Sustainable Farming Fund Project L05/036

To develop a robust statistical method for assessing bird damage to crops, particularly fruit.

V.P. Saxton

Final report to the Sustainable Farming Fund
22 June 2006

The contribution of NZ Winegrowers, Lincoln University, and participating vineyards is gratefully acknowledged.

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Abstract
In order to estimate the economic impact of damage inflicted by birds the damage inflicted must be measured. This project addressed the need for a technique for a robust, repeatable and accurate damage assessment method, which to date has not been available, or which has been labour-intensive or inconvenient due to other pressures on labour at the time an assessment is needed. The methodology was developed using grapes as a model crop, but it could be used for other assessments such as crop forecasting, and by adjusting the sampling method other crops could equally well use it. The methodology is available in the form of a protocol which consists of a robust sampling design, aids to training of personnel in visual estimation of damage, calibration of estimates with calculation of a correction factor for the subjective element of the assessment, and final calculations of actual damage. Templates in excel accompany the protocol.

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1. Introduction

Decisions about wildlife are often dominated by economic considerations, an approach that has remained unchallenged to date (Gowdy, 2000). Bird pests constitute a significant limitation to productivity (Bruggers *et al*., 1998), which is not limited to simple yield loss, but in the case of wine grapes carries through to loss of quality in wine (Loinger *et al*., 1977). Many crops are damaged by birds, with little knowledge available of actual economic loss (Porter *et al*., 1994; Boyce *et al*., 1999; Tracey and Saunders, 2003). Population explosions of depredating species were already noted by Boudreau (1972) and are still noted (Somers and Morris, 2002). Present bird management programmes are implemented mostly without accurate knowledge of damage levels, but with knowledge only of the cost of mitigating the damage, and of the cost of not mitigating it. One major reason for this inability to determine economic loss is the inconsistent nature of the damage, both spatially and temporally, due to the sporadic feeding behaviour and mobility of the birds. A second difficulty is the nature of the damage which cannot be weighed, estimated or calculated directly in the field (De Haven and Hothem, 1979, 1981). A third difficulty is that for fruit crops the greatest damage occurs close to harvest when workers are very busy with harvesting and have no time for extra work such as sampling for statistical purposes. And finally, fruit may show disease damage that may have or may not have been caused or exacerbated by bird damage. However, if the objective is to minimise damage, damage assessment is an essential first step (Engeman, 2000)

Cost-effectiveness is the fundamental economic test of any damage control or damage mitigation strategy (Engeman, 2000). There is a need for an assessment method at several levels of cost-effectiveness: firstly to establish a break-even point or economic threshold to determine whether damage is sufficient to warrant any action. The benefits of access to precise and accurate damage data are equivalent to the costs of not having access to such data. For instance, Boyce *et al*. (1999) found that 18% of their grape grower respondents in Marlborough spent more on bird control than they estimated they saved in damage. In some cases the economic threshold is simply the value of the crop, especially in cases where no bird control would result in total loss. This clearly is not a sustainable scenario.

Damage assessment will help evaluate the efficacy of control measures, and assist in cost-effective timing of their use. However waiting until damage levels reach the economic threshold, a strategy reported by Tracey and Saunders (2003) may be too late to change bird behaviour. DeHaven and Hothem (1981) noted that bird damage incidence that occurred early in the season could be used to predict potential loss to birds later, and could also pinpoint the spatial locations of loss. Regular and consistent damage assessments that are quickly and accurately effected will provide longitudinal data that may help management decisions by predicting location and possibly levels of bird pressure. Eventually such data could be used in a model such as is used by the sunflower growers of the Dakotas, which is based on how much seed one bird needs metabolically, multiplied by the numbers of birds – all statistics that were available from previous research (Peer *et al.*, 2003).

Any sampling and measurement will incur effort and costs (Engeman, 2000). The need for a rapid and robust assessment method that requires minimal input of labour and furnishes accurate results that are reliable is longstanding (Tracey and Saunders, 2003). This document describes a method that has been developed from other methods described in the literature, and that has been tested and refined to meet the practical requirements of growers while furnishing data that is useful for scientific analysis.

Seven vineyards were assessed in the process of trialling the method. Development of the method comprised the following steps:

1. Literature search
2. Development of preliminary method
3. Trialling of the method
4. Refining the method
5. Analysis of data collected during trialling
6. Evaluation of method
7. Developing supporting protocol

2 Sampling methods

2.1 Literature Search

There is a minimal amount of written work on the topic of bird damage assessment. One reason for this may be that damage assessment methods, which still depend on someone going out into the field and counting (laborious and time-consuming) or estimating (subjective and notorious for underestimation), have not been much modified over forty years, and there are clear limits to these methods in terms of reliability, cost and effort involved. The possibility of using precision viticulture to evaluate damage levels is an obvious next step, but if photography is used then access to vines through netting poses a problem. Damage to sunflower crops in the Dakotas that is calculated using a model incorporating Red-Winged Blackbirds metabolism, defining the amount of sunflower seeds one bird would need, and multiplying this by a population calculated from a square kilometre population at the time of damage (Peer *et al.*, .2003). This assessment is used to claim compensation, so the accuracy required may be less important than the ease with which the figure is arrived at.

