# ESTIMATION OF THE EFFICIENCY OF PEST DETECTION SURVEYS

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## ABSTRACT

Surveys of port environs and forests to detect new introductions of harmful insects or fungi are carried out in New Zealand by Forest Health Advisers. The efficiency of three survey methods was analysed, using simulated damage. The first two methods involved the use of drive-through or walk-through sampling of plantation forests, and the third method focused on sampling port environs.

At the slowest vehicle speed tested (15 km/h), the drive-through forest sampling gave detection efficiencies very similar to walk-through sampling. In the drive-through surveys, 88%, 79%, and 63% of simulated damage was detected at 0 m, 20 m, and 40 m from road edge, with corresponding efficiencies of 97%, 71%, and 47% for the walk-through surveys. Detection levels for the drive-through survey reduced sharply at greater vehicle speeds. One port environs survey detected 49% of all simulated damage, but cumulative detections from repeated surveys gave a lower gain than at first assumed, with two surveys detecting 66% of all symptoms rather than the 75% predicted.

Using the new efficiency data, and a revised method of calculating the probability of detecting a randomly located infection centre, detection probability scores for drive-through surveys and walk-through plots were considerably higher than predicted, but the port environs trial showed that re-inspections gave lower probabilities of detection than predicted.

**Keywords**: pest detection surveys; forest health; surveillance.

## INTRODUCTION

Current forest health surveys have early detection of newly introduced pests or pathogens as their primary aim. Different combinations of aerial survey, drive-through survey, and ground inspection of randomly located points are used, as well as intensive surveys of the environs of ports (both airports and seaports), and a model has previously been developed (Carter 1989) to indicate the most cost-efficient combination for each of the biological regions (Crosby *et al.* 1975) of New Zealand. The aim is to achieve the highest probability of detecting a new introduction for a given cost.

The accuracy of the probability predictions produced by the Carter model depends on various assumptions regarding the efficiencies of each individual sampling method. At the time the Carter model was constructed, limited data were available on the efficiency of aerial and drive-through surveys and no experimental data were available on the detection efficiency of ground inspections of randomly located points or of the survey of port environs. Observations by Forest Health Advisers had indicated that using the current procedures, if damage caused by a pest or pathogen was obvious from the air at the time an aerial survey took place, it would always be detected. It has been estimated that only 13% of the potentially harmful exotic organisms would cause damage that would be visible from the air before the organism had spread so widely as to be considered ineradicable (Carter 1989). A lower efficiency than assumed would not lead to a gross error in the calculation of the total detection probability as the maximum contribution from aerial surveys cannot exceed 13%. No further tests to establish the efficiency of aerial surveys have therefore been undertaken.

This paper describes the efficiency of detection by Forest Health Advisers based on trials using simulated damage in drive-through, walk-through, and port environs surveys. The Carter model has been revised, using the results of these trials, to obtain methods of calculating the probability of detecting a randomly located target infection.

## METHODS

### Field Trial Procedures

Three surveys were conducted to assess efficiency of detection. The first was a drive-through survey, carried out in May 1995 in southern Kaingaroa Forest, in which observers travelled along forest roads by vehicle. A total of 27 separate stands were used in this survey. The second was a walk-through survey, undertaken in the same forest in September 1995, in which observers walked along narrow forest roads in eight separate stands. In both surveys, surveyors looked for simulated damage on both sides of the road. The third survey was a port environs survey carried out in Auckland during May 1995, in which observers walked through parks situated near a major port. In all three surveys similar means of simulating damage were used—paint or tags applied to stems, branches, or foliage, or coloured stakes. Five observers, not necessarily the same individuals, participated in each survey, and the following treatment factors were included.

*Drive-through survey*

(1) Stand age—in all stands selected crop trees had been pruned, and some stands contained additional unpruned follower trees. Stands were classified into two age-classes:
- young stands, average age 10 years, containing a mixture of pruned (averaging 230 stems/ha) and unpruned trees, with total stocking averaging 650 stems/ha
- mid-rotation stands, average age 16 years, mostly containing only pruned stems (averaging 240 stems/ha), although 24% of these targets were located in stands containing additional unpruned trees with total stocking in these stands averaging 530 stems/ha

(2) Simulated damage:
- 1.2 m stakes painted with red fluorescent paint
- red enamel paint sprayed on 1.2 m of stems or foliage of three tree groups

(3) Distance from road:
- road edge

- 20 m from road edge
- 40 m from road edge

(4) Driving speed—each observer drove along the assigned route three times at:
- 15 km/h
- 30 km/h
- 45 km/h

Surveyors did not know the location of the simulated damage prior to the trial being carried out, and a recorder sat in the back of the vehicle to navigate and to record the damage detected. There were a total of 592 individual targets divided evenly among damage types, distances from road, and stand age-classes.

