

A technique to estimate bird damage in wine grapes

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ABSTRACT

Bird damage is a world-wide problem in agriculture. Measurement of such damage is an important first step in its effective management. We develop a visual assessment technique and a progressive sampling strategy using 5 strata and suggest sample sizes necessary to achieve an estimate of bird damage within a standard error of 5%. This strategy improved sampling efficiency by 67%, 79% and 80% compared to stratified systematic, standard systematic and random sampling. With an average cost of under \$(AUS) 6 per block this technique is a rapid inexpensive method to estimate bird damage to vineyards and has application to most crop-bird situations.

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1. Introduction

Birds are a world-wide problem for agriculture (United States: De Grazio, 1978; Canada: Somers and Morris, 2002; Europe: Mooij, 2001; Africa: Bruggers and Elliot, 1989; Asia: Nemtsov, 2004; Australia: Tracey et al., 2007). Accurate and efficient damage assessment techniques underpin any research and management efforts to reduce damage. Assessment techniques currently available to researchers and managers are either unverified, or are time consuming and therefore costly. Previous studies use standard random or systematic sampling procedures by counting individual fruits or plants (Nemtsov, 2004), or by weighing or visually assessing them (De Grazio et al., 1969; Dolbeer, 1975; DeHaven and Hothem, 1979; Stevenson and Virgo, 1971). In this paper we describe a visual assessment technique and progressive sampling strategy to estimate bird damage in wine grapes and discuss applications to other crops.

2. Materials and methods

2.1. Study site

The study was conducted in vineyards of the Orange region of New South Wales tablelands (33.3° S, 149.0° E) and are interspersed with scattered eucalypts (*Eucalyptus macrorhyncha*, *Eucalyptus seeana*, *Eucalyptus tereticornis*, *Eucalyptus viminalis*), pine (*Pinus*

radiata) plantations, mixed farming, apple and stone-fruit orchards and sheep and cattle grazing country. The area has a cool climate (mean temperature: 7 °C to 18 °C) with medium to high rainfall (mean annual rainfall: 920 mm). Vineyards range in size from 0.3 to 480 hectares, but the majority are less than 20 ha. Most vineyards have five or more varieties of grapes. The main types include cabernet sauvignon, cabernet franc, merlot, shiraz, pinot noir, sauvignon blanc and chardonnay. The main pest bird species were starlings (*Sturnus vulgaris*), noisy friarbirds (*Philemon corniculatus*) and silvereyes (*Zosterops lateralis*), with red wattlebirds (*Anthochaera carunculata*), yellow-faced honeyeaters (*Lichenostomus chrysops*), noisy miners (*Manorina melanocephala*), pied currawongs (*Strepera graculina*) and crimson rosellas (*Platycercus elegans*) also causing damage.

2.2. Random bunch selection

To avoid over-sampling of more visible bunches of grapes we used a technique for selecting bunches on each vine at random. A pole marked at 10 cm intervals was placed vertically in one of seven (0–6) locations along each selected vine. Random numbers were generated between 7 and 12 for the vertical axis and 0 and 6 for the horizontal axis. The vertical numbers corresponded to all harvestable bunches occurring between 70 and 120 cm above ground level. Grapes were grown within this height for all vineyards sampled, except one with lower trellises where a height of between 50 and 100 cm was selected. A horizontal number of 3 required placement of the pole at the vine stem; 0 at the left hand edge; 6 at the right hand edge; and 1 through to 5 at equidistance between the extremes (see Fig. 1). The closest bunch to the pole was selected.