Tracey and Saunders in their detailed 2003 report (192 pages) used eleven workers to take 26,500 samples. If 200 samples takes 1 person 4 hours (DeHaven and Hothem, 1979) this equates to 520 hours which at a cost of $15 per worker/hour is over $8000. This is clearly not a sum that will be readily expended annually on damage assessment.

Tracey and Saunders (2003) included in their review 19 studies that had estimated bird damage to grapes, of which 3 were questionnaires to growers, 2 involved bird counts, 3 estimated percent damage and 9 used a ranking scale. All were visual estimates. One used a ranking scale, counting and weighing. Of these only 4 evaluated the accuracy of the method, one was their own percent estimate, and 3 were ranking studies that focussed on the statistical method of arc-sine transformations to normalise the data for analysis.

The following studies contributed greatly to development of the sampling method reported here.
DeHaven and Hothem (1979, 1981) sampled using a hoop and rope apparatus to eliminate human bias in cluster selection, and a ranking scale to visually estimate damage.

Martin and Crabb (1979) used a plastic pipe with a T joint to which was attached a rope to eliminate bias in selection of clusters. They trained their personnel previously with simulated damage to picked clusters until the estimates were consistently acceptably accurate, and visually estimated using ranked classes.

Somers and Morris (2002) pre-selected vines at 8m intervals and marked them for future years, resulting in a sampling design of 3 tiers of 3 clusters on 32 vines in each of 3 sections of the block. Estimates were visual and on a ranked scale; after the ranking random integers were generated and assigned to the ranked estimates to allow parametric analysis of the data. Bird counts were also conducted.

Tracey and Sunders (2003) first stratified the vineyard block, used a pre-marked frame to select bunches and estimated percent damage visually with previous training for personnel and a post estimate calibration.

2.2 Development of Design of preliminary method

2.2.1. Sampling

A robust sampling strategy is a major constituent of ensuring that variability is controlled for. Errors at this stage are magnified through the remainder of the quantifying process (Engeman, 2000). Sources of error in sampling are: spatial variability (sampling from an area of higher or lower than average damage, Martin and Crabb, 1979), human error in selecting bunches (unconscious bias towards bunches that are seen to be damaged, or that are higher, lower, or more or less exposed on the vine than average), human error in the subjective judgement of damage (often less than actual damage, Ibid., Tracey and Saunders, 2003) and taking a sample number that is too low to furnish robust data. Workers do not have time to take large samples, but the minimum size sample that will give a robust result must be obtained. Various methods of sampling that have been reported in the literature were studied, together with statistical literature, and a manageable optimum developed. This was tested in the field and revised to some extent before being adopted.

2.2.2 Sampling design

This stage is critical and involves two factors – the size of the sample and sampling design. The greater the variability of the population, the more samples should be taken to achieve statistical robustness. There is a trade-off between the costs and effort involved in sampling and the need for a large sample if the population is variable (Engeman, 2000). Bird damage is variable, and this problem is overcome in this case by sampling design – most bird damage occurs at the edges of plots, close to bush and trees that the birds use for cover (Somers and Morris, 2002). Edges of rows, or rows of the grapes bordering on roads, or any other environment that is not more grapes, sustain more damage than interior rows. If damage at the edges is minimal, substantial sampling the interior may be unnecessary (Tracey and Saunders, 2003). There is a rider to this: if starlings are the damaging species, where flocks descend to ravage an area that is often in the interior, and often until the food supply is exhausted (Dall *et al.*, 1997) sampling would have to be throughout the interior as well.

The sampling design adopted was found by Tracey and Sunders (2003) to be statistically adequate. It involves stratification of the vineyard plot into 5 strata. The two edge rows on each plot are strata 1 and 3, the two end vines on the other two edges are strata 2 and 4, stratum 5 is the interior of the plot. This stratification is adjusted for in the final damage figure by a ratio of edge vines to interior vines.

In crops other than grapes where damage patterns differ a variation in the stratification design may need to be applied.

2.2.3 Sample number

The minimum sample number suggested by Tracey and Saunders (2003) depends on the accuracy required of the assessment. Figure 1 shows a graph developed by those authors with sample numbers needed for 3%, 5% 7% and 10% Standard error (SE)

The sample number also depends on the damage level – in the range from 30 to 70% more samples are needed to be accurate within the SE required, because in this range visual estimates are generally less accurate (Tracey and Saunders, 2003). In this trial calibration was adopted to correct estimates to make them more accurate, and damage levels were not expected to exceed 20%, so a sample number of 100 per plot – 20 on each edge and 20 interior – were taken. On Tracey and Saunders' graph 100 samples would be accurate within 5% for a damage level of just below 20% (Figure 1).

