A sequential sampling system for the white pine weevil, *Pissodes strobi* (Coleoptera:Curculionidae)

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ABSTRACT

A sequential sampling system is described for determining degree of infestation by the white pine weevil, *Pissodes strobi*, in stands of spruce, *Picea* spp. The method requires that a maximum of 60 trees be randomly selected in sequence and that the cumulative number of infested trees be plotted against the total number of trees sampled. Sampling is stopped as soon as decision lines calculated for $<$ 10% infestation or $\geq$20% infestation are crossed.

Key words: spruce, *Picea* spp., monitoring, pest management

INTRODUCTION

The white pine weevil, *Pissodes strobi* Peck, is a serious pest of reforestation and natural regeneration, causing severe damage to Sitka spruce, *Picea sitchensis* (Bong) Carr., Engelmann spruce, *Picea engelmannii* Parry, white spruce, *Picea glauca* (Moench) Voss, and their hybrids, in British Columbia. This weevil is widely distributed in North America, being found in most provinces of Canada and in many states of the Union. The hosts attacked in eastern North America include eastern White pine, *Pinus strobus* L., Jack pine, *Pinus banksiana* Lamb., and Norway spruce, *Picea abies* (L.) Karst.

P. strobi adults overwinter in the duff (Silver 1968), usually near the tree from which they emerged in the previous fall. Early in the spring (late March, April), adults fly or crawl to the terminal leader of host trees and commence feeding and mating. Oviposition begins soon after. Eggs are laid near the tip of the leader, just under the apical bud, in feeding punctures which are then covered with a fecal plug. After hatching, the larvae orient downwards and begin consuming the phloem. As their galleries merge, the larvae form the characteristic "feeding ring", in which larvae move downwards in synchrony, consuming all phloem around the circumference of the leader. This causes the girdling and destruction of the leader. Pupation takes place in chambers excavated in the xylem and covered with wood fibers. New adults emerge from late July to September. After emergence, these fall adults feed for a while, disperse, and when temperatures drop and photoperiod shortens, they go into hibernation in the duff.

Effective pest management programs for the white pine weevil (Alfaro *et al.* 1995) require regular monitoring in order to determine if existing insect populations and damage levels are at or near levels requiring treatment. Post-treatment assessments are also required to determine the efficiency of control measures.

The theory of sequential sampling was developed during World War II for use in quality control and in the 1950's it began to be applied to forest pest control decisions (Waters 1955). Regular sampling methods usually require a fixed number of samples that will estimate a level of infestation to a desired level of precision. However, for the same precision, the specified number of samples will invariably be inadequate at low and excessive at high pest densities. Sequential sampling is a system designed to simply choose between two alternatives: is the density of the pest or the level of damage higher or lower than a given critical level? Sampling continues only until results indicate that one alternative is more likely than the other at some constant, acceptable level of probability. When infestations are very high or very low, the most likely alternative becomes apparent very quickly. Hence savings of up to 50% in time and cost of sampling can be achieved (Onsager 1976).

The objective of this paper was to report a sequential sampling system developed for the rapid assessment of white pine weevil infestations.

MATERIALS AND METHODS

The sampling system reported here was developed following the formulae indicated by Waters (1955). Infestations by the white pine weevil will be classified as light if the proportion of trees with current weevil damage is less than 10% (H_1) and severe if 20% (H_2) or more of the trees are attacked. Damage levels between 10 and 19% are termed moderate. These thresholds were based on practical considerations: estimates of merchantable volume at rotation, assuming infestations lasting 20 years, at the above thresholds, indicate losses of 13 and 21%, respectively (Alfaro 1994). Infestations below 5% of the trees/year are thought to represent endemic levels. The sampling plan developed here calls for examining sufficient trees until cumulative results indicate that either hypothesis H_1 or H_2 is more likely to be correct at some pre-established degree of reliability.

As in regular sampling, the specified degree of reliability will determine, to a large extent, the feasibility of the survey in terms of logistics and costs. For the sampling method reported here, both probability of Type I error (probability of accepting H_2 when H_1 is true) as well as for Type II error (probability of accepting H_1 when H_2 is true), were set to 10% (i.e. $\alpha = \beta = 0.10$). We use the operations for the binomial distribution reported by Waters (1955) to find the slope and intercepts of the parallel decision lines.