*Walk-through survey*

(1) Stand silviculture—all stands were of a similar age (average 11 years) and stocking (650 stems/ha). They were classified according to their silvicultural history into two classes:
- unpruned stands containing only unpruned trees
- pruned stands containing a mixture of pruned crop trees (240 stems/ha) and unpruned follower trees

(2) Simulated damage:
- 1.2 m stakes painted with red fluorescent paint
- red enamel paint sprayed on 1.2 m of stems or foliage of three tree groups

(3) Distance from road:
- road edge
- 20 m from road edge
- 40 m from road edge

The sample points were mapped before the trial, and distance along the roads was marked at 20-m intervals so that the surveyors could record the location and type of symptom detected as they walked along the road. Survey times were recorded for each road walked. There were a total of 624 individual targets divided equally between damage types and distances from road, with 466 targets located in pruned stands and 158 in unpruned stands.

*Port environs survey*

(1) Sites—three parks close to the Port of Auckland were selected:
- Dove-Myer Robinson Park
- The Domain
- Albert Park

(2) Simulated damage:
- red enamel paint sprayed on foliage of selected trees
- greenish-yellow tape (3 × 30 cm) tied to branches
- orange-red tags (2.5 × 9 cm) placed under the bark of dead and dying trees or stumps (with at least 0.5 cm in view), to imitate breeding colonies of newly introduced insects.

The visibility of sample points ranged from quite obvious to cryptic. After all parks had been inspected by all surveyors, each surveyor repeated the exercise. This provided information on (a) efficiency of one or two inspections by the same surveyor, and (b) efficiency of one to five inspections by different surveyors. The total number of potential observations was: 3 parks × 3 damage types × 5 observers × 20 replicates × 2 times = 1800.

## Statistical Analysis

Detection percentages from all three surveys were analysed using logistic regression models. The associated analyses of deviance were used to test the statistical significance of the experimental factors (McCullagh & Nelder 1989). For the drive-through survey, an analysis of deviance containing three variance strata was used. The error terms for each stratum were defined by the following combinations of factors: stand, target type, distance; stand, target type, distance, observer; and stand, target type, distance, observer, speed. The analysis of deviance for the walk-through survey was similar, except for the absence of vehicle speed. For the port environs survey, a multi-factor analysis of site, target type, and observer was used.

All the above analyses were of detection percentage as identified by single observers. It was also of interest to analyse any improvement in detection resulting from using two or more observers. Given that five observers participated in each trial, there were 10 ways of combining them into pairs. To estimate the two-observer detection rate, the cumulative detection rate for each pair was obtained, and these were then averaged across all 10 possible pairs. Similar calculations were used for estimating detection rates for three, four, and five observers for each of the three surveys. From these values, nonlinear regression models were developed for relating detection percentage to the number of observers.

# RESULTS

## Drive-through Survey

Analyses of deviance for all three surveys are attached in the Appendix. The most important factors influencing target detection in the drive-through survey were distance from road (68% of all simulated damage was detected at road edge, 52% was detected 20 m from the road, and 35% at 40 m into the stand) and driving speed—77% of all simulated damage was detected at 15 km/h, 46% at 30 km/h, and only 32% at 45 km/h (Table 1). There was little interaction between speed and distance. Other experimental factors were less important, although statistically significant. Detection was slightly better overall in the older and lower-stocked stands than the younger stands, but there was also a significant interaction between age/stocking and distance from road, with better detection close to the road but worse detection further from the road in the younger, higher-stocked stands (Fig. 1). Stakes, which were intended to imitate damage more easily seen (such as a recently killed tree), were detected more readily than painted foliage or stems, particularly close to the road. There was also some difference between observers, with average detection rates ranging between 46% and 55%.

