Detection of *Pissodes strobi* (Coleoptera: Curculiondae) using large-scale 70 mm colour photography

S. P. TAYLOR[1], B. S. LINDGREN[2] and J. JOHNSON[3]

[1]BRITISH COLUMBIA FOREST SERVICE PRINCE GEORGE, B. C. V2L 3H9
[2]UNIVERSITY OF NORTHERN BRITISH COLUMBIA PRINCE GEORGE, B. C. V2N 4Z9
[3]TIMBERLINE FOREST INVENTORY CONSULTANTS PRINCE GEORGE, B. C. V2L 3R3

ABSTRACT

A 17 year old white spruce plantation with a current rate of white pine weevil infestation of 23% was photographed using 70 mm colour photography at scales of 1:500 and 1:650. The two photo-scales were then interpreted by two different sets of photo-interpreters, with varying degrees of experience, and compared to ground surveys. Results showed that the use of skilled photo-interpreters improved the accuracy of interpretation of current weevil attacks by 18% to 79% over the use of unskilled interpreters. A significant relationship was also observed between the amount of red foliage remaining on the leader and the accuracy of interpretation of current attacks. Large-scale 70 mm photography can detect currently attacked spruce leaders as small as 35 by 30 cm with an accuracy approaching 90% providing at least 30% of the red needles remain on the damaged leader and experienced photo-interpreters assess the results.

Key words: white pine weevil, *Pissodes strobi*, colour photography, aerial survey

INTRODUCTION

The white pine weevil, *Pissodes strobi* (Peck), is rapidly becoming a serious problem in British Columbia. For example, the Prince George Forest Region (PGFR) of British Columbia has about 0.4 million ha of white spruce, *Picea glauca* (Moench) Voss * *engelmannii* (Parry ex Engelm.) and approximately 36% of this area may be susceptible to attack by the weevil according to an assessment of the hazard using threshold temperatures for weevil brood development and oviposition (Spittlehouse *et al.* 1994).

In early spring the weevil lays its eggs in the terminal leader from the previous year (Stevenson 1967). The eggs hatch and the larvae mine downwards consuming the phloem. Successful attacks kill the top whorl of the tree resulting in leaders that first droop when half grown (Mitchell *et al.* 1990) and then the needles turn yellow and red before dropping off in late autumn. Damaged leaders then show deformities that can reduce the merchantibility of the tree (Alfaro 1989).

Effective management of the weevil depends on the ability of Forest Managers to accurately predict the attack status over large areas of forest land. If high levels of weevil attack are predicted then either mixed species management or partial brush manipulation can be used to reduce the damage (Taylor and Cozens 1994, Taylor *et al.* unpublished observations). Accordingly, survey methods must be developed that are both inexpensive and accurate, to survey the large areas of plantations contained in the PGFR. Such methods will undoubtedly involve a combination of aerial and ground techniques.

Large-scale 70 mm colour photography was demonstrated to be 90% accurate in detecting the weevil on white pine and cost 20% less than conventional ground detection (Aldrich *et al.* 1959). However, the ability of colour photography at a large-scale to distinguish between current versus old attacks was not assessed in that study. The success of colour photography at a large-scale is dependent on good photo-interpretation and pest symptoms (Wallis and Lee 1984), hence the distinctions between current and old attacks must be considered.

The purpose of this study was to use 70 mm colour photography at a large-scale to determine the effect of weevil attack symptoms and photo-interpreter experience on the accuracy of photo-interpretation of leaders attacked by the weevil.

METHODS

Ground Survey

A 17 year old white spruce plantation with a current rate of weevil attack of 23% was selected for study. The criteria for selecting this area were: easily accessible and within 50 km of the city of Prince George; a high current rate of weevil attack; a pure white spruce plantation; the majority of the trees at or greater than a height of 1.0 meters and therefore would be susceptible to the weevil; relatively little brush to complicate aerial photography and interpretation; and the plantation was located in the wet cool sub-boreal spruce subzone (See Pojar *et al.* 1987 for details of this classification system), which is a highly susceptible subzone for weevil attack in the PGFR.

Eight separate 5.64 m radius plots (0.01 ha) were established on the ground and marked for subsequent large-scale aerial photography. The plot center was marked on the ground with a cross of white plastic strips oriented north and south, and the perimeter of the plot was marked with white plastic at the cardinal directions. Within each plot the bearings and distances of all coniferous trees from plot center were measured. The tree species were recorded as were the attack status of each spruce tree. The attack on the top whorl of each tree was recorded as:

i) **current**: an attack which occurred that year (1994). This type of attack was distinguished on the ground based on: the presence of red foliage, the sap exuding from the oviposition sites was still sticky, and the date of attack was traced back from the nearest uninfested lateral branch;

ii) **old**: an attack which had occurred in the previous year or earlier. These attacks had no foliage at all; the sap had hardened and dried; and the attack was traced back from the nearest uninfested lateral branch; and

iii) **healthy**: a leader where no weevil damage was present and the needles exhibited normal colouration.

