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FILE REPORT 63

Forcasting Leader Loss in Jack Pine Plantations Infested with the White Pine weevil, *Pissodes strobi* Peck (Coleoptera: Curculionidae)

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Ontario

This file report is an unedited, unpublished report submitted as partial fulfilment of NODA/NFP Project #4012, "Silvicultural prescriptions for management of white pine weevil in jack pine".

The views, conclusions, and recommendations contained herein are those of the authors and should be construed neither as policy nor endorsement by Natural Resources Canada or the Ontario Ministry of Natural Resources.

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Technical Note to NODA[1] on

Forecasting leader loss in jack pine plantations infested with the white pine weevil, *Pissodes strobi* Peck (Coleoptera: Curculionidae)

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[1]This paper has been formated to be submitted as a scientific note to the Can. J. For. Res. Thus, it contains results from both my research funded by NODA (within-year predictions) as well as results from V. Nealis's work (not funded by NODA) (between-year predictions). Authorship of the manuscript will be shared with P. Lomic and V. Nealis.

Abstract

Within- and between-year predictive models were investigated to forecast leader loss by the white pine weevil (*Pissodes strobi* Peck) in jack pine (*Pinus banksiana* Lamb) plantations. The best predictions were based on between-year models where an estimate of absolute density, calculated as the number of emergence holes per dead leader times the proportion of dead leaders/ha in the previous fall, was the best variable to predict the proportion of damaged trees in the subsequent year. Sampling effort should focus on stands rather than on transects, as the variation among stands did not differ significantly from the variation among transects within a stand.

Introduction

The white pine weevil, *Pissodes strobi* Peck, is a serious pest of conifers such as white pine (*Pinus strobus* L.), Scots pine (*Pinus sylvestris* L.), and jack pine (*Pinus banksiana* Lamb.) in eastern Canada, and Sitka spruce (*Picea sitchensis* (Bong) Carr), Englemann spruce (*Picea englemannii* Parry) and White spruce (*Picea glauca* (Moench) Voss) in western Canada. Weevil biology and life cycle is well documented (e.g., Wallace and Sullivan 1985). The larvae feed on the phloem of previous years' leader which eventually results in leader mortality and reduced tree height, volume, and lumber grade (Brace 1971, Davidson 1991). Weevil damage in northern Ontario has had a dramatic impact on the quality of pulp logs (Retnakaran and Harris 1995). Economic losses from the weevil can reduce timber value by 25% in white pine (Brace 1971) and 13% in jack pine (Davidson 1991). Because infestations are most common in young trees between 2-6 m tall with leaders >4 mm (Hodge *et al.* 1990), weevils may negatively impact productivity and quality of high-value trees in young conifer plantations. In Ontario, for instance, white pine weevil infestations to young jack pine plantations led to 16-25% leader damage in the late 1980's (Howse and Applejohn 1989).

Control measures for the white pine weevil are limited and expensive. Currently, methoxychlor is the only registered pesticide for the white pine weevil in Canada. However, the weevils' life cycle makes insecticide application difficult because weevils spend most of their life cycle in host trees or overwintering in the duff which protect them from insecticide application during long periods of time. Methoxychlor is usually applied early in the spring while the adults are emerging from the pupae. Other effective control strategies include pruning and removing or destroying infested leaders (Lavallée and Morissette 1989, Hodge *et al.* 1990). This type of intervention, however, is labour intensive and consequently expensive. To date, control strategies such as natural enemies, chitin synthesis inhibitors, and entomopathogenic nematodes have not been successful (Retnakaran and Harris 1995).

The difficulty and expense associated with the control of the white pine weevil require the ability to pinpoint when and where control strategies will be needed. To accomplish this, finding a variable that allows forecasting leader loss is essential to provide the lead time necessary to plan and implement interventions. Current guidelines for the white pine weevil in Ontario are limited to suggest that 200 trees be surveyed within the plantation in the spring to estimate levels of the weevil, and that careful inspection of the leaders for adults is required (Hodge *et al.* 1990). These guidelines are for white pine and there are no such guidelines for jack pine.

The purpose of this study was to find a practical model to predict white pine weevil damage by examining within- and between- year mortality of leaders. Variables describing white pine weevil abundance were evaluated, and the variable explaining the highest proportion of the variation in leader mortality was selected as the best predictor of leader loss. The sources of variation within stands with respect to weevil density are also evaluated to assist in development of sampling programs.