## Walk-through Survey

In the walk-through survey, the most influential factor was distance (Table 2): 97% of the roadside symptoms were detected, decreasing to 71% at 20 m into the stand, and 47% at 40 m

TABLE 1–Percentage of targets detected in drive-through survey. Levels of each treatment factor followed by the same letter do not differ significantly (p=0.05).

| Treatment | | Detection (%) |
|---|---|---|
| Stand | Young (10 yr) | 48 b |
| | Mid-rotation (16 yr) | 55 a |
| Symptom | Stakes | 56 a |
| | Paint on trees | 47 b |
| Distance | Road edge | 68 a |
| | 20 m | 52 b |
| | 40 m | 35 c |
| Observer | A | 55 a |
| | B | 54 a |
| | C | 51 b |
| | D | 50 bc |
| | E | 46 c |
| Speed | 15 km/h | 77 a |
| | 30 km/h | 46 b |
| | 45 km/h | 32 c |
| **Average** | | 51 |

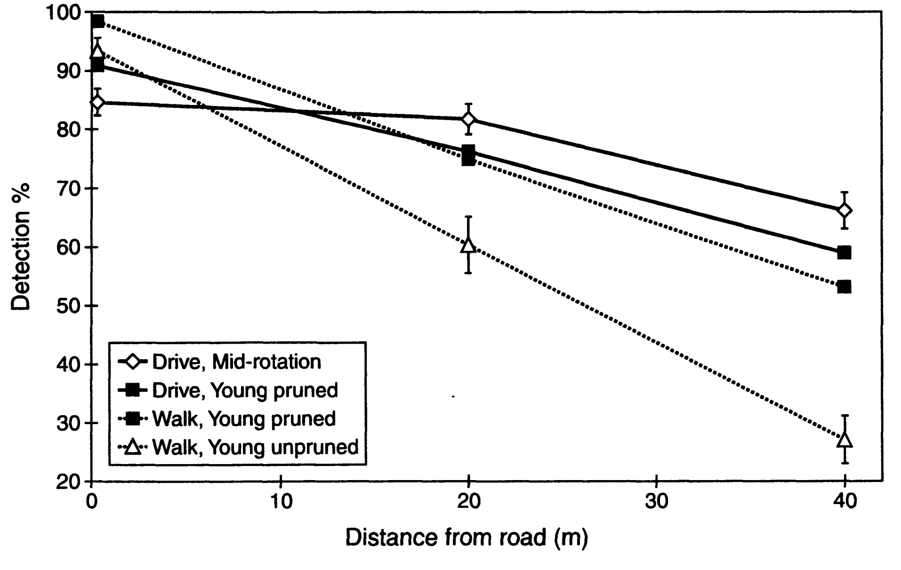


FIG. 1–Mean detection rates at 15 km/h from the drive-through survey and the walk-through survey *v*. distance from road. Error bars show standard errors for selected means.

into the stand. Detection rates were significantly higher in the pruned stands (75%) than the unpruned stands (60%). There was no significant interaction between stand type and distance. All the surveyors gave similar results, apart from one who was substantially better than the others (p=0.0001). However, he took significantly longer to walk the transects than

TABLE 2–Percentage of targets detected in walk-through survey. Levels of each treatment factor followed by the same letter do not differ significantly (p=0.05).

| Treatment | | Detection (%) |
|---|---|---|
| Stand | Unpruned | 60 b |
| | Pruned with followers | 75 a |
| Symptom | Stakes | 74 a |
| | Paint on trees | 69 b |
| Distance | Road edge | 97 a |
| | 20 m | 71 b |
| | 40 m | 47 c |
| Observer | A | 80 a |
| | B | 71 b |
| | C | 69 b |
| | D | 69 b |
| | E | 69 b |
| **Average** | | 72 |

the other surveyors, at 37 minutes per plot compared with 24 minutes for the others. As in the drive-through survey, stakes were more easily identified than paint.

## Comparison Between Drive-through and Walk-through Surveys

The young pruned stands in the drive-through surveys were directly comparable to the pruned stands in the walk-through survey in terms of age, stocking, and silviculture. Detection rates for the 15 km/h drive-through survey were very similar to those of the walk-through survey in these stands (Fig. 1).

