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Fundy Model Forest Year-end Report 2006/2007

Development of Hazard Ratings for the Balsam Woolly Adelgid

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Executive summary

The balsam woolly adelgid was introduced into Canada from Europe early in the century, occurs on both coasts, and has caused extensive tree damage to balsam fir in Atlantic Canada. Its lack of wings results in limited dispersal and infestations build up locally, causing an irregular or spotty distribution of outbreaks. Affected trees are unsuitable for lumber owing to uneven shrinkage causing warping and splitting, and pulp is of inferior quality to that from normal wood. Stem attack can result in growth reductions in excess of 50%, with high populations killing large trees within three years. Chronic crown infestation can cause a tree to succumb in 10 to 20 years and also predisposes trees to infection by a root-rot. Unfortunately, there is no commercially viable tactic to deal with this pest. We will determine the type of damage (stem attack vs. branch distortion or 'gout') and the distribution and intensity of BWA populations in thinned and unthinned balsam fir stands of varying ages in New Brunswick and relate this to characteristics of the forest stands to produce hazard ratings. The hazard ratings will predict the probability of damage by the balsam woolly adelgid for different stand conditions. This information will be used by the forest industry, provincial forest managers and private woodlot owners to make decisions regarding what tree species to favour in their stands and to decide whether they should harvest stands beginning to show symptoms of damage by this pest.

Objectives

a) To determine the frequency and intensity of balsam woolly adelgid populations in managed and unmanaged balsam fir stands.
b) To determine whether BWA damage is associated with other stand characteristics

Background

The balsam woolly adelgid (BWA) was introduced into Canada from Europe early in the century, occurs on both coasts, and has caused extensive tree damage. BWA has a high biotic potential because of its high fecundity and parthenogenetic method of reproduction. Its lack of wings results in limited dispersal and infestations build up locally, causing an irregular or spotty distribution of outbreaks (Balch 1952). Affected trees are unsuitable for lumber owing to uneven shrinkage causing warping and splitting, and pulp is of inferior quality to that from normal wood. Stem attack can result in growth reductions in excess of 50%, with high populations killing trees of merchantable size within three years. Chronic crown infestation can cause a tree to succumb in 10 to 20 years (Carroll and Bryant 1960). Damage also predisposes trees to infection by Armillaria root-rot.

There has been only limited success in reducing damage caused by BWA using insect predators or chemicals (Harris and Bowers 1995). The resurgence of BWA in New Brunswick in the past few years in balsam fir, the principal component of wood supply, is of particular concern. Similar concerns occur in Nova Scotia, Newfoundland (Milne 1990) and Maine. Earlier studies indicated that thinned stands, in which many trees developed deep crowns, may have suffered more damage than neighbouring, fully-stocked stands (Balch 1952). With the anticipated future wood shortages and the increased costs of intensive forest management, it is important to determine the occurrence and significance of the insect in high-value stands and evaluate the role of the BWA in managed stands.

During the past summer, we surveyed BWA damage in thinned and unthinned fir stands in New Brunswick. Within a subset of these stands we measured stem density, development stage of stand, elevation, aspect, percentage slope, soil moisture, soil type, soil texture, depth of humus layer, ground vegetation and tree growth rate. We also used data collected by the New Brunswick Department of Natural Resources to relate the presence and absence of BWA to stand characteristics and temperature. Finally, we also measured the incidence of gouting during the previous ten years in New Brunswick and carried out analyses to determine whether the level of damage was related to winter temperatures.

Although only two authors are listed on this report, data in it are the result of our collaboration with colleagues from DNR (Nelson Carter, Lester Hartling and Dan Lavigne) and the Canadian Forest Service (Ian DeMerchant).

Methods

Estimates of BWA Damage

In each stand, 5 plots located at 30 m intervals were established to determine the type (stem attack vs. branch distortion or 'gout') and intensity of damage caused by BWA in thinned and unthinned balsam fir stands of varying ages in southern New Brunswick. In addition, the following data was collected from each stand: number of stems (by species), pre-spacing density, development stage of stand (regenerating (1-2m), sapling (<7m and < 10 cm DBH), young (10 < x < 16 cm DBH), immature (16 < x < 26 cm DBH), mature/overmature (> 26 cm DBH), bearing of cruise, elevation, aspect, percentage slope, soil moisture regime (dry, fresh, moist, or wet), soil type (podzol, brunisol, gleysol, organic, etc.), soil texture, depth of humus layer, and ground vegetation (major species). Additional data on site conditions will also be collected from stand maps. Five trees closest to the centre of each plot were rated for gout using a rating scheme developed by Schooley and Bryant (1978). To facilitate the exchange of information with provincial entomologists, crown or gout attack was classified using the same five categories used by DNR.