Methods

Within-year prediction of leader loss

Estimates of relative abundance of weevils and leader loss were conducted in two 10-12 year old jack pine plantations (Mirimichi and Pike Lake), approximately 30 km south of Gogama (47° 31' N; 81° 40' W). Two sites were selected in each plantation (Mirimichi I, Mirimichi II, Pike Lake I, and Pike Lake II). Plantations ranged from 1.6-2.7 m in height and were planted at approximately 2,000-3,000 trees/ha. Within each site, 200 m transects were used to sample approximately 98-128 trees/transect. The number of transects per site was 6 in Mirimichi I, 3 in Mirimichi II, 6 in Pike Lake I, and 3 in Pike Lake II. These transects were systematically surveyed during the spring-fall of 1993, counting the number of weevils/tree, recording presence/absence of feeding and oviposition holes, and estimating leader loss. The following variables were examined to predict leader loss to weevils (Table 1): 1) mean number of adult weevils per tree in May (early sample); 2) mean number of adult weevils per tree in June (final sample); 3) maximum number of adult weevils per tree (recorded at any one sampling date); 4) proportion of trees showing feeding holes in May (early sample); 5) proportion of trees showing feeding holes in June (late sample); 6) proportion of trees showing feeding holes in July (final sample); and 7) proportion of trees showing oviposition holes in July. These variables were selected as estimates of relative density of adult weevils because they were expected to be highly correlated with the actual weevil density. To relate these relative density estimates to leader loss, the transects were revisited in November of the same year to assess the number of dead leaders/transect. The proportion of trees with feeding and oviposition holes and subsequent leader mortality were calculated on a transect basis, and an average was estimated for each site. Data were analyzed on both a transect and stand basis.

To give guidance to future sampling, the variance among stands versus the variance between transects was tested using an F-test (Morris 1955).

Between-year prediction of leader loss

The study was conducted in a jack pine plantation in Hurlburt Township, 55 km northeast of Sault Ste. Marie, Ontario (46° 44' N; 83° 41' W). The plantation was established in 1985 on a glacial, fluvial outwash plane of fine sandy, deep soil at a stocking rate of approximately 2,400 trees/ha.

Census of trees with weeviled leaders was carried out by recording the frequency of undamaged and damaged trees in every fifth row of trees during the fall 1988-1995. Each annual sample involved examination of 500-3,000 trees. A subsample of damaged leaders was collected throughout the plantation during the census. Sample size of damaged leaders ranged from 20 to 129 per year. These leaders were examined and the number of distinctive holes formed by emerging adult weevils were counted on each leader. The number of weevils per ha was estimated as the mean number of weevils emerging per leader times the number of leaders killed by weevils per ha. Also, the proportion of dead leaders from the previous year was tested to determine if it could predict the proportion of dead leaders in the current year.

Statistical analysis

Data were analyzed using regression and correlation analysis with Student's *t* as the test statistic (Zar 1996). A one sided t-test was used because it is most reasonable to assume that an increase in weevil density resulted in an increase in weevil damage. Assumptions of normality were tested by probability plots of the residuals and those of homogeneity of variance were tested by plotting the residuals versus their estimate. All data sets met the assumptions of both normality and homogeneity of variance and no transformations were necessary. Statistical analysis was performed using Systat (Wilkinson 1990).

Results

Within-year prediction of leader loss

The proportion of trees showing feeding holes in early July was the best predictor of leader loss ($r = 0.78$, d.f. = 15, $p < 0.01$) when considered on a transect basis (Table 1). Generally, prediction improved the closer the measurement of the variable was to death of the leader, although not all correlations were significant. When the proportion of trees showing feeding or oviposition holes in early July was used to predict leader loss on a stand basis, the correlations were only marginally significant (Figs. 1 and 2). This may be attributed to the few degrees of freedom that resulted from only 4 stands used in the analysis.

There was no significant difference between the variance among sites versus the variance between transects for the proportion of trees showing final feeding ($F_{1,16}$ =

0.364, $p = 0.555$) and oviposition holes ($F_{1,16} = 0.283$, $p = 0.776$). The results suggest that in the future fewer transects and more stands should be sampled, given that stands is the unit about which one wishes to make predictions.

Between-year prediction of leader loss

The number of adult weevils produced per ha (estimated as the mean number of emergence holes/damaged leader times the number of damaged leaders/ha) was a very good predictor of the proportion of trees damaged in the subsequent year, explaining 88% of the variation in the proportion of damaged trees. The predictive equation, $y = -853.4 + 344.1\,x$, and the correlation coefficient were significant at $p < 0.002$ and $p < 0.01$, respectively. Although the regression between the mean number of emergence holes per damaged leader versus the proportion of damaged trees in the subsequent year was also significant ($p < 0.02$), it explained only 72% of the variation in the proportion of damaged trees.