## Port Environs Survey

Results of the port environs survey are presented in Table 3. The three parks surveyed were different in both character and area surveyed. Albert Park and Dove-Myer Robinson

TABLE 3–Percentage of targets detected in port-environs survey. Levels of each treatment factor followed by the same letter do not differ significantly (p=0.05).

| Treatment | | Single inspection | Double inspection |
|---|---|---|---|
| Site | Dove-Myer Robinson Park | 61 a | 77 a |
| | The Domain | 37 b | 51 b |
| | Albert Park | 47 c | 67 c |
| Symptom | Paint | 70 a | 85 a |
| | Tag | 36 b | 57 b |
| | Tape | 38 b | 53 b |
| Observer | A | 56 a | 67 a |
| | B | 50 ab | 69 a |
| | C | 46 ab | 69 a |
| | D | 46 ab | 64 ab |
| | E | 43 b | 56 b |
| **Average** | | 48 | 65 |

Park were roughly similar in area (about 7 ha) but Albert Park had more large trees crowded together whereas Dove-Myer Robinson Park was more open. The portion of the Domain included in this trial was about 15.5 ha in area, and it was well stocked with trees of all ages and many species. As the amount of time allowed for the inspection of all parks was the same (2 h/park), the trees in the Domain inevitably did not receive the same degree of scrutiny as did the trees in the other two parks. These differences between the three parks are reflected in the detection rates: Dove-Myer Robinson Park had the highest detection rate (77% after two inspections), followed by Albert Park (67%) and the Domain (50%).

There were differences between the detection rates of the three types of simulated damage and paint was the easiest to see with 85% detection after two inspections; the tags and the tape were rather more difficult to find, 57% and 53% respectively being detected after two inspections (Table 3). There was little difference in detection ability between the surveyors.

## Effect of Using More Than One Observer

Using more than one observer increased the probability of detection considerably in all three surveys (Table 4). A model for determining the effect of numbers of observers on detection level was developed as follows. Firstly, it was noted that if targets have an equal probability of detection, $p$, by a single observer, the expected percentage detection using $n$ observers acting independently is:

$$\%\text{detection} = 100(1-(1-p)^n)$$

This model was modified by including $n$ as a fractional power, to account for the fact that targets are not equally detectable in practice, i.e.,

$$\%\text{detection} = 100(1-(1-p)^{n^k})$$

This equation was found to fit the data well (Table 4, Fig. 2), with $k$ between 0.5 and 0.6 for the drive-through and walk-through surveys, and nearly 0.7 for the port environs survey (Table 5).

For the port environs survey, it was possible to compare the effects of a single observer performing a double inspection with a pair of observers each carrying out single inspections.

TABLE 4–The influence of observer numbers on detection rates (%).

| Number of observers | Drive-through | Walk-through | Port environs |
|---|---|---|---|
| 1 | 77 | 53 | 49 |
| 2 | 89 | 66 | 66 |
| 3 | 94 | 73 | 76 |
| 4 | 96 | 78 | 82 |
| 5 | 98 | 82 | 87 |

TABLE 5–Coefficients of regression equations predicting percentage detection as a function of number of observers.

| Survey | p | k | $R^2$ |
|---|---|---|---|
| Drive-through | 0.773 | 0.579 | 99.4 |
| Walk-through | 0.529 | 0.510 | 99.3 |
| Port environs | 0.487 | 0.685 | 99.7 |

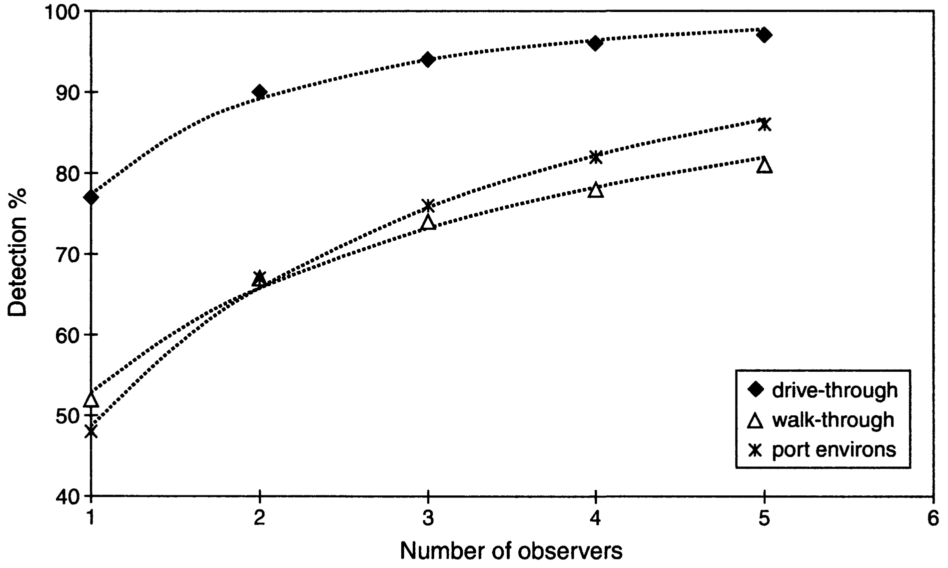


FIG. 2–Mean detection percentages and nonlinear regression curves plotted against number of observers from all three surveys.