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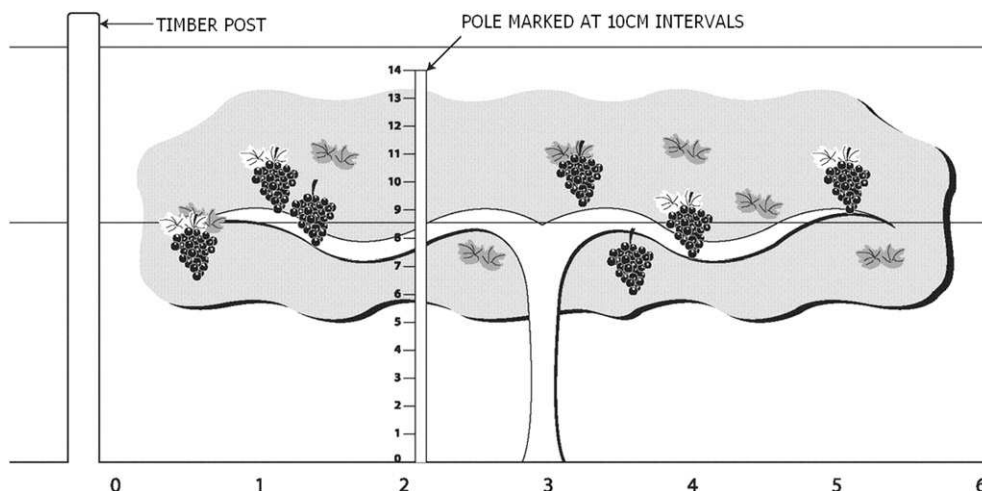


Fig. 1. Technique for selecting random bunches of grapes for assessment of damage.

Once the vine was located, one observer could locate and assess a bunch in approximately 10 seconds.

2.3. Visual assessment

Grape bunches ($n = 26500$) were visually assessed by eleven observers to determine mean percentage bird damage. Visual estimates of damage to each bunch were initially made to the nearest 1 percent, then to the nearest 5 percent if the damage estimate was between 10 to 90 percent, and to the nearest 1 percent otherwise, as assessment accuracy is higher at the extreme levels of damage. This overcame difficulties associated with ranking scales (DeHaven, 1974a). In an attempt to minimise error, observers practiced on bird-damaged bunches and used a chart of bunches with simulated damage. The visual assessment procedure was tested in the field by comparing visual estimates ($n = 594$, 8 observers) with actual percent damage. Actual percentage damage to individual bunches was calculated by counting the number of missing, pecked and remaining grapes on each bunch.

2.4. Initial sampling strategy

One hundred and twenty-nine blocks of grapes on nine properties were sampled for bird damage, with a block being a continuous planting of a single variety sampled in a particular time period. Sixty blocks were sampled immediately prior to

harvest, twenty-one of which were also sampled between veraison, when grapes first change colour, and one week before harvest. The first and last rows from each block were sampled sequentially from a randomly chosen vine. Interior rows and vines were also systematically sampled. One bunch was selected from each interior vine and two bunches from all edge vines on sampled rows.

2.5. Progressive sampling strategy

To improve sampling efficiency we developed and used a progressive sampling strategy based on data collected during the initial survey. This technique is justified in Results and summarised here.

To estimate the mean percent damage within a vineyard we stratified each block into 5 strata (Fig. 2).

The stratification scheme above is based on results showing that damage is more severe at the boundaries of the block (Fig. 3), but not always uniform between boundary strata. For example, end rows of a block contained within rows of other grape varieties were not as severely damaged as outside rows adjacent to perching habitat. Hence the separate strata for each of the four boundaries.

For each block, mean bunch damage for bunches within each stratum was estimated separately. Here we assumed that the percent damage per bunch is a linear combination of an overall mean percentage damage, a random component due to the vine

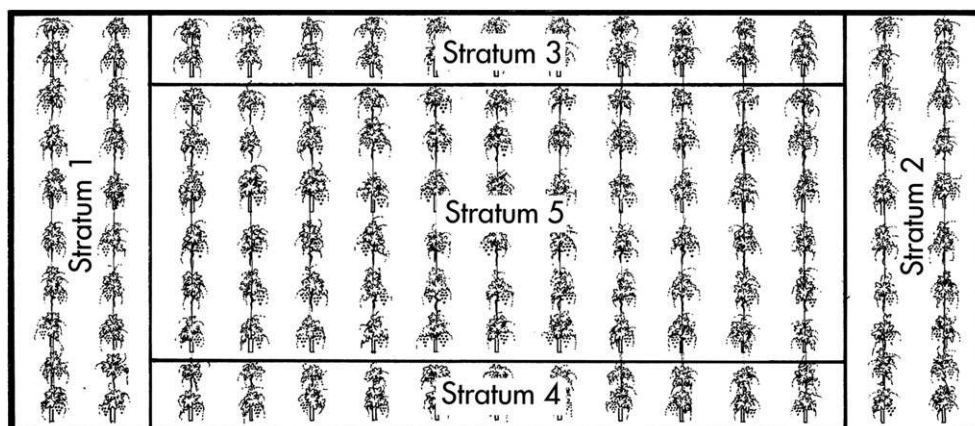


Fig. 2. Stratification scheme for vineyard blocks adopted in this study.