In addition, we were provided with BWA damage estimates from a DNR survey of several hundred plots throughout New Brunswick. Although no other stand characteristics were directly measure in this survey, we were able to obtain many stand characteristics from the New Brunswick GIS database.

Influence of temperature on BWA damage

Geographic information systems were employed to relate the incidence of BWA damage in the samples described above to winter temperatures and plant hardiness zones.

Mean minimum daily and mean daily temperatures for November, December, January and February for all regions of New Brunswick were obtained from the Canadian Climate website (http://climate.weatheroffice,ec.gc.ca/Welcome_e.html). We also obtained mean daily minimum and mean daily temperatures for the month of January for each of the last 10 years from the same website. Estimates of plant hardiness zones, which take other abiotic parameters into account in addition to temperature, were also obtained for each site.

In a subset of the stands described above, one midcrown branch from two trees per plot (i.e., 10 trees per stand) was cut with pole pruners and the incidence of gouting by BWA on the terminal axis was recorded. As midcrown branches had up to 10 age-classes of foliage, this enabled us to estimate the incidence of gouting for the previous 10 years. The incidence of branch gouting during the 10-year period was related to January temperatures.

Analyses

General linear models and principal component analysis were used to evaluate the relative influence of the measured stand variables, expressed on a stand level to avoid pseudo-replication, on the level of damage attributable to BWA in thinned and adjacent unthinned stands. Correlation analysis was used to evaluate the influence of mean winter temperatures on the incidence of gouting by BWA.

Preliminary results

Estimates of BWA Damage

General linear models and principal component analysis were used to evaluate the relative influence of the variables measured on the level of damage attributable to BWA in thinned and adjacent unthinned stands, as well as in a larger data set with only thinned stands. BWA damage was usually highest in stands where the water table was higher or lower than normal, suggesting that trees may have been more stressed and grew at a slower rate. Consequently, these results suggest that increases in tree growth rate, resulting from thinning, should not make trees more susceptible to BWA. Our analysis supports this hypothesis. There was no general and consistent increase in BWA damage that could be attributed to thinning, although damage was slightly higher in thinned stands (Fig 1). Levels of BWA damage were also influenced by elevation, crown closure, volume and height of trees of dominant tree species, density of dominant tree species, and basal area of dominant tree species. These trends were often curvilinear.

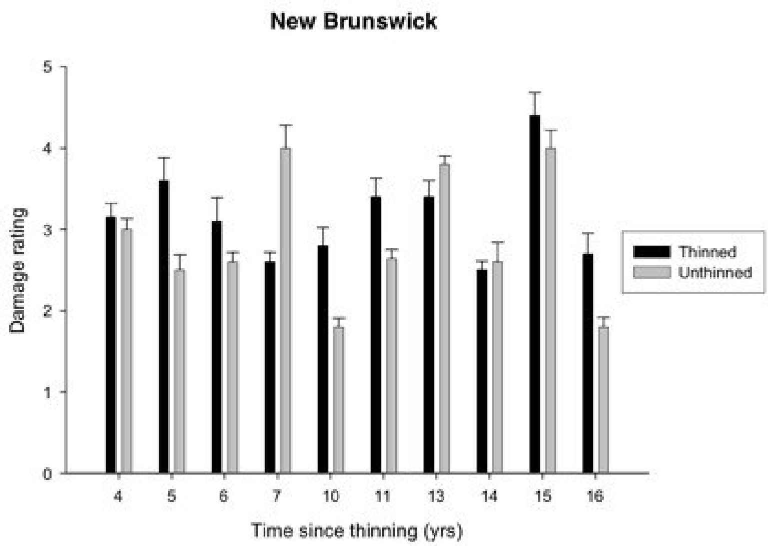

Fig. 1. Mean (+ SE) damage by BWA in fir stands in southern New Brunswick thinned during the last 16 years.

Influence of temperature on BWA damage

The distribution of BWA in New Brunswick appears to be strongly influenced by winter temperatures. There was little evidence of damage by BWA in areas where the mean annual temperature in January was below –11°C (data not shown). The presence/absence of BWA is even more strongly related to plant hardiness zones. Damage by BWA was absent in all regions with a plant hardiness rating of 4a or lower (Fig.2).