Intercepts:

$$a_1 = \frac{\log\left(\frac{1-\alpha}{\beta}\right)}{\log\frac{p_2}{p_1}\left(\frac{1-p_1}{1-p_2}\right)} \qquad a_2 = \frac{\log\left(\frac{1-\beta}{\alpha}\right)}{\log\frac{p_2}{p_1}\left(\frac{1-p_1}{1-p_2}\right)}$$

Slope

$$b = \frac{\log\left(\frac{1-p_1}{1-p_2}\right)}{\log\frac{p_2}{p_1}\left(\frac{1-p_1}{1-p_2}\right)}$$

Where α and β are the established probabilities for Type I and II errors and p_1 and p_2 are the classification thresholds of 10 and 20% infestation.

RESULTS AND DISCUSSION

The following equations were calculated for the upper and lower decision lines (Fig. 1):

$$d_1 = 0.145n + 2.71 \qquad d_2 = 0.145n - 2.71$$

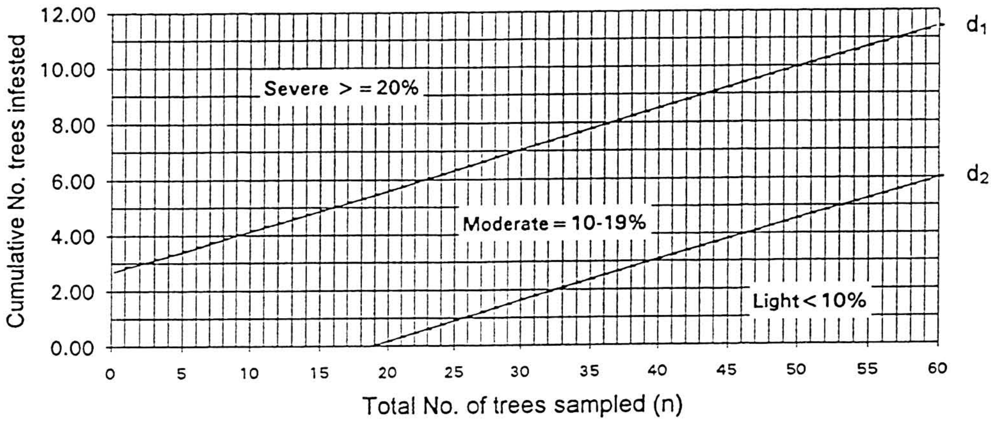

Figure 1. Parallel decision lines for a sequential sampling system for the white pine weevil, *Pissodes strobi*

Stands are classified as severely infested (>=20% of the trees attacked) if a plot of the cumulative number of attacked trees versus the total number of trees sampled crosses the upper line. Stands are classified as light (<10%) if the lower line is crossed. If after sampling 60 trees (see below) neither of the lines is intercepted, the stand is labeled as moderately infested (10-19% attack),

The reliability of this sampling system can be evaluated by examining the Operating Characteristic (O.C.) curve (Waters 1955) which indicates, for any infestation level, the probability of correctly classifying an infestation as light (Fig. 2). The probability of labeling a stand as light drops sharply when stands have higher than 10% infested trees.

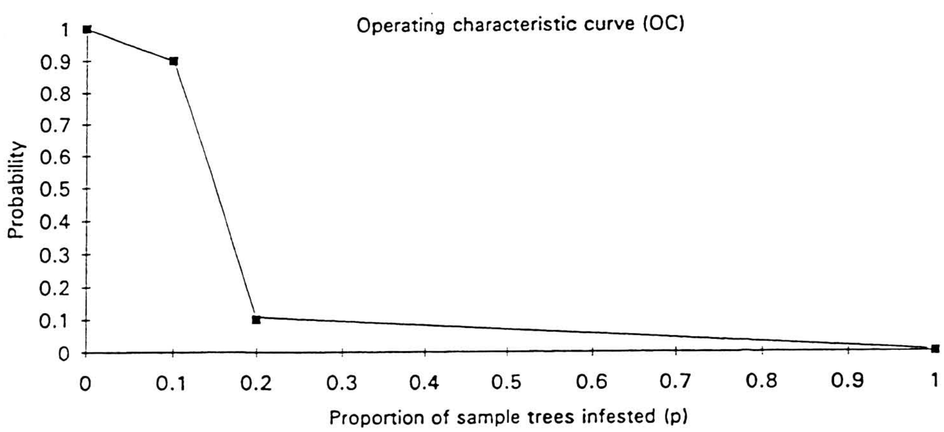

Figure 2. Probability (p) of classifying a stand as light for different degrees of infestation