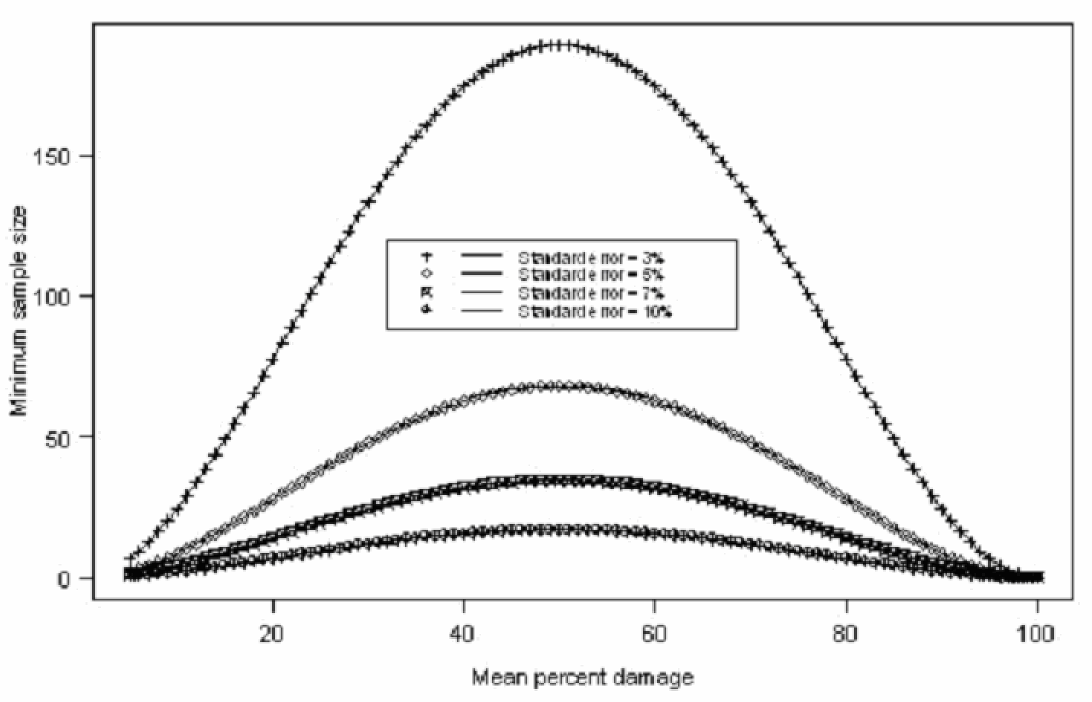

Figure 1. Predicted minimum sample sizes for estimating percent bird damage within strata with a 3,5,7 and 10% standard error (from Tracey and Saunders, 2003, reproduced with permission).

2.2.4 Timing of data collection

Bird damage increases as time progresses, though this may be spatially variable. DeHaven and Hothem (1981) found that birds tended to 'test' areas at the onset of damage, but that later on they continued to damage already damaged bunches rather than attack new areas. If a block is only to be sampled once it is clear that the closer to harvest the more accurate the damage assessment. If sampling is done at harvest workers will be extremely busy with removing nets, and actual harvest duties. At this stage large resources will not be available for damage assessment.

There may be reasons for sampling earlier, such as to determine which areas are being damaged more, or what type of damage is being inflicted where.

The time taken to collect samples is a cost that needs careful consideration. Large sample numbers can only be justified where accuracy is very important. For most purposes a 5% standard error is acceptable. In this trial 100 samples were taken and this took approximately 2 hours per visit. This equates with DeHaven and Hothem (1979, 1981) who estimated 4 hours for 200 samples. Here six vineyards and seven blocks were assessed in 2 days. Some time on the first day was spent organising visits.

The presence of nets impacts on speed and accuracy of estimates. Nets are generally removed as late as possible before harvest to avoid unnecessary damage. In two vineyards nets were off or being taken off in preparation for harvest the following day. In the others nets were still on and harvest was expected the following week. All vineyards sampled had been netted with side-netting, which was not always easy to get inside to locate bunches. Other types of netting may impact on the time taken to sample.

2.2.5 Vine and Bunch selection

Within the strata it is necessary to eliminate bias. Tracey and Saunders recommend choosing a vine at random within a stratum and sampling 5 vines sequentially. If looking for damage, a bias would be possible toward sampling near environmental factors that are known to correlate positively or negatively with damage (such as trees or buildings). If the vineyard is unknown and damage not expected it should be possible to largely avoid this bias. This trial selected to begin sampling in the middle of each stratum, i.e. half way along the edges, and in the centre. In strata 1 and 3 (edge rows) a vine was selected at random and samples taken from that and the following 9 vines from the edge row and the second to edge row by walking between the rows (20 samples per stratum). In strata 2 and 4 (end of rows) a row was selected at random and the 2 end vines sampled, followed by the end two vines from the next 9 rows (20 samples per stratum). For the fifth stratum (interior vines) a vine from the interior was selected at random and that vine plus the following 9 vines and those in the next row were sampled by walking between the rows (20 samples, total 100 samples).

The process of selecting a bunch to sample is a point at which individual bias can be most subtly expressed. It is easy to select more exposed bunches, larger bunches, more damaged or less damaged bunches, or to over-compensate for such bias. To avoid any individual human bias DeHaven and Hothem (1979) used a hoop and later (1981) used a rope or pipe with predetermined spacings to select bunches. Martin and Crabb (1979) used a plastic pipe with a plastic T joint with a rope with 3 knots tied at equal spacing. Tracey and Saunders (2003) used a length of conduit with pre-selected random numbers generated and applied on the frame. The trial reported here used a simpler device of a metre rule with a knotted string slipped over (see Appendix 2). The rule was marked at 10, 30, 50, 70 and 90cm, giving 5 horizontal locations for the string to drop from. The (bright purple bale twine) string was knotted at 10cm intervals with a loop at the top that was slipped over the metre rule. A latin square pattern of letters from A to E that ensured that no letter appeared more than any other was used to give a horizontal location along the rule, from which point the string dropped. A second set of numbers for the string gave a vertical location. The rule was held to the left of each vine trunk at the level of the first foliage wire. The bunch at the selected knot on the string was sampled. If there was no bunch at that spot the nearest cluster on the trunk side of that knot was sampled.