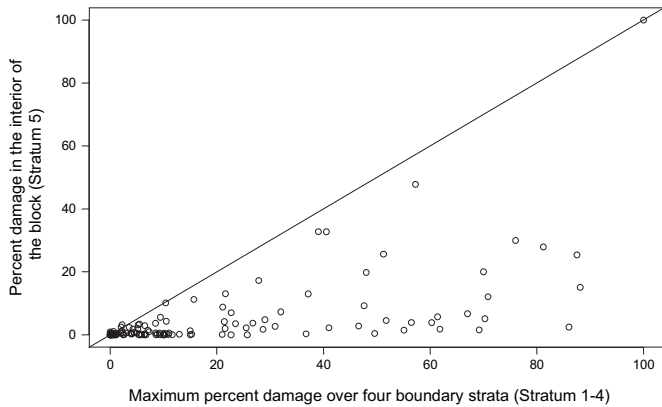


Fig. 3. Bird damage (%) in the interior strata versus bird damage (%) to boundary strata within individual blocks of grapes.

and the bunch. These means, and associated standard errors, were estimated using ASREML (Gilmour et al., 2002).

One bunch was randomly selected from 10 systematically selected vines in each outside stratum (1–4) of sampled blocks. If mean damage exceeded 5% in any outside stratum 10 samples were taken from the interior of the block (Stratum 5). If damage was greater than 10% in any of the 5 strata, additional bunches were also sampled from those strata. In each case, Table 1 was used to determine the extra number of samples required.

We compared the efficiency of the progressive sampling strategy with (1) a stratified systematic sample using the same 5 proposed strata, (2) a standard systematic sample and (3) a random sample, necessary to achieve an estimate of damage, within a 5% standard error, to 261 vineyard blocks sampled. Cost of labour was assumed to be \$AUS18.26 per hour (Farm and/or Orchard Hand – Level 4 Casual: Tasmanian Industrial Commission, 2006).

3. Results

3.1. Evaluation of visual assessment methods

Despite training, observers under-estimated bird damage to individual bunches, particularly at mid percentages (40–60%). To allow correction of damage data, observer effects were treated as random and data was pooled for all observers. An inverse estimator for the calibration data was also used for simplicity in calculating confidence intervals (Armitage and Colton, 1998).

To determine a correction model, percentages of actual (X) and estimated (Y) damage were first logit transformed to linearise the response and to remove variance heterogeneity. By definition, $\text{logit}(Y) = \log(Y/(100 - Y))$.

The prediction model for $\text{logit}(X)$ is then $\text{logit}(X) = 0.708 + 0.811 \times \text{logit}(Y)$, or equivalently

$$X = 100 / (1 + \exp(-[0.708 + 0.811 \times \text{logit}(Y)]))$$

3.2. Development of a progressive sampling strategy

In all cases, damage inside a block was less than the damage observed on the boundary, except when overall damage was less than 5% ($n = 129$ blocks; Fig. 3).

Table 1

Sample sizes needed to estimate percent damage with 5% standard error (derived from Fig. 5).

Bird damage (%)	5	10	20	30	40	50	60	70	80	90	95
Sample size	4	10	24	37	46	49	46	37	24	10	4

To estimate the mean percent damage for a block we assumed an equal number of bunches per vine in each block. A weighted average of the estimated means within each stratum was then determined, with the weights proportional to the number of vines in each stratum; $\sum d_i p_i$, where, for $i = 1, \dots, 5$, d_i = mean damage for stratum i and p_i = proportion of total number of vines in block that are in stratum i . To determine appropriate sample sizes we examined first the standard deviation of the results versus the mean within each stratum (Fig. 4). The least squares fit for the line (Fig. 4) as: $SD = \alpha [\text{Mean}(100 - \text{Mean})]^\beta$, where $\alpha = 0.079$ and $\beta = 0.778$.