The proportion of leaders killed by weevils in the previous year did not accurately predict the proportion of damaged leaders in the current year ($r^2 = 0.34$).

Discussion

This is the first attempt to predict leader loss in response to infestation by white pine weevil where within- and between- years predictions are examined. The best prediction of weevil damage in a given year appears to be based on the number of adult weevils emerging from leaders during the previous fall. Although predictions made within a year were adequate, year-to-year predictions explained a larger proportion of the variation in the number of damaged trees in the subsequent year. Besides, within-year prediction may occur too late to plan and implement meaningful control measures for that year. Year-to-year prediction offers the advantage of sample time to plan and implement interventions. It should be noted that the high correlation for prediction between years may in part be attributable to the fact that samples are from only one stand. However, the large and highly significant correlation when predicting leader damage between years is an indication that this approach has considerable merit.

This study shows two key ways in which sampling methods to predict weevil damage can be improved. First, increasing the number of stands sampled rather than the number of transects will improve the predictability of the estimates. This conclusion is consistent with other sampling schemes such as Morris's (1955) work on spruce budworm, that showed variation in a cluster of trees within a plot was not significantly different from trees within clusters. Second, estimates of absolute density of weevils seem to predict damage better than estimates of relative density. The best damage predictor was the absolute density estimate (number of weevils per ha), followed by the mean number of emergence holes per damaged leader. Using the mean number of emergence holes per damaged leader to predict weevil damage has the advantage of requiring only collection and inspection of damaged leaders (and not the counting of damage leader/ha). The next most predictive variables (all of them estimates of relative density) were the proportion of trees showing feeding holes in July, the proportion of trees showing oviposition holes, and finally the proportion of leaders killed by weevils in the previous year. This result should be interpreted with caution because this could also be due to the time frame in which the prediction occurred (i.e. prediction of damage between years). Our results are similar to those by Schaalje and Butts (1992) who also found a very good relationship between Russian wheat aphid density and the percentage infestation, while the standard error of predictions based on presence/absence sampling were 30-40% depending on the sample unit.

This study is a critical step in improving prediction of white pine weevil damage. Focus should be on predicting between-year leader mortality using density estimates such as the number of emergence holes (weevils emerged) from leaders from the previous fall (number of weevils/ha). The number of transects and stands sampled should be investigated further to improve prediction of white pine weevil damage.

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Table 1. Variables examined to predict the proportion of jack pine damaged by weevils in the same year.

Variable	Sampling Date (1993)[1]	d.f.[2]	*r*
Mean number of adult weevils/tree (early sample)	20 & 27 May	11	0.25
Mean number of adult weevils/tree (final sample)	23 & 24 June	11	0.16
Maximum number of adult weevils/tree (number on any one sampling date)	regardless of date	11	0.61*
Proportion of trees showing feeding holes (early sample)	20 & 27 May	11	0.37
Proportion of trees showing feeding holes (late sample)	23 & 24 June	11	0.46
Proportion of trees showing feeding holes (final sample)	9 July	15 (16)	0.78** (0.65)[1]**
Proportion of trees showing oviposition holes	9 July	15 (16)	0.68** (0.65)[1]**

* $p < 0.05$
** $p < 0.01$
[1] All white pine weevil stages were sampled between May and July 1993 and leader mortality was assessed in November 1993
[2] Degree of Freedom
[3] the *r* values in brackets include one outlier