2.3 Training

Visual estimation of damage is difficult and tends to result in underestimation (Martin and Crabb, 1979; Tracey and Saunders, 2003). For this trial minimal training was undertaken prior, but calibration was done. Acquisition of a digital camera enabled photographs of damaged bunches to be taken for purposes of training in the future.

2.3.1 Practice in visual estimation

Visual estimation is highly subjective. Photographs of damaged bunches showing both sides of a bunch could be used for practice. The trainee first estimates damage visually, then counts the damaged berries on the photographs of each side to see how accurate the estimate was. In about two to three hours (Martin and Crabb, 1979) estimates should become more accurate. It is important to have both sides of the bunch since peck damage mostly occurs only on the outside. Missing grapes however are often taken from both sides of the bunch.

2.3.2 Calibration

Calibration of a small number of bunches will correct for error in visual estimation. DeHaven and Hothem (1981) suggest 3-10% of total sample be removed and berries counted. In this trial every tenth bunch estimated was removed for subsequent counting of damaged berries, some of which were photographed, and 50% of which were counted for calibration. On the counted bunches removed berries were counted first, then damaged berries and then intact berries. The numbers were totalled to give total number of berries and a percentage damage calculated. The damage estimates were then compared to the actual and a percentage correction calculated. The formula used was

$$\text{Percentage damage} = \frac{\text{Number lost and damaged berries}}{\text{Total number of berries}} * 100.$$

(For data see Appendix 2)

This was then compared to the estimate to give a correction factor

$$\%\ \text{Correction factor} = \frac{\text{Estimated percent damage}}{\text{Actual percent damage}}$$

The average correction factor was 6%, meaning that damage was underestimated by 6%. This correction factor was factored into the estimated damage to give a more accurate damage assessment using the following formula

*Accurate damage assessment = Estimated damage *6/100 + estimated damage*

These formulae were all built into the calibration spreadsheet. The calibration spreadsheet also had a graph created to show a trendline if damage level estimates were skewed in any way. (If this line was not horizontal then more samples needed to be taken in the area proving difficult to estimate visually, Tracey and Saunders, 2003).

3. Damage calculation

3.1 Calculation from assessment data

When visual estimates of damage are made in the strata, they must be converted to a stratum % damage and then to an overall % damage. The formula for this is

Edge damage = S1 total/N + S 2 total/N + S 3 total /N + S 4 total/N
(Average edge damage = total /4)

Interior damage = S5/N

Where S=stratum
N = sample number taken (usually 20)

3.2 Weighting factor

Since edge vines normally sustain more damage than the interior, the greater number of edge vines sampled compared to interior vines is adjusted for using the following formula

$$\% \text{ Edge vines} = \frac{[(\text{total \#vines in block/\# rows}) + (\text{\#rows} *4) -8]}{\text{total \# vines in block}} * 100$$

$$\% \text{ Interior vines} = \frac{[\text{Total \# vines} - \text{edge vines}] *100}{\text{Total \# vines}}$$

The average damage assessment for S1 to 4 are multiplied by % edge vines
The damage assessment for S5 is multiplied by % interior vines

Total damage of the block is the sum of the two damage assessments.

The total damage assessment percentage is then corrected from the calibration using the formula

Accurate damage assessment = Calibration factor/100 % damage + % damage*

In the trial the calibration factor was 6, meaning that damage estimates were underestimated by 6% of the damage estimate.

All these formulae were built into the spreadsheet for damage assessment calculation. The calibration factor had to be copied from the calibration spreadsheet (using the dropdown menu edit - paste special – values).

If desired, a ratio of plucked (lost) berries (signifying blackbird or starling damage) could be compared to peck damage (silvereyes). In this trial 80% of damage was from silvereyes and 20% from blackbirds or thrushes. There appeared to be little or no starling damage in the vineyards surveyed on the Wairau Plain and in the Waihopai Valley.

4. Converting figures to economic values

4.1 Grapes lost

In the case of crop taken (berries plucked) percentage damage incidence for the whole vineyard can be converted to an economic value by taking the final price for the crop and extrapolating the extra revenue that would have accrued had those berries not been missing. That the lost berries would have been the ripest cannot be compensated for directly.

4.2 Grapes damaged

In the case of damaged berries that are still on the vine and are harvested, the case is more complex:

- Where some of the crop been rejected by the winery or not submitted due to bird damage, the loss can be calculated directly, and may include loss from undamaged crop in the same batch.
- In the case where price paid was below the maximum and the reason given was damage, this reduction is an economic value.
- In the case where full price has been paid but the winery has grumbled, a figure should be placed on the future cost of that lack of satisfaction (loss of contract, reduction of crop requested in future years, reduction in price offered in further contracts)

If the grapes are grown by the winery so that no money is specified, loss can only be calculated by assuming a notional contract price that would have been paid, or else a drop in bottle price due to the level of damage sustained.