The number of samples required to reach a decision can be evaluated by calculating the Average Sample Number (A.S.N.) curve (Waters 1955), which gives the number of samples that will, on the average, result in acceptance of either H_1 or H_2 for any level of infestation (Fig. 3). The A.S.N. allows us to realize the efficiency of this sequential sampling system. An uninfested stand will be identified after 19 sequential random samples without weevil attack (the X intercept in Fig. 1). A 100% infested stand (an unlikely situation) could be identified by finding only three infested trees in sequence (the Y intercept in Fig. 1). The largest number of samples (60) required to reach a decision occurs when the infested stand has between 10 and 19% infestation. If no decision has been reached after examination of 60 trees, the stand must be declared "Moderately infested".

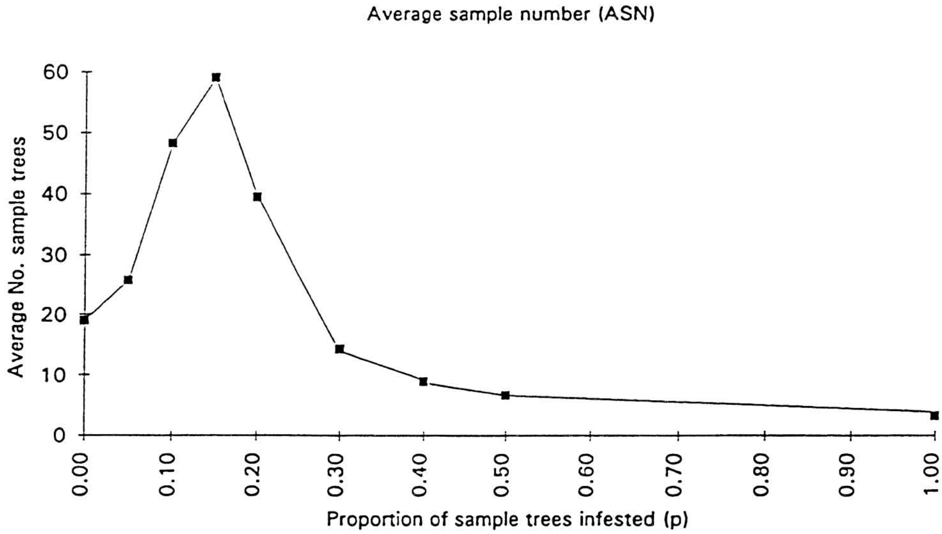

Figure 3. Average number of sample trees examined to reach a decision in stands with different degrees of infestation (p).

FIELD APPLICATION. One of the major drawbacks of sequential sampling in forestry is the requirement that trees are sampled at random and in the sequential order in which they were selected. This would result in an inefficient criss-crossing of the stand in order to maintain the sequence. I suggest that, in the office, the area of the stand be divided into a grid of X,Y coordinates (e.g. a 5m × 5m grid). Then, using a random number table or a packaged software program, select 60 random X,Y coordinates in the stand, keeping track of the sequential order of selection, i.e. 1 to 60. Divide the list into two groups: coordinate points numbered 1-30 and 31-60. Sample all trees in the first group as you move through the stand in the most efficient manner, i.e., without regard to the sequence, using a compass and measuring tape to locate the tree nearest to the selected X, Y coordinate. After sampling the first group, plot the cumulative number of attacked trees in Fig. 1, <u>maintaining the order in which the coordinates were selected.</u> If either of the decision lines have been crossed, stop sampling and record the stand as lightly or severely infested. If after 30 samples the cumulative attack line is still in the intermediate zone, sample the entire second 30-tree group, in the most efficient manner. At the end of this second pass through the stand, add to the cumulative plot drawn for the first group, keeping the sequential order of selection. This sequential plot will have either crossed one of the decision lines, or remained in the intermediate zone, causing the stand to be classified as light, moderately or severely infested. It is anticipated that lightly or severely infested stands will be identified in the first pass. Moderately infested stands will require two passes, i.e. the sampling of the entire 60-tree sample. It is expected that this method will result in significant time saving when classifying stands for treatment.

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