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Nearest Neighbour Method for Quantifying Wildlife Damage to Trees in Woodland

PRACTICE NOTE

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1. INTRODUCTION

Forest managers should be aware of the scale and extent of animal damage in the forest as this is essential to decision making on wildlife management and crop protection. An annual assessment of vulnerable compartments will provide information on the degree of damage, damage trends and whether damage control measures should be implemented.

To obtain the exact extent of damage it would be necessary to examine every tree. Since this is not practical, except in very small blocks, assessment is usually of a representative sample. Whenever quantitative assessments need to be made, efficient, reliable and repeatable techniques must be used. Different assessors should be able to employ the same method on a given area and obtain estimates which are not significantly different from each other. Subjective sample selection or assessment is vulnerable to bias, unreliable and not consistently repeatable.

To estimate wildlife damage to a forest, an assessment method is needed that is accurate and consistent but also simple and quick. **The Nearest Neighbour Method** involves the systematic selection of a number of points throughout the area to be assessed, then at each point examining for damage a pre-determined number of trees closest to the point. Although originally devised to assess mammal damage the Nearest Neighbour Method can be used to assess any spatial aspect of trees.

What is meant by *damage* must be clearly defined in the light of the forest manager's requirements before carrying out a forest damage assessment. For example:

- When considering browsing the survey is usually limited to an assessment of the proportion of trees with current year's *leader* damaged. Side shoot browsing, although it may at times appear serious, does not necessarily have the economic significance of leader browsing.
- When assessing bark-stripping the normal procedure is to record the presence or absence of damage on each tree to determine the proportion of trees with damage. The severity of damage can be determined by measuring the area of bark removed from each damaged tree.

The Nearest Neighbour Method is suitable for any tree damage that requires assessment but the form of damage to be assessed and how it is to be recorded must be clearly specified. More than one type of damage or tree species (for example, browsing and fraying by roe deer on a mixture), can be surveyed in the same assessment.

The Nearest Neighbour Method is most appropriate when a single damage assessment on a particular compartment is needed. In a forest with compartments of different tree species and ages, the assessment method should be applied separately to each compartment. The method also may be used to monitor changing damage levels, but permanently marked monitoring plots are generally more efficient for monitoring trends as long as plot marking does not affect the behaviour of the damaging mammal.

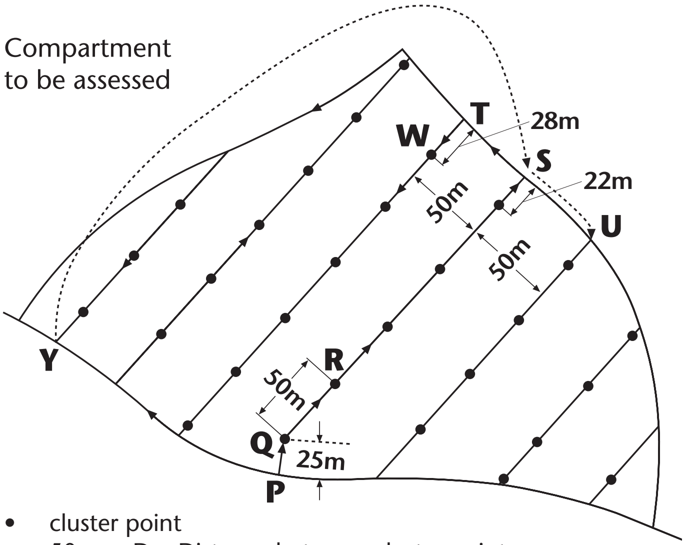
2. THE NEAREST NEIGHBOUR METHOD

The method involves the selection of a number of points (cluster points) evenly spread throughout the area and about each cluster point a predetermined number of trees (a cluster) are assessed for damage. Trees in a cluster are chosen objectively and independently of the damage which has occurred.

2.1 Selection of cluster points

Systematic spacing of cluster points throughout the area to be assessed ensures that the assessment is not biased by varying intensity of damage through the stand. The cluster points are chosen to lie upon a set of approximately parallel lines, distance D apart, the points being spaced D apart along a given line. The value of D is calculated as shown in Section 2.6 and may be measured by pacing.