It becomes much more difficult to assess cost of damage when damaged grapes result in a wine that is of lower quality and therefore commands a lower price, as there may be confounding factors such as basic quality of the grapes, winemaker ability, or market demand. That such a loss exists cannot be disputed. Loinger *et al.*, (1977) found that 20% rot reduced a superior wine to a medium wine.

5 Evaluation of method

5.1 Sampling

Sampling was laborious and at times somewhat confusing. A sampling sheet was developed, and has been modified (Appendix 3) to reduce confusion. A calculation box is included in the sheet that should be completed at the time for each stratum.

5.1.1 Sampling design

The sampling design consisting of the 5 strata was robust and offered no difficulties. The only reservation was that spatial variability of damage that was not due to edge effect was not really factored into the design. In this trial such variability was not apparent in any vineyards. If such variability is known then the recommendation is to separate the areas, sample them both and calculate damage for both areas. A weighting according to vine numbers in each area would enable an overall damage statistic to be calculated.

5.1.2 Sample number

The number of 100 samples for each block was robust at the damage level measured, and was relatively quick to complete. Extra samples would be needed if any stratum exceeded 20% damage. Initial calculations must be done at time of sampling to establish whether this is necessary. The sampling sheet includes a box for this.

5.1.3 Timing of data collection

Harvesting decisions are often taken at short notice. If sampling is to be done then close contact with the harvest decision must be maintained. The time taken to do the sampling (2 days for 7 vineyards) was a cost-effective return for the data collected.

5.1.4 Vine and bunch selection

The metre rule and string worked very well. The simplicity of this design and ease with which it can be assembled recommend it. The latin square number selection was copied from a statistics text and is easily assembled. The design can be copied to the reverse of the data collection sheet (Appendix 3). Sampling should use the latin square sequentially.

5.1.5 Training and Practice in visual estimation

It was not possible to train before the trial run as there were no photographs of damage bunches. Photographs have since been assembled and form part of the method (Appendix 2).

5.1.6 Calibration

Calibration was straightforward but was time-consuming. It is an essential contributing factor to the overall accuracy since it addresses error at the basic level before magnification through further calculations. A data sheet has been developed to assist in the calibration itself and an excel spreadsheet has been developed to manage the calculations.

5.1.7 Data collection

Collecting data out in the field can be confusing. It was clear that two people would find the process easier but this involves a greater investment of time and money. DeHaven and Hothem, 1979, cited four hours for one person to collect 200 samples, but three hours for two people to do the same. A data collection sheet has been prepared to step through the process without missing data or getting confused. A further datasheet has been developed to make sure that calibration is successful.

5.1.8 Weighting

To obtain an overall figure for the block the interior damage must be weighted more heavily than the edge strata. In the spreadsheet there are cells for the total number of vines and the total number of rows. This gives the number of vines in the interior stratum compared to in the edge strata. See 3.2 for the formula used. The spreadsheet then does this calculation when the data are entered. The total number of vines and number of rows in a block must be entered before this is done.

5.2 Accuracy

Accuracy depends on the representativeness of the sample. Tracey and Saunders (2003) did the statistical work to find a sample size that would return a result at a 95% confidence level for a certain damage level. The damage levels were all 15% or well below. For the 15% damage level the sample size of 20 was therefore accurate to within 95%. The lower levels of damage can be taken as accurate to between 95% and 98%.

5.3 Robustness

Robustness of data is the essential factor in any statistical analysis. With data that are as variable as bird damage, which can range from 0% to 100%, the sample size should ideally be very large. Because the effort and cost of taking large samples is not an acceptable scenario for the purposes for which this method has been developed, stratification has been integrated to reduce the sample size needed. For repeatability each step of the procedure is pre-designed to eliminate bias in the collection and analysis of the data. For longitudinal studies datasheets could be referred to and samples selected from exactly the same area each year.

6 Results

Seven vineyards were surveyed. The damage that was assessed for each of these appears in Table 1. Edge damage levels ranged from 0.5% for a newly planted Pinot noir block surrounded by other grapes, to 27.18% on the edge of an older Pinot noir block. Interior damage values ranged from 0% to 9.85%, both on Sauvignon blanc blocks. The overall average damage after weighting for the vineyard sizes was 5.20%.

Table 1 - % Bird damage sustained through nets in 2006

Vineyard	Edge	Interior	Overall
1 (S blanc, 25692 vines)	10.60	9.85	9.45
2(P noir, 14500 vines)	6.36	8.16	7.72
3 (S blanc, P noir, 66,000 vines)	0.07	0.48	0.59
4 (S blanc 22715 vines)	22.53	14.62	15.07
5 (S blanc 20263 vines)	26.42	2.43	2.68
6 (various, 84000 vines)	10.59	3.23	3.65
7 (P noir, 6699 vines)	27.18	18.75	23.38

There were large differences in the damage levels between vineyards. Reasons for the differences are not part of this brief, but it could be noted that the interior damage drives the final result especially in the case of large blocks of vines.