The average detection rates for single and double surveys were 48% and 65% respectively (Table 3). Rather unexpectedly, the above model gives a calculated detection rate for a pair of observers of 65%, the same as the average rate for a double survey by a single observer.

## Probability of Detection from Drive-through Surveys

Carter (1989) assumed that efficiency of detection at the road edge was 100%, and declined to 30% for symptoms up to 10 m from the road edge. He assumed the roads formed a square grid, and that a 20-ha circular infection area was located randomly with respect to the roads. Based on these assumptions, he found that the probability of detecting the infection at a roading density of 15 m/ha was 0.378.

This method has been modified using the results of the drive-through survey, by assuming that the probability of detection is a linear function of the distance of the edge of the infection from the road, i.e.,

$$P = a - bD_{edge}, \qquad D_{edge} \leq a/b$$

$$P = 0, \qquad D_{edge} > a/b$$

where $P$ is the probability of detection, and $D_{edge}$ is the distance to the edge of infection from the road. Note that this is a somewhat conservative assumption, as it considers only the distance between the observer and the edge of the infection. In practice, an observer might detect symptoms within the area of infection even if he or she missed the edge of the infection. Two regression equations were derived from the data presented in Fig. 1. For the younger, higher-stocked stands, $a = 0.912$ and $b = 0.0078$, and for the mid-rotation, lower-stocked stands, $a = 0.860$ and $b = 0.0042$.

Assuming the infection area is circular of radius R metres, the distance between the observer and the centre of detection is $D = D_{edge} + R$ metres, and the probability of detection is,

$$P = a, \qquad D \leq R$$
$$P = a - bD, \qquad R < D \leq R + a/b$$
$$P = 0, \qquad D > R + a/b$$

If the roads form a square grid with a distance of $L$ metres between roads, the probability of detection of an infection with centre anywhere within a given grid square is shown in Fig. 3. The integral (or volume) of this function over the square, divided by the area of the square, is therefore the probability of detecting a randomly located infection within the square. Using simple geometry, this is found to be,

$$P_{DT} = \frac{a\left\{L^2 - (L-2R)^2 + 2(L-2R)\frac{a}{b} - \frac{4a^2}{3b^2}\right\}}{L^2}$$

Probabilities of detection using the method described by Carter (1989) and the revised method for the two stand types are given in Table 6.

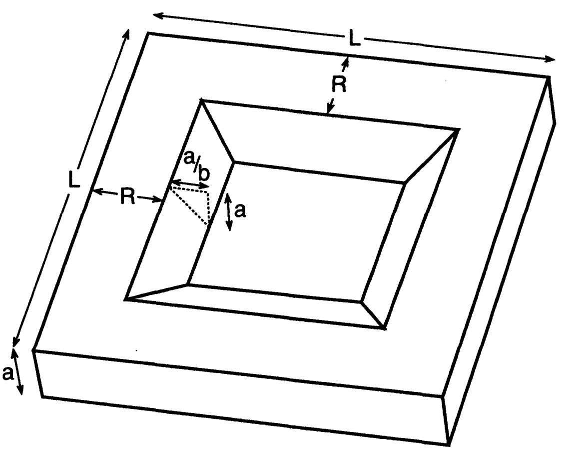


FIG. 3—Geometry for calculation of probability of detecting an infection randomly located within a road grid square, during a drive-through survey.