Based on the above model for the variation of results within strata we can determine the minimum sample size needed to estimate the mean percentage damage within a stratum so as to place an upper bound on its standard error. For example, should the mean percent damage within a stratum need to be estimated with a standard error of 3% or less, then the sample size needed, n say, must satisfy: $0.079 [\text{Mean}(100 - \text{Mean})]^{0.778} / \sqrt{n} \leq 2$. If Mean is 20% say, then n must be at least 80. Fig. 5 plots the minimum sample size versus mean for when the standard error of the mean equal 3%, 5%, 7% and 10%.

When estimating the percentage damage of a block based on a weighted average of the mean damage within each of the separate strata, the standard error of the overall mean estimate will depend on the relative sizes of the strata. Let p_i denote the proportion of vines in stratum i ($i = 1, 2, \dots, 5$) relative to the total number of vines in all five strata and τ_i equal the corresponding standard error of the percent damage estimate in that stratum. Then the standard error of the estimated mean percent damage for the block, τ say, is given by: $\tau = \sqrt{(\sum p_i^2 \tau_i^2)}$. Hence τ is influenced by the maximum p_i ($i = 1, 2, \dots, 5$).

The progressive sampling procedure is based on the results of Fig. 5 for any desired standard error. We aimed at achieving a standard error of 5% and assumed the underlying percent damage was 10%. Hence we chose $n = 10$ vines from each outside stratum (1–4). If damage was less than 5% in any outside stratum, then no more sampling was necessary as we could be confident that overall damage was less than 5% (Fig. 3). If any stratum was greater than 5% in any outside stratum, the interior of the block was also sampled in the same way (Stratum 5). If damage was greater than the assumed 10% in any stratum then more samples were taken from that stratum relative to the estimated percent damage (Table 1).

3.3. Efficiency of damage assessment techniques

The mean time taken to sample a block using the progressive sampling strategy was significantly less than when using stratified

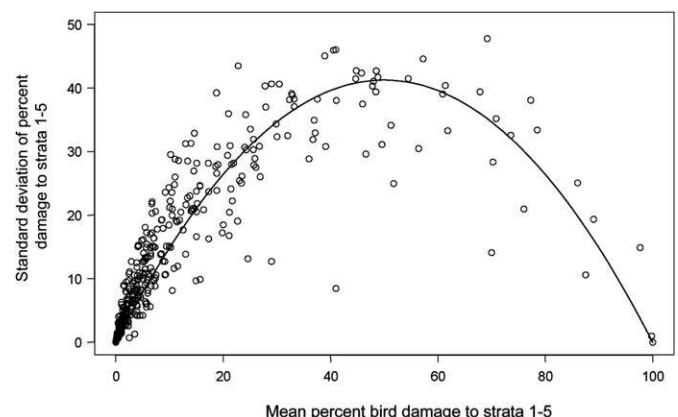


Fig. 4. Standard deviation versus mean percent bird damage for each stratum.

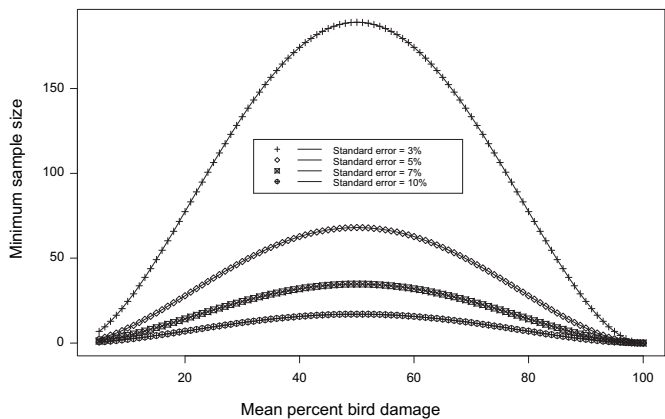


Fig. 5. Sample sizes needed for estimating damage per stratum with standard error (3%, 5%, 7% and 10%).

systematic, standard systematic and random sampling ($P < 0.001$, $df = 520$, t statistic = -46.4 , -39.3 , -20.2 , Fig. 6), improving sampling efficiency by 67%, 79% and 80% respectively. On average the cost of sampling a vineyard block using our progressive sampling technique was \$AUS $5.77 \pm \$0.35$ ($n = 261$, range \$0.97–\$18.95).