Of the clusters that were counted for calibration (32 clusters, 5.2% of total clusters assessed), in total 3% of grapes were plucked, 26% pecked. Of the damage suffered 14% was pluck damage and 87% peck damage. Of the clusters examined for calibration 53% had suffered some pluck damage and 97% had suffered some peck damage. This suggests that low level peck damage occurs throughout the vineyards despite netting. In seasons where weather conditions promote various rots, this type of damage could result in considerable downgrading of grapes.

7 Extension and technology transfer

Black (2000) identifies several strategies for technology transfer. They include

1. Top-down, a strategy where innovators adopt the technology first as leaders,
2. Bottom-up, starts with problems and priorities of farmers, analysis and knowledge sharing
3. Community based workshops
4. One to one (consultants, usually user-pays)
5. Formal education (courses etc.)
6. IT (internet, online courses)

All of these have advantages and disadvantages and reasons and occasions why and when they are less effective (for details see Black, 2000). For this project a mixture of top-down, workshops and IT are proposed. The top-down method is suited to the adoption of technologies that are promoted singly, which this is. The top-down method is suited to users that are better-endowed financially and intellectually (Black, 2000), and takes time to percolate through to other users. Workshops to explain the idea would suit the grape-growing industry which already runs regular workshops in the regions. The disadvantage of community based workshops according to Black (2000) is that they are complex in human interactions and may need empowering of some members to be pro-active. The third option for this method is the IT route, which has already been used for the QuikCARD but which has the disadvantage that many potential users are not at ease with or do not have the online facility or time for this method. This scenario is however changing rapidly.

Planning has already begun to disseminate the damage assessment method, both the sampling and the assessment, for use next season in the Falcons for Grapes project. This season’s assessments were geared to vineyards that already have falcon nestlings, or which are likely sites for falcon nestling barrels in the immediate future. Personnel have already been identified in these vineyards that have responsibility for the nestlings and these people could undertake the damage assessments at times that will furnish results for the project.

The QuikCARD that is available on the NZ Winegrowers website will be updated to reflect a slightly longer but much more accurate assessment method for the winemaking industry nationally. The datasheets will be added to the present stratification sheet. Instructions for the measuring device and contact details for obtaining the excel spreadsheets on CD will also be available online.

Other fruit industries, particularly the kiwifruit industry, and CRIs such as Hortresearch, Landcare, Agresearch and Crop and Food could be contacted and a report sent to them at SFF's discretion.

8 Conclusion

This assessment method provides accurate damage assessment data that can be used for scientific research and for evaluation of bird management methods and devices. It is robust for sample size and for repeatability between personnel. The calibration method contributes data for in-depth analysis of types of damage, which can be used to determine bird pressure, which bird species are involved, and the size of the population compared to other areas or years.

The method has been streamlined to reduce effort and cost to a minimum, simplified to enable novices to undertake the assessments. The cluster selection process will reduce individual bias in cluster increase accuracy of the visual estimations. Prepared data collection sheets and excel spreadsheets support the method.

With minor modifications the method could be used for other crops, and for other purposes such as sampling for crop forecasting, disease monitoring or for ripening. The method will also help anyone to take reliable and accurate assessments that could be used by many crop-growers and for any purposes that require sampling or assessment.

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Appendix 1

Method protocol

1. Obtain a metre rule and coloured string. Mark off from 10cm at 20cm intervals (5 marks) as A, B, C, D and E. Loop the string over the rule and knot. Make further knots at 10 cm down the string. This is the sampling apparatus.

2. Obtain 5 polythene plastic bags for each vineyard block to be sampled, and a waterproof marker pen.

3. Take copies of the sampling datasheet, one for each block to be sampled. On the back of this sheet copy a latin square of numbers for selecting bunches.

4. This is the latin square for the rule:

A	B	C	D	E
B	D	A	E	C
D	E	B	C	A
E	C	D	A	B
C	A	E	B	D
E	D	C	B	A
C	E	A	D	B
A	C	B	E	D
B	A	D	C	E
D	B	E	A	C

And for the string:

1	2	3	4	5
2	4	1	5	3
4	5	2	3	1
5	3	4	1	2
3	1	5	2	4
5	4	3	2	1
3	5	1	4	2
1	3	2	5	4
2	1	4	3	5
4	2	1	5	3

5. Choose a line at random from the letters and a different line at random from the numbers. Work sequentially with these selection numbers.

6. Place the metre rule with the end at the vine trunk, selecting either left or right of the trunk but maintaining the same direction throughout the sampling. Move the string to the letter on the rule dictated by the latin square.

7. When selecting a bunch, if there is no bunch at the selected point move first up or down the string to find a bunch, if one is found note the string knot number. If still no bunch is evident move towards the vine trunk and locate the nearest bunch to the string.

8. Handle the bunch to assess both sides for damage.

9. Note the estimated percentage damage on the scoresheet.

10. Cut off one assessed bunch from each stratum for calibration and place in the plastic bag which is marked with the cell number from the datasheet to identify it. Also mark on the bag the % damage visually assessed for this bunch.

11. When the scoresheet is complete do a quick calculation with a calculator. If damage is 20% or greater in any stratum then more samples should be taken, according to the following table:

% Damage	20	30	40	50	60	70	80	90	95
Total sample size	24	37	46	49	46	37	24	10	4

(From Tracey and Saunders, 2003)

Transcribe data into the spreadsheets provided to obtain results

Spreadsheets:

Calibration sheet

Take the bunches carefully out of the plastic bag and place in a dish so no berries get detached. Enter the estimated damage in the column. Count missing berries (where only the bush remains) and enter into 'missing grapes' column. Take off and count whole berries and enter into 'good grapes' column. Count remaining damaged berries and enter into 'bad grapes' column. Total number of berries should appear in total # berries column.