For illustration, Figure 1 shows a compartment which is to be assessed. Assume that D = 50 m. The initial task is to obtain the first cluster point. To do this, choose a 'convenient' starting point P, on the boundary of the compartment and then measure a distance D/2, in this example 25 m.



• cluster point
50 m = D = Distance between cluster points

Figure 1

Illustration of how to locate cluster points.

The point reached, Q, is the first cluster point. The second point, R, is then obtained by choosing a convenient direction (across the compartment) and pacing from Q a distance of 50 m in this direction. If the rows of trees are clearly visible then the direction QS should be chosen to be along a row. If the rows are not apparent, then P at a compartment corner and QS parallel with the compartment edge is a good choice. A compass will be needed in order to maintain this bearing during the assessment.

Further cluster points are obtained by continuing to pace in the same direction until the boundary of the area is reached (S in Figure 1). Mark 'S' and make a note of the distance left before the next cluster point is reached. The assessor then moves to either point T or U, as is convenient, these points being on the compartment boundary and on lines parallel to QS, at a distance of D (50 m). Assuming T is chosen, the assessor should continue to walk the remaining distance to the next cluster point W. Further points are then obtained in the same manner; at each boundary the assessor moves away from QS, until that part of the compartment on the T-side of QS has been covered. If the end point reached is Y, the assessor returns to S and proceeds to U, continuing the assessment in exactly the same manner.

In practice, the point P can often be chosen so that it becomes unnecessary to return to S, particularly when the rows of trees run parallel to an edge of the area.

2.2 Selection of the trees in a cluster

The trees in a cluster should be selected in an objective manner which is independent of the damage present. A simple method is to choose the predetermined number of trees (Section 2.6) lying closest to the cluster point. However, in the case of an area which is being assessed using tree rows, it may be more convenient to select trees occurring in the nearest row to the cluster point.

2.3 Accuracy required and sample size

The *accuracy* of an assessment is related to the number of trees sampled. The assessor must decide on the degree of accuracy required in order to calculate the number of trees that must be assessed. *Accuracy required* will be judged according to expectation of damage level and the risks associated with obtaining an inaccurate estimate of damage. If the number of trees damaged is within either 0-20% or 80-100% then the management decisions will not usually be affected by where in these ranges the estimate falls. However, if the number of trees damaged is likely to lie somewhere in the range of 21-79% then higher accuracy is needed.

Accuracy required depends on the age and value of the crop as well as the size of the compartment being surveyed. A large compartment of a high value crop approaching felling age (e.g. a mature Norway spruce stand of 50 ha which has been bark-stripped by red deer) may justify an accuracy of ± 5%;. On the other hand a 20 ha recently planted compartment suffering from browsing damage need only be surveyed to an accuracy of ± 10 or 15%.

The Nearest Neighbour Method has an accuracy based on 95% confidence limits. To achieve an accuracy of ± x with this level of confidence, the number of trees that must be assessed (N) is given by Formula 1.

$$N = \left(\frac{100}{x}\right)^2$$

where N = total number of trees to be assessed; and
x = accuracy desired (±) @ 95% confidence level.

Formula 1

An accuracy of ±10% would require a sample size of at least:

$$N = \left(\frac{100}{10}\right)^2 = 100 \text{ trees}$$

An accuracy of ±5% would require a sample size of at least:

$$N = \left(\frac{100}{5}\right)^2 = 400 \text{ trees}$$

Unfortunately, although a ±5% accuracy may be the target, achievement of this is not certain, particularly if damage is not randomly distributed through the stand. This is often the case; for example, roe deer browsing on re-stocked areas may be concentrated on the edge nearest to more mature crops or, with red deer bark-stripping damage, restricted to particular tree species and sizes. It is therefore necessary to calculate the actual accuracy achieved using the data from the assessment (see Section 2.9).

2.4 Cluster size

The cluster size c is fixed at any value from 4 to 7 with the choice of size being influenced by plantation conditions. A cluster size of 5 trees is normally recommended, i.e. $c = 5$.

2.5 Number of clusters

Formula 2 is used to calculate the number of clusters required.

$$n = \frac{N}{c}$$

where n = the required number of clusters;
N = the total number of trees to be assessed (from Formula 1); and c = the chosen fixed cluster size.

