem infections are producing spores and cankers are most visible. All trees with stem infections should be removed during the thinning operation. Prefer non-host and uninfected trees as crop trees. Leave extra stems as future infections may occur. Thinning should not take place in stands where minimum stocking standards cannot be met with non-host, non-infected, or lightly infected trees.
Many species of decay fungi		Long-term reduction of wood quality, reduced growth, and possible mortality.	Thinning affects inter-tree distance, and may wound stems and thereby create infection courts. Stem wounds may result from several factors: -careless lay out of skid trails, -inexperienced equipment operators, - thinning during the growing season, and -whole tree logging. Volume losses of 5-10% can be expected.	Minimize wounding by: - suspending operations during the growing season, - selecting the least susceptible species as crop trees, - falling trees to facilitate skidding, - laying out skid trails without sharp turns, - using rub trees at corners, and - using experienced crews

As the stand ages following thinning, the remaining trees grow until crown closure occurs once more. At this point inter-tree competition is re-established and tree vigour gradually declines until subsequent thinning or disturbance occurs.

Insects and diseases are present over forest landscapes and are commonly present in stands which are suitable for density manipulation. Most are endemic, playing a role in normal ecosystem functioning, and may not cause significant damage. In a recent British Columbia wide survey, pests recognized in the Forest Practices Code - Forest Health Guidebook were recorded in over 50% of the stands surveyed. However, pest damage exceeded Forest Health Guidebook action thresholds in only 27% of the stands. Only the insects and diseases which have a high potential to damage stands are included in Tables 1 and 2.

Pests are more prevalent in some ecosystems than others; therefore, local insect and disease conditions should be considered when planning changes in stand density.

Long-term Implications

Managers must be aware of the long-term implications of manipulating stand density. In many cases, pest incidence may be reduced by removing affected trees during thinning. However, if pests are left untended or ignored, their consequences may last into the next rotation.

For some pests, such as root diseases, mistletoes and terminal weevils, special surveys are needed to determine whether and to what extent they are present in a stand.

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