For current attacks the amount of red foliage was recorded to the nearest five percent. Further, the length of damage down the leader and the radius of the damage was recorded for all old and current attacks. The volume of damage to the leader was then calculated in cubic centimetres using the formula for a conoid (Area of base x height /3).

Photographic Specifications

On October 18, 1994 all eight plots were photographed under a high overcast sky between 1:00 pm and 3:00 pm. At this time of year some attacked leaders have lost their needles allowing the relationship between red foliage and correct identification to be determined. We recognized that this was not the optimum time of year to otherwise photograph the damage.

The Ministry of Forests Camera Boom System (Timberline version) was utilized to collect the large-scale photography for the eight plots (MOF 1981). This camera boom consists of two remote-controlled, synchronized, Hasselblad MK 70 cameras mounted 6.1 m apart on a flight-aligned boom which attaches to the underside of a Bell Jet Ranger helicopter. The cameras were fitted with 100.555 mm focal length lenses. Agfa Avichrome 200 colour film was exposed using skylight filters. All plots were flown at heights of approximately 50 to 65 m giving scales of 1:500 and 1:650, respectively.

Interpretation from the 70 mm diapositives was done using a Ross SFS-3 stereocomparator. Five independent observations were made for all plots at the two photo-scales, therefore requiring ten photo-interpreters. Three of the ten interpreters had both extensive field and photo-interpretation experience. The remaining interpreters had no previous experience and were students from the University of Northern British Columbia.

All photo assessments were conducted independently of each other and were supervised by the authors. The supervisor first determined which tree was to be assessed before the photo-interpreters viewed the damage to minimize any mistakes in viewing the wrong trees.

Analysis

Analysis of variance with a nested factorial structure was conducted to test whether there were significant differences between photo-scales (1:500 to 1:650), among plots and between skill level, and between experienced versus non-experienced photo-interpreters based on the percentage of correct decisions. Three dependent variables were used for the analysis. They were percentage of correct observation for red trees, percentage correct observation for old trees, and percentage of correct observation for healthy trees. The following linear model was used for the analysis of variance:

$$Yijkl = u + Si + Xj(i) + Pk + Eijkl$$

- where u is grand mean, Si is scale effect (i from 1 to 2), Xj(i) is skill effect (j from 1 to 2) and Pk is plot effect (k from 1 to 8) and Eijkl is the residual.

Analysis of variance was conducted to test whether there were significant differences between photo-scales (1:500 to 1:650) and among categories of percentage of red foliage and categories of volume. Thus the dependent variable was the percentage of correct identification. The following linear model was used for the analysis of variance:

$$Yijk = u + Si + Cj + Eijk$$

- where u is grand mean, Si is photo scale effect (i from 1 to 2), Cj is category effect (% red foliage or volume) and Eijk is the residual.

A curvilinear polynomial regression was then conducted to relate percentage of correct decision of current attack with percentage of red foliage. The model used was:

$$Y = a + bx + c\,x^2 + e$$

- where Y is percentage of correct decision, a is a regression constant, b and c are regression coefficients, x is the percentage red foliage and e is the residual.

All statistical analyses were done using SAS software (SAS Institute 1990).

RESULTS

On the eight plots a total of 645 trees were examined which contained 165, 175 and 305 trees that had current attacks, old attacks, and healthy leaders respectively. The mean dimensions of the current and old attacks were: 34.5 cm ± 12.8 (Standard Deviation) for the length of damage and 29.1 cm ± 12.8 for the diameter of the damage.

Table 1 shows a comparison of percent correct choices of current attacks, old attacks and healthy leaders between different skill levels of photo-interpreters. The initial analysis of variance revealed that there was a significant difference between the accuracy rate of 60.6% for non-skilled interpreters and that of 78.8% for skilled ones in identifying current attacks. Also, the variation of skilled interpreters, as represented by the standard deviations, was less than that of non-skilled interpreters. No significant differences were observed between old attacks and healthy leaders, and skill levels.

Table 1

A comparison of percent correct choices of current, old and healthy leaders between different skill levels of photo-interpreters.

	Percent Correct Choice (Mean ± SD)	
Health of Leader	3 Skilled Interpreters	7 Non-skilled Interpreters
Current Attack	78.8(8.8)a*	60.6(12.7)b
Old Attack	37.2(1.6)a	20.0(17.2)a
Healthy	90.2(3.4)a	86.9(16.3)a

Current: currently attacked leader with red foliage
Old: an old attack from previous years with no foliage.
Healthy: a healthy leader with green foliage.
* Means in each row followed by the same letter are not significantly different, ($p \geq 0.01$) according to an analysis of variance.

An analysis of variance showed no differences between the correct selection of current attacks, old attacks, and healthy leaders and the two photo-scales (Table 2). Healthy leaders, old attacks and current attacks were identified with a 85 - 90%, 29 - 37% and 60 - 71% success rate, respectively.

Table 2

A comparison of percent correct choices of current, old and healthy leaders between the two photo-scales.