Formula 2

However, in order to get an adequate representation of the damage at least *20 clusters* must be assessed. Thus, to achieve an expected accuracy of ± 10% which necessitates a sample size of at least 100 trees (from Formula 1), no more than 5 trees per cluster are assessed. If the actual number of clusters assessed at the prescribed spacing is less than 20, the assessment should be completed by assessing the necessary number of additional clusters selected at random throughout the area.

2.6 Distance between clusters

The distance between each cluster, D (Figure 1) is calculated using Formula 3.

$$D = \sqrt{\frac{A \times 10\,000}{n}}$$

where D = distance between clusters, in metres;
A = area of the stand, in hectares; and n = number of clusters to be assessed (from Formula 2).

Formula 3

As an example, if the area of a compartment to be assessed is 10 ha with required accuracy of ± 8% using 5 trees per cluster, the calculation would be as follows:

Number of trees to be assessed (using Formula 1):

$$N = \left(\frac{100}{8}\right)^2 = 156 \text{ trees}$$

Number of clusters to be assessed (using Formula 2):

$$n = \frac{156}{5} = 31 \text{ clusters (rounded)}$$

Distance between cluster points, D (using Formula 3):

$$D = \sqrt{\frac{10 \times 10\,000}{n}} \text{ m} = 57 \text{ metres}$$

The assessment is now carried out as described in Sections 2.1 and 2.2. Every tree in each cluster is visited, the presence or absence of damage observed and recorded, and if assessing bark-stripping the area of bark removed may also be measured and recorded.

2.7 Possible biases

It is possible for bias to occur in the assessment. Firstly, during the pacing of the distance between cluster points it may be tempting to lengthen or shorten the paces so as to finish with a cluster of trees which is either in an area of damage or in an area of no damage. This should never be done, even if the assessor feels that by doing so, the assessment would be more typical of the area. Secondly, since it is not necessary for the proximity of the nearest neighbour tree to the cluster point to be physically measured, the assessor may subjectively choose either damaged or undamaged specimens in a cluster regardless of their location. Care must be taken that the choice of cluster trees is independent of the damage on the trees.

2.8 Percentage of damage

The percentage of damage is determined from the recorded assessment figures using Formula 4.

$$\text{Percentage damage} = \frac{d}{a} \times 100$$

where d = total number of damaged trees counted; and a = total number of trees assessed.

Formula 4

2.9 Accuracy

It is not possible to be certain that the accuracy achieved is the same as the target level of accuracy (Section 2.3), as actual accuracy obtained is determined by the variability in damage between clusters. Low variability between clusters will give a high degree of accuracy, whilst high variability reduces accuracy. Accuracy achieved is determined as follows:

(i) Square the number of trees damaged in each cluster and add them to obtain X.

That is, if d_i is the number of damaged trees in the i^{th} cluster and there are n clusters actually assessed, then using Formula 5:

$$X = \sum_{i=l}^{n'} (d_i)^2$$

Formula 5

Example - if the number of damaged trees in 5 different clusters each of 5 trees is 3, 2, 4, 1 and 3 then:

$$X = (3)^2 + (2)^2 + (4)^2 + (1)^2 + (3)^2 = 39$$

(ii) The actual accuracy, that is the estimated error at 95% confidence limits, can now be calculated using Formula 6:

$$\text{Actual error} = \frac{\pm 200 \sqrt{X - \left(\frac{d^2}{n'}\right)}}{a} \%$$

where d = total number of damaged trees counted; a = total number of trees assessed; and n' = number of clusters assessed.

Formula 6

2.10 Distribution of damage

When the assessments and calculations are complete, the data should be plotted back onto the map of the area surveyed. If there is particularly intense damage in one region of the compartment then this can be regarded as a separate region in its own right. The data collected for this region can be used in formulae 4, 5 and 6 to estimate damage and to assess the accuracy of the estimate. If the accuracy of this estimate is insufficient then further clusters should be selected at random, or a reassessment made, within this limited area.

3. MIXED SPECIES STANDS

In mixed crops clusters should consist of an equal number of trees of each species. For example, in a lodgepole pine/Sitka spruce mixture with 5 trees per cluster, 5 lodgepole pine and 5 Sitka spruce should be assessed at each cluster point.