TABLE 6—Predicted probability of detection using drive-through sampling models. Standard errors of predictions given in brackets were obtained by repeatedly sampling the regression coefficients, using their estimated covariance matrix.

| Roading density (m/ha) | Probability of detection | | |
|---|---|---|---|
| | Carter (1989) | Revised method, young stands | Revised method, mid-rotation stands |
| 10 | 0.255 | 0.478 (0.009) | 0.499 (0.019) |
| 15 | 0.383 | 0.650 (0.012) | 0.665 (0.018) |
| 20 | 0.511 | 0.777 (0.014) | 0.775 (0.038) |
| 25 | 0.638 | 0.860 (0.016) | 0.832 (0.046) |

## Probability of Detection from Walk-through Surveys

Carter (1989) assumed that if a transect line bisects an infection centre the surveyor would recognise the symptoms of a new introduction. He also assumed a detection swath of 10 m, i.e., that surveyors would identify symptoms up to 5 m into the stand each side of their transect line and would not detect anything outside this zone. Two regression equations were derived from the data presented in Fig.1. For the unpruned stands, $a = 0.932$ and $b = 0.0165$, and for the pruned stands, $a = 0.984$ and $b = 0.0114$.

Assuming a circular infection zone of radius $R$ metres is situated somewhere in a forest of $A$ ha, the probability of detection using a single randomly located transect of length $L$ metres is shown in Fig. 4. The probability of detecting an infection with a single transect is therefore the integral (or volume) of this function divided by the area of the forest in square metres. Using simple geometry, this is found to be,

$$P = \frac{a\left[L\left[2R+\frac{a}{b}\right]+\pi\left[R^2+\frac{a}{b}R+\frac{a^2}{3b^2}\right]\right]}{10\,000\,A}$$

As shown by Carter (1989), the probability of detection using $n$ transects is:

$$P_{WT} = 1-(1-P)^n$$

Probabilities of detection using this method are compared with the earlier method in Table 7.

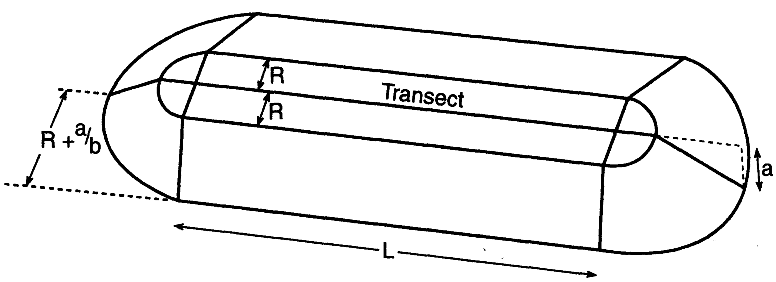


FIG. 4–Geometry for calculation of probability of detecting an infection using a randomly located transect, during a walk-through survey.

TABLE 7–Predicted probability of detection using walk-through sampling models. Standard errors of predictions given in brackets were obtained by repeatedly sampling the regression coefficients, using their estimated covariance matrix.

| Sampling intensity (plots/1000 ha) | Probability of detection | | |
|---|---|---|---|
| | Carter (1989) | Revised method, unpruned stands | Revised method, pruned stands |
| 5 | 0.209 | 0.223 (0.005) | 0.251 (0.003) |
| 10 | 0.375 | 0.397 (0.007) | 0.439 (0.004) |
| 20 | 0.609 | 0.636 (0.009) | 0.686 (0.005) |
| 25 | 0.691 | 0.717 (0.008) | 0.765 (0.004) |
| 50 | 0.905 | 0.920 (0.005) | 0.945 (0.002) |

## Probability of Detection from Port Environs Surveys

Carter (1989) assumed that 50% of all damage would be detected at the first inspection with subsequent re-inspections detecting 50% of the remaining undetected damage. From the trial data, the mean detection rate for a single inspection was 48% (Table 3), very close to the rate assumed by Carter (1989). However, the repeat inspection increased the detection rate only to 65%, rather less than predicted. This rate was the same as that achieved using single inspections by two observers. This suggests, as shown above, that a better model for predicting the probability of detection is:

$$P_{PE} = (1-(1-p)^{n^{0.685}})$$

where $p$ is the probability of detection in a single inspection of similar duration to those used in the trial, and $n$ is the number of inspections times the number of observers.

The model described above gives the efficiency of inspections of a single inspection site—for instance, a park or reserve. The probability of detecting a randomly located infection in an area within a 5-km radius of a port depends on the coverage of the area. The nominal size of the infection centre for port environs surveys is taken to be 50 ha. This is larger than the 20 ha taken for forest surveys because of the nature of urban forests where potential hosts may be well scattered and sparse. Using the method of Carter (1989) for calculating the probability of a 500 × 20-m transect plot bisecting an infection centre, 300 randomly distributed transect plots throughout the 5-km-radius survey zone give a 96.6% probability of a plot bisecting a 50-ha infection centre, decreasing to 81.5% if 150 plots are used. A major study of port environs surveys, undertaken by the Ministry of Agriculture and Forestry, will be completed in 1999; inspection site selection and sampling intensity within port environs are components of this study.