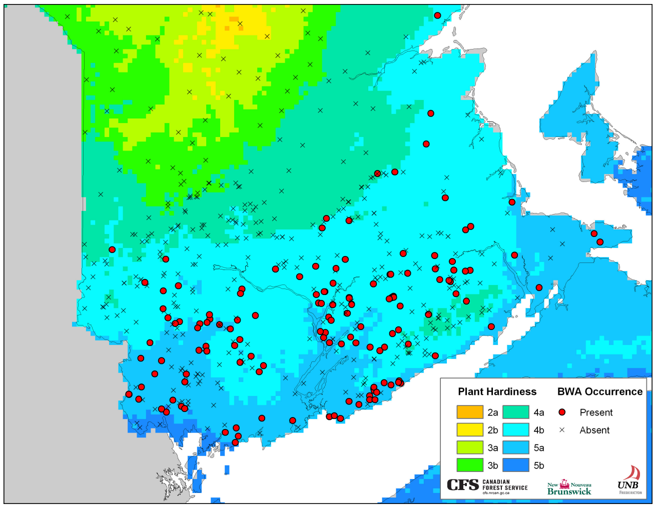

Fig. 2. Relationship between plant hardiness zone and presence/absence of damage by BWA in New Brunswick.

Temperature also explained year-to-year fluctuations in the level of damage by BWA. The incidence of gouting along the central axis of mid-crown branches was positively related to mean temperature during the preceding January (Fig. 3).

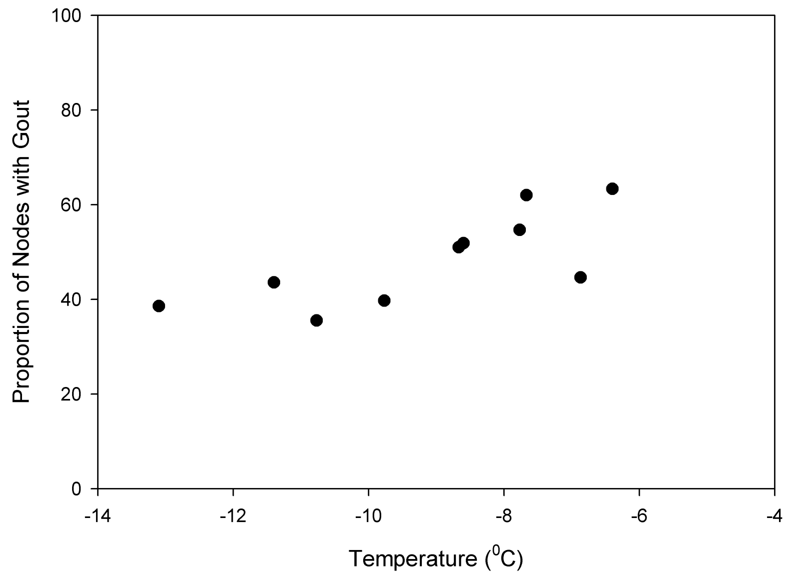

Fig. 3. Relationships between the mean January temperature from 1995-2005 in New Brunswick and the mean proportion of terminal shoots that developed the following summer that showed evidence of gouting caused by BWA. Spearman's rank correlation coefficient is 0.82, p=0.004.

Discussion of preliminary results

It is clear from this study that temperature plays an important role in determining the presence or absence of BWA. Generally, BWA does not occur in areas of the province where mean January temperatures are < -11C. The presence/absence of BWA can be predicted even more accurately using plant hardiness zones, as BWA does not occur in zones colder than Zone 4a. Just as the presence/absence of BWA in an area can be predicted based on temperature, so can the severity of attack in regions where BWA is present. The incidence of gouting was positively related to the mean temperature in January, supporting the findings of Greenbank (1970), who reported a similar phenomenon for survival of overwintering nymphs.

Several variables explained variations in BWA damage when examined alone. However, when large multivariate analyses were carried out these variables were often not significant. This is probably due to reduced sample sizes for extreme values of these variables as well as the non-linear (usually curvilinear) relationships often observed between stand characteristics and BWA damage. We are currently addressing the statistical challenge by carrying out other multivariate tests. However, we will also need to increase our sample size of the very high and low values of several variables to obtain the power needed for this analysis. The good news for the forest industry and woodlot owners is that there is not a large effect of thinning on the level of BWA damage. We have found a similar trend in Newfoundland, lending support to this conclusion.

Acknowledgements

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