4. STOCKING DENSITY

Data on percentage damage are of limited value without knowledge of the stocking density. If a newly planted crop has 20% deaths, this is obviously not as serious in a fully stocked crop as in one which has less than 1000 trees per hectare. The fewer trees there are, the less damage can be accepted. An estimate of the stocking density can be achieved by including some further measurements during the course of the nearest neighbour damage assessment. Three simple methods are suggested here (Sections 4.1 to 4.3) one of which should be suitable for the crop being assessed. They are all based on the use of fixed area plots. The number of plots required can be determined as detailed in Section 2.3 but generally 20 plots should be completed for any area assessed. For an irregularly distributed crop having an actual stocking of 1000 trees/ha, twenty 0.01 ha plots ensure that the estimated 95% confidence interval is 900-1100 trees/ha. Further details and methods relating to stocking density estimation may be found in Forestry Commission Booklet 49 *Timber Measurement - A Field Guide* (Edwards, 1992).

If a nearest neighbour damage assessment was aiming to achieve an accuracy of ± 5%, requiring a 400 tree sample, or 80 clusters at 5 trees per cluster, then a stocking density plot would have to be completed at every 4th cluster. In all situations the stocking density is given by dividing the total number of trees counted by the total area of the plots on which they are counted.

Knowledge of the General Yield Class (obtained through plot height and age) may be useful to determine loss of vigour of crop when making damage control management decisions based on the damage assessment results. The top height of a stand is obtained by measuring the height of the tree of largest diameter at breast height (DBH) in each 0.01 ha plot and calculating the average of all the measured top height trees. Table 1 gives the minimum number of top height trees required to give an estimate of the stand top height.

Table 1 Number of top height trees

Area of Stand (ha)	Uniform Crop	Variable Crop
0.5 - 2	6	8
2 - 10	8	12
over 10	10	16

Assessing stocking density in:

4.1 Crops under 1.5 m in height where no visible rows are present

Use a circle of 5.6 m radius for 0.01 ha plots. The simplest method is to anchor a 5.6 m length of string at the plot centre and using its full extension to define the plot boundary within which all trees are counted.

4.2 Crops over 1.5 m in height where no visible rows are present

For crops over 1.5 m in height it is more difficult to use a circular plot so 10 x 10 m plots are recommended.

4.3 Crops with rows

Measure the width of 4 rows of trees from the centre line of the first row to the centre line of the 4th row. Divide this distance into 100 to give the length in metres that has to be measured along a row to provide the other side of a 0.01 ha plot. Run a tape measure out along either of the central rows of trees for this distance and count all the trees in that row and in one row on either side.

SUMMARY OF METHOD

1. Specify the form of damage to be assessed and how it is to be recorded.
2. Decide on the accuracy required (Section 2.3).
3. Determine the total number of trees to be sampled from **Formula 1** (Section 2.3).
4. Decide on how many trees should be assessed in each cluster (Section 2.4).
5. Calculate the number of clusters required from **Formula 2**, (Section 2.5), with no less than 20 clusters and no more than 100.
6. Using **Formula 3**, calculate the distance between clusters (*D*) required to cover the area evenly (Section 2.6).
7. Choose an arbitrary starting point $^{D}/_{2}$ into the area and walk into the area to be assessed in a straight line in a convenient direction, usually parallel to the edge of the area or along rows. Stop at each cluster point, at the prescribed spacing (distance D calculated from Formula 3) and assess and record the damage on each cluster tree.
8. Measure and record the stocking density and stand top height (Section 4) if required.
9. Calculate the percentage damage using **Formula 4** (Section 2.8) and the accuracy of the assessment using **Formula 6** (Section 2.9).
10. Calculate stocking density and stand top height.
11. Mark the damage in each plot on the map to show the pattern of damage distribution.

EQUIPMENT REQUIRED

- A map of the area to be assessed, preferably 1:10000 scale or larger.
- Compass.

If stocking required:

- 30 m tape to measure 10 m x 10 m 0.01 ha plots.
- Posts to mark corners of 10 m x 10 m plots.
- DBH tape and hipsometer - if stand top height required.
- Record forms, clipboard and pencils.

REFERENCES

The Nearest Neighbour method was first published in Melville, R. C., Tee, L. A. and Rennolls, K. (1983). *Assessment of Wildlife Damage in Forests* Forestry Commission Leaflet 82. HMSO, London.

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