# DISCUSSION

The simulation of a drive-through survey clearly showed the importance of the speed at which the survey is conducted. The detection rate of both types of simulated damage at all distances tested (0, 20, and 40 m from the road) in both open and dense stands was much higher at a driving speed of 15 km/h than at 30 km/h or 45 km/h. This is not an unexpected finding but the magnitude of the difference needed to be established. Another obvious finding was that it is easier to detect symptoms of damage 20 or 40 m from the road in an open thinned stand than in a stand with followers. There was a difference in the detection rate of the readily visible painted stakes and the more cryptic patches of paint on stems or foliage within a stand. This finding suggests that drive-through surveys are useful for detecting signs of obvious damage—for example, foliage discoloration caused by a newly-introduced needle blight such as *Lophodermium seditiosum* (Minter, Staley and Millar) or copious resin bleeding caused by the Sequoia pitch moth *Synanthedon sequoiae* (Hy. Edwards).

The original model assumed that all roadside damage and 30% of damage at a distance of 10 m would be detected. In the trial, the maximum detection rate for roadside damage was 88% but to balance this the detection rate away from the road was much higher than assumed (63% at 40 m) at a driving speed of 15 km/h. The probability of detecting a randomly located target at a roading density of 20 m/ha has increased considerably from 0.51 to 0.77.

The model assumed that walk-through surveys would detect 100% of symptoms up to 5 m each side of the transect line. The trial showed that 97% of roadside symptoms were detected, and the detection rate (as was found in the drive-through trial) away from the transect line was much higher than assumed (71% at 20 m and 47% at 40 m). Surveyor 2 was substantially better at detecting symptoms than the other four surveyors, but took almost twice as long to walk the tracks as the other surveyors, indicating there is an interaction between efficiency and time taken to conduct the survey. As for the drive-through surveys, the probability of detecting a target infection in pruned stands has been increased from 0.61 to 0.69 at a 2% sampling intensity.

The trials testing the efficiencies of drive-through and walk-through surveys showed that drive-through surveys gave a higher probability of detecting symptoms than walk-through surveys (efficiencies were 88%, 79%, and 63% at 0 m, 20 m, and 40 m from road edge for the drive-through, compared with 97%, 71%, and 47% for the walk-through surveys). The two trials were carried out in the same region of Kaingaroa Forest, but not all stands were surveyed using both methods—totally unpruned stands were not tested during the drive-through survey and mid-rotation stands containing only pruned trees were not tested in the walk-through survey. A better comparison of the efficiencies of the two methods is obtained by comparing the results from young stands containing pruned trees with unpruned followers. In these stands, for the type of damage simulated in these trials, it appears that drive-through surveys driven at 15 km/h are as efficient as walk-through surveys. However, there is no substitute for the close-up examination of foliage and potential insect-breeding sites. Frass or pitch tubes are produced from an initial attack by *Dendroctonus* spp. bark beetles; later, foliage discoloration produces more noticeable symptoms but sometimes discoloration doesn't occur until the brood have matured and flown away (Furniss & Carolin 1977). It is highly unlikely that frass or pitch tubes would be detected during drive-through surveys.

Other factors, such as the effect of the target area not being circular, or the roading pattern not being in a square grid pattern, need to be examined. It is also probable that a straight line relationship between distance from the road and the efficiency of detecting symptoms is not appropriate; it may be that at distances over 40 m from the road or transect, efficiency decreases at a faster rate. It is recommended that the conservative estimate using data from the younger pruned stands with followers should be used to derive probabilities of detection used in the Carter model.

The port environs survey showed the importance of allowing sufficient time to carry out observations. The detection rate in the Domain which had twice the area of the other two parks was clearly lower, very probably because less time could be spent there looking at individual trees. Further work needs to be carried out on operational aspects of port environs surveys, such as developing standard times for inspecting specific parks and reserves. As expected, the detection rate for painted foliage which was relatively easy to spot was higher than that for tape or tags. However, it was expected that the tags, which were hidden under bark, would be more difficult to find than the tape which was out in the open; this expectation was proved to be wrong, which probably reflects the training of the surveyors during the course of which emphasis is placed on the importance of looking at sites where insect attack would be expected to occur before symptoms of the damage had become visible. The most significant finding of the port environs trial was that re-inspections had a lower than expected probability of detection.