When data has all been entered the calculation will be done and a factor number calculated. The factor number is the amount by which your visual estimate needs correcting either up or down.

This figure will need to be manually transcribed to the damage calculation spreadsheet in cell B26.

Appendix 2

Photographs

Sample photographs of damaged bunches for training.

Each pair of photographs is the top and underside of a damaged bunch. Counting the damaged berries will give an accurate damage assessment. This can be compared to visual assessments made by training personnel, and staff trained until the assessments are more accurate. More photographs will be available next season for training.

The sampling device is a simple arrangement of a metre rule and bale twine.

Sampling device to eliminate bias in bunch selection

This device consists of a metre rule with bale twine. The rule is marked A,B,C,D,E at the 10cm, 30,50,70 and 90cm mark (5 positions). The string is knotted at 10, 20, 30, 40 and 50cm.

They are used in combination with a Latin square design number generator to ensure no number is generated more than another.

The latin square for the rule:

A	B	C	D	E
B	D	A	E	C
D	E	B	C	A
E	C	D	A	B
C	A	E	B	D
E	D	C	B	A
C	E	A	D	B
A	C	B	E	D
B	A	D	C	E
D	B	E	A	C

And for the string:

1	2	3	4	5
2	4	1	5	3
4	5	2	3	1
5	3	4	1	2
3	1	5	2	4
5	4	3	2	1
3	5	1	4	2
1	3	2	5	4
2	1	4	3	5
4	2	1	5	3

Appendix 3
Damage Assessment Sheet

The Damage Assessment Sheet is a PDF file that can be copied for field work.

Grape damage assessment sheet Vineyard

Block Total vines # rows

Date Name of assessor Cultivar

Edge values (% damage assessed visually)

Row	Vine 1	2	3	4	5	6	7	8	9	10	total
1											
2											

Total ________ /20 = ________

Row	Vine 1	2	3	4	5	6	7	8	9	10	
1											
2											

Total ________ /20 = ________

End values

Row#	vine 1	vine 2
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Total ________ /20= ________

Row#	vine 1	vine 2
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Total ________ /20= ________

Interior values

Row	Vine 1	2	3	4	5	6	7	8	9	10

Total ________ /20 = ________

Appendix 4

Spreadsheets

1.Sample damage assessment sheet

2. Damage assessment template

3. Sample calibration sheets
    - 3.1 calibration calculation to give correction factor
    - 2.2 correction factor assessment

4 Calibration templates
    - 4.1 calculation template
    - 4.2 calculation assessment template

Block			edge row1p	edgerow2p (	row end1 sb	endrows2p (	interior			
area	11.04ha		10	60	0	30	2			
vines	22715		8	40	2	50	40			
rows	566		5	10	5	5	2			
cultivar	s blanc		10	15	60	60	8			
			1	30	10	0	4		stratum damage	
vines per row	40.132509		30	0	12	0	5		edge	17.7
vines at edge	1212.265		10	15	10	60	0			17.75
	2424.53		50	10	15	2	5			14.55
weighting			40	0	10	5	2			19.85
% edge vines	10.673696		5	40	5	30	3			13.8
% interior vines	89.326304		40	40	0	12	15			3.45
			15	25	3	50	10			0.207
			20	5	2	4	5		edge damage	3.657
sample size	0.0044024		10	15	20	60	0		int	13.8
sample size edge	0.0329961		50	2	15	0	50			0.828
			5	2	20	4	40		interior damage	14.628
weighting factor			20	2	60	0	60			
end and edge rows	2.668424		20	2	2	0	20			
interior rows	89.326304		0	2	15	10	5			
			5	40	25	15	0			
			354	355	291	397	276			
			17.7	17.75	14.55	19.85	13.8			
weighting factor			0.472311	0.472311	0.472311	0.472311	12.32703	14.216274		
damage %of whole										
calibration correction	6	revise up						15		
Final damage %								15.069251		

Block			1edge row	2endrows	3edgerow	4endrows	5interior	
area								
vine number								
row number								
cultivar								
vines per row	#DIV/0!							
vines at edge	#DIV/0!							
total edge vines	#DIV/0!							
weighting								
% edge vines	#DIV/0!							
% interior vines	#DIV/0!							
sample size	#DIV/0!							
sample size edge	#DIV/0!							
weighting factor								
end and edge row	#DIV/0!							
interior rows	#DIV/0!							
			0	0	0	0	0	
			0	0	0	0	0	
weighting factor			#DIV/0!				#DIV/0!	#DIV/0!
damage %of whole								
calibration correction		fill in here from calibration sheet						#DIV/0!
Final damage %								#DIV/0!