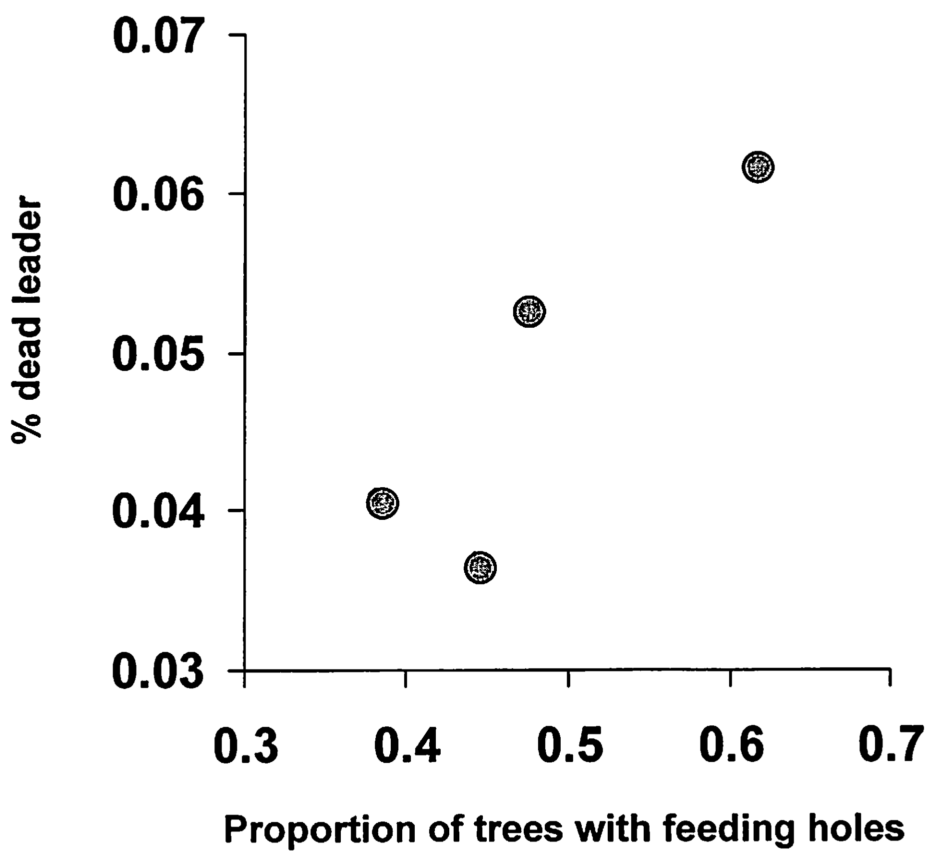

Fig. 1. Relationship between the percentage of dead leaders and the proportion of trees showing feeding holes (final feeding estimate). The correlation ($r=0.88$) was marginally significant at the $p<0.1$ level ($t= 2.45$, $df=2$). Each data point represents a stand based on a sample of approximately 300-600 trees.

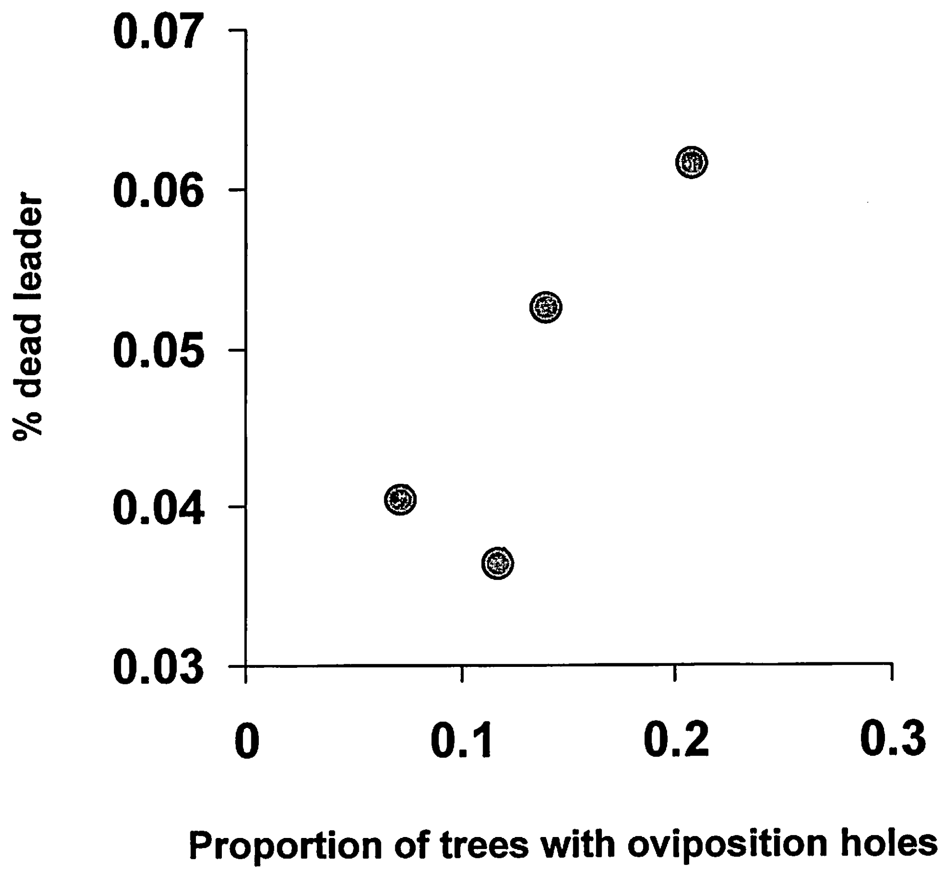

Fig. 2. Relationship between the percentage of dead leader and the proportion of trees showing oviposition holes. The correlation ($r=0.88$) is marginally significant at the $p<0.1$ level ($t= 2.58$, $df=2$). Each data point represents a stand based on a sample of approximately 300-600 trees.