	Percent Correct Choice (Mean ± SD)	
Health of Leader	Photo-scale 1:500 (n=5)	Photo-scale 1:650 (n=5)
Current Attack	60.2(14.1)a*	70.6(15.9)a
Old Attack	28.6(12.7)a	37.1(19.5)a
Healthy	85.2(18.2)a	90.2(4.1)a

Current: currently attacked leader with red foliage
Old: an old attack from previous years with no foliage.
Healthy: a healthy leader with green foliage.
* Means in each row followed by the same letter are not significantly different, ($p \geq 0.01$) according to an analysis of variance.

The analysis of variance indicated that percent red foliage is significantly correlated with correct selection of current attacks (df = 5, F = 4.26, p = 0.0025), but not with volume. Further, the curvelinear relationship (percentage correct selection = 49.08 + 1.81 (percentage red foliage) - 0.02 (percentage red foliage)^2 was highly significant (R^2 = 0.926, $p < 0.05$) (Fig. 1).

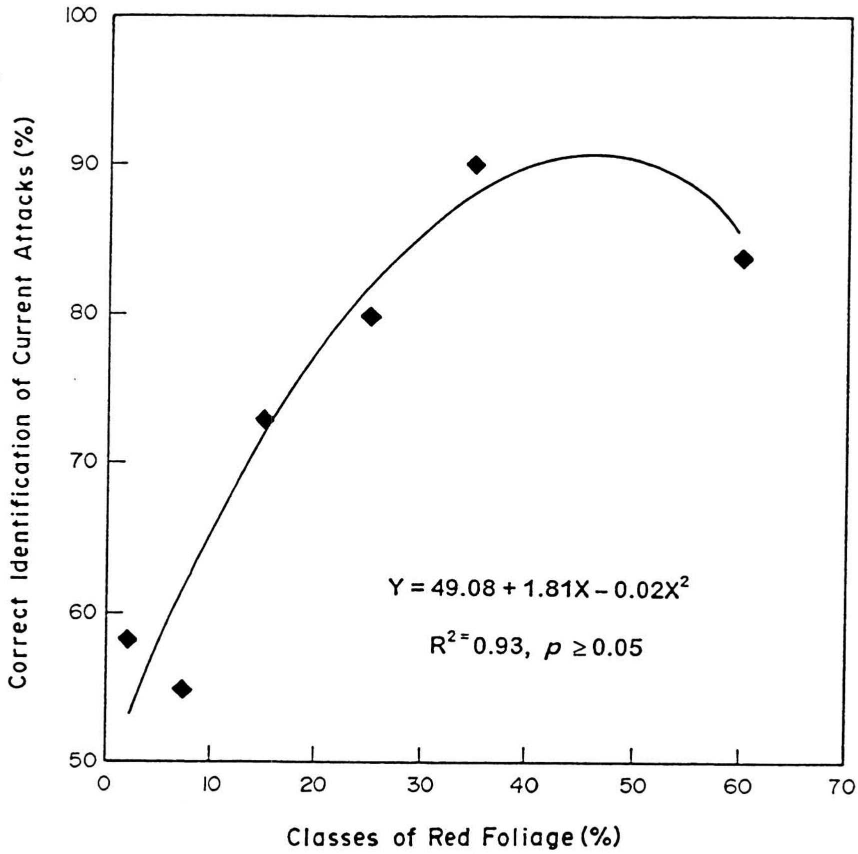

Figure 1. The relationship between the correct identification of current attacks and the percentage of red foliage.

DISCUSSION

The use of skilled photo-interpreters resulted in a 18% increase in accuracy from 61 to 79%. A skilled interpreter is one that has two seasons of both field and photo-interpretation experience. Such an individual is more able to determine differences in foliage colourations due to brush or other factors from those due to the white pine weevil. Separating different colourations is important as the optimum period for photography coincides with the beginning of leaf abscission for deciduous species, and hence coloured foliage on brush and deciduous species is visible.

A relationship between the amount of red needles on the currently attacked leaders and the accuracy of the photo-interpretations exists. When the retention of red needles is at 30 - 40% the accuracy of correct interpretation seems to level off at about 85%. More date is required to study this relationship beyond 60% red foliage. Therefore, colour photography should be timed to coincide with the period of maximum red needle retention for the best accuracy. In the PGFR this period will probably vary between the last two weeks of August and the first two weeks of September depending on the annual weather conditions. After this, rain and wind will wash or blow away the red needles, causing a considerable decrease in the accuracy of detection.

The combinations of using skilled photo-interpreters and taking the photographs at the optimum period may increase the accuracy of selecting current attacks to over 90% when compared to ground detection. If the cost savings of 20% mentioned in Aldrich *et al.* 1957 can be realized then 70 mm photography represents a realistic option for detecting current weevil attacks.

The results also indicate that any damage on a tree's canopy that is at least as big as 35 cm by 29 cm is likely to be observed on aerial colour photographs at a scale of 1:500 to 1:650 as long as the colouration is distinct and located in a prominent position on the canopy. Further, low-level observation of weevil attacks from the air, without photography, at heights of 65 m or less is likely to provide comparable accuracy. Aerial detection of weevil attacks may provide another survey option or an option to be used in conjunction with 70 mm photography.

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