Date	% estimate	bag ID	missing gra	good grape	bad grapes	total grapes	percentage	adjustment ratio
16-Mar-06	60	a1	0	50	28	78	35.89744	
	70	a2	0	11	40	51	78.43137	
	9	a3	4	64	6	74	13.51351	
	10	a4	2	10	8	20	50	
	60	a5	5	32	17	54	40.74074	
	5	b1	0	100	6	106	5.660377	
	10	b2	6	62	21	89	30.33708	
	30	b3	6	72	14	92	21.73913	
	5	b4	0	78	7	85	8.235294	
	50	b5	8	23	38	69	66.66667	
	40	c1	0	28	30	58	51.72414	
	40	c2	0	110	30	140	21.42857	
	50	c3	8	23	4	35	34.28571	
	10	c4	0	25	23	48	47.91667	
	3	c5	0	75	3	78	3.846154	
	15	d1	2	21	40	63	66.66667	
	60	d2	0	13	20	33	60.60606	
	15	d3	2	45	28	75	40	
	30	d4	7	73	19	99	26.26263	
	60	d5	5	20	16	41	51.21951	
	10	e1	0	58	17	75	22.66667	
	642						777.8444	
av damage per bunch	29.18182						35.35656	6.17474484
correction factor								6.17474484

Date	% estimate	bag #	missing gra	good grape	bad grapes	total grape	percentage	adjustment ratio
						0	#DIV/0!	
						0	#DIV/0!	
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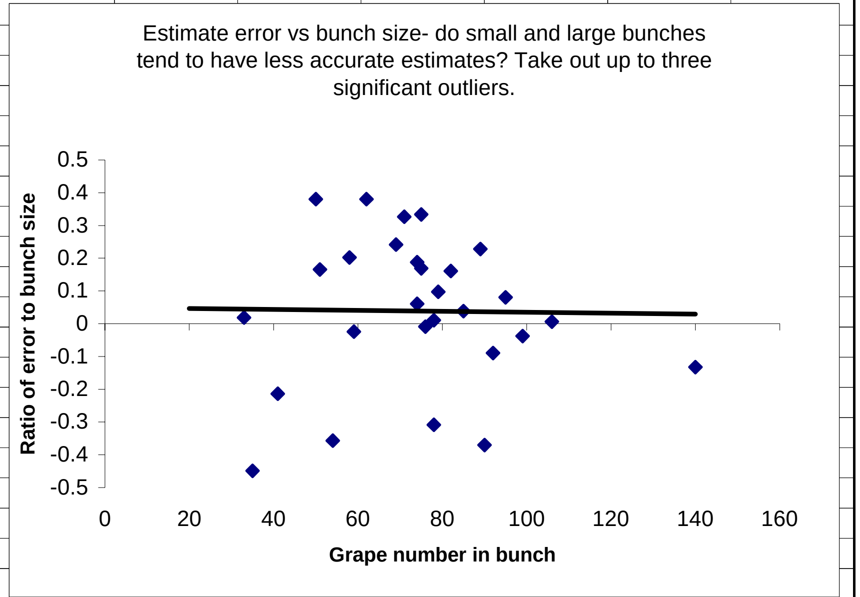
						0	#DIV/0!	
						0	#DIV/0!	
	0						#DIV/0!	
av damage per bunch	0						#DIV/0!	#DIV/0!
correction factor								#DIV/0!

Date	% estimate	total grape	actual % damag	ratio out		total grape	ratio out
	60	78	35.8974359	-0.309007		78	-0.309007
	70	51	78.43137255	0.165321		51	0.165321
	9	74	13.51351351	0.060993		74	0.060993
	10	20	50	2		20	
	60	54	40.74074074	-0.356653		54	-0.356653
	5	106	5.660377358	0.00623		106	0.00623
	10	89	30.33707865	0.228507		89	0.228507
	30	92	21.73913043	-0.089792		92	-0.089792
	5	85	8.235294118	0.038062		85	0.038062
	50	69	66.66666667	0.241546		69	0.241546
	40	58	51.72413793	0.20214		58	0.20214
	40	140	21.42857143	-0.132653		140	-0.132653
	50	35	34.28571429	-0.44898		35	-0.44898
	10	48	47.91666667	0.789931		48	
	3	78	3.846153846	0.010848		78	0.010848
	15	63	66.66666667	0.820106		63	
	60	33	60.60606061	0.018365		33	0.018365
	15	75	40	0.333333		75	0.333333
	30	99	26.26262626	-0.037751		99	-0.037751
	60	41	51.2195122	-0.214158		41	-0.214158
	10	75	22.66666667	0.168889		75	0.168889
	10	79	17.72151899	0.097741		79	0.097741
	10	82	23.17073171	0.160619		82	0.160619
	20	62	43.5483871	0.379813		62	0.379813
	2	76	1.315789474	-0.009003		76	-0.009003
	70	90	36.66666667	-0.37037		90	-0.37037
	5	71	28.16901408	0.326324		71	0.326324
	5	74	18.91891892	0.188093		74	0.188093
	5	50	24	0.38		50	0.38
	15	59	13.55932203	-0.024418		59	-0.024418
	5	95	12.63157895	0.080332		95	0.080332



% estima	total gra	actual %	ratio out		total	ratio out
			#DIV/0!	These values should be pasted over	120	-0.2
			#DIV/0!	They are only in to create the graph	20	0.2
			#DIV/0!		0	#DIV/0!
			#DIV/0!		0	#DIV/0!
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			#DIV/0!		0	#DIV/0!
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