These trials involved surveyors looking for types of simulated damage that did not necessarily look like symptoms caused by a pest or disease. One might be tempted to conclude that the detection of simulated damage was a function of good eyesight rather than the ability to recognise unusual symptoms. It is acknowledged that fully-trained experienced personnel should carry out pest detection surveys because recognition of a new pest or disease is a skilled job. However, one must first see a symptom before one can evaluate if it is caused by a newly established pest or disease. These trials effectively determined what proportion of symptoms one could see over specific distances using three survey methods. A trial carried out at three urban sites in Auckland during late-1998 tested efficiency of detecting "biotic" type symptoms such as wilted foliage, frass runnels, and small leaf spots. The mean detection rate for a single inspection was 51%, supporting the findings of the port environs trial described in this paper.

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# APPENDIX

## ANALYSES OF DEVIANCE

| Source | d.f. | Deviance | Mean deviance | Deviance ratio |
|---|---|---|---|---|
| **1. Drive-through survey** | | | | |
| Age | 1 | 33.56 | 33.56 | 9.41 |
| Stand | 25 | 314.97 | 12.60 | 3.53 |
| Distance | 2 | 659.81 | 329.90 | 92.51 |
| Target | 1 | 77.90 | 77.90 | 21.85 |
| Age × Distance | 2 | 104.21 | 52.10 | 14.61 |
| Age × Target | 1 | 38.42 | 38.42 | 10.78 |
| Target × Distance | 2 | 72.81 | 36.40 | 10.21 |
| Stand.Distance.Target Residual | 117 | 417.22 | 3.57 | |
| Observer | 4 | 31.84 | 7.96 | 8.52 |
| Age × Observer | 4 | 5.9227 | 1.48 | 1.59 |
| Distance × Observer | 8 | 38.6773 | 4.83 | 5.18 |
| Target × Observer | 4 | 7.6041 | 1.90 | 2.04 |
| Observer.Stand.Distance.Target Residual | 604 | 564.16 | 0.93 | |
| Speed | 2 | 1685.02 | 842.51 | 964.33 |
| Age × Speed | 2 | 50.03 | 25.02 | 28.63 |
| Distance × Speed | 4 | 16.72 | 4.18 | 4.79 |
| Target × Speed | 2 | 10.72 | 5.36 | 6.13 |
| Observer × Speed | 8 | 22.62 | 2.83 | 3.24 |
| Residual | 1486 | 1298.28 | 0.87 | |
| Total | 2279 | 5450.51 | | |
| **2. Walk-through survey** | | | | |
| Silviculture | 1 | 58.05 | 58.05 | 17.12 |
| Stand | 7 | 141.71 | 20.24 | 5.97 |
| Distance | 2 | 818.03 | 409.01 | 120.59 |
| Target | 1 | 15.35 | 15.35 | 4.53 |
| Silviculture × Distance | 2 | 4.46 | 2.23 | 0.66 |
| Silviculture × Target | 1 | 0.84 | 0.84 | 0.25 |
| Target × Distance | 2 | 12.57 | 6.28 | 1.85 |
| Stand.Distance.Target Residual | 35 | 118.71 | 3.39 | |
| Observer | 4 | 49.37 | 12.34 | 20.00 |
| Stand × Observer | 4 | 5.17 | 1.29 | 2.09 |
| Distance × Observer | 8 | 7.13 | 0.89 | 1.44 |
| Target × Observer | 4 | 6.44 | 1.61 | 2.61 |
| Residual | 228 | 140.68 | 0.62 | |
| Total | 299 | 1378.51 | | |
| **3. Port environs survey** | | | | |
| Site | 2 | 34.99 | 17.50 | 13.90 |
| Target | 2 | 90.65 | 45.33 | 36.02 |
| Observer | 4 | 8.43 | 2.11 | 1.67 |
| Site × Observer | 4 | 12.74 | 3.19 | 2.53 |
| Site × Target | 8 | 9.58 | 1.20 | 0.95 |
| Target × Observer | 8 | 12.5419 | 1.57 | 1.25 |
| Residual | 24 | 30.2002 | 1.26 | |
| Total | 44 | 186.59 | | |