4. Discussion

4.1. Random bunch selection

Random bunch selection is necessary to avoid over-sampling of more visible bunches, which has been achieved previously using a combination of ropes, several poles or hoops and two or more observers (DeHaven and Hothem, 1979; Martin and Crabb, 1979). The selection procedure we developed was simple and efficient in selecting random bunches. The same pole could be used in vineyards of any trellis height, provided random numbers were generated separately for different heights of vines. Once the vine was located, one observer could locate and assess a bunch in approximately 10 seconds. This was six to 18 times more efficient than previous techniques which took between 30 and 60 seconds with two or three observers (DeHaven and Hothem, 1979; Martin and Crabb, 1979).

4.2. Evaluation of visual assessment methods

Despite training, all eight observers underestimated percent damage to selected bunches, particularly at mid percentages

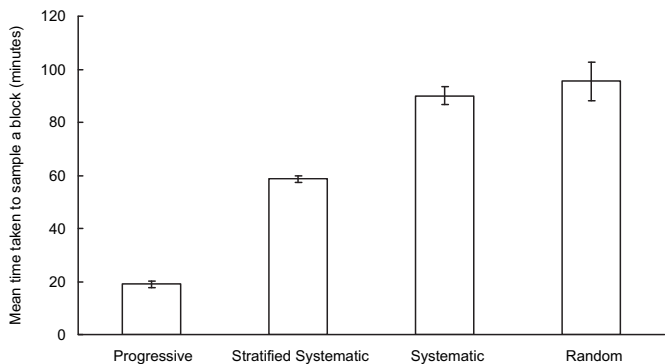


Fig. 6. Mean time (minutes) taken to sample a block using progressive, stratified systematic, systematic and random sampling with 95% confidence intervals.

(40–60%). This emphasises the importance of calibrating visual estimates. Most other studies which visually estimated bird damage to wine grapes used either a damage class or a pre-transformed ranking scale (Table 2). In studies that compared visually estimated damage with known damage, most concluded that damage was accurately classified after a period of training. However, large classes were used (e.g. rank 1 = 0–5%; 2 = 5–20%; 3 = 20–50%; 4 = 50–80%; 5 = 80–95%; 6 = 95–100%, Stevenson and Virgo, 1971; Somers and Morris, 2002), and with the exception of Somers and Morris (2002), accuracy within classes was not reported.

An observer's ability to estimate actual bird damage may also differ from bunches with simulated damage, particularly when birds peck rather than remove grapes. Bird damage will also have occurred at different stages of grape growth so will often be less obvious than freshly removed grapes. This may partly explain the underestimation evident in this study. Somers and Morris (2002) reported that pecked damage was extremely rare in their study (<1% of all damaged bunches).

We recommend estimating percent damage to individual bunches as described rather than using a ranking scale, as this is equally efficient, overcomes difficulties with uneven distribution of damage within classes (DeHaven, 1974a), and allows corrections of likely errors. If damage classes are to be used, we suggest testing the accuracy of classes and distribution of estimates within classes and using, where possible, bunches with actual rather than simulated damage for validation.

4.3. Progressive sampling strategy

This study found bird damage was always higher in at least one outside edge than in the interior of the block, except when overall damage is low (<5%). Higher damage on the edges of the crop is consistently observed for many bird species and crop situations (e.g. starlings, cedar waxwings, *Bombycilla cedrorum*, and American robins, *Turdus migratorius*, in wine grapes: Somers and Morris, 2002; sulphur-crested cockatoos, *Cacatua galerita*, and galahs, *Eolophus roseicapilla*, in sunflowers: Fleming et al., 2002; grackles, *Quiscalus mexicanus*, in grapefruit: Johnson et al., 1989). The progressive sampling strategy is significantly more efficient than other methods of sampling ($P < 0.001$), with this difference likely to

Table 2
Type of assessments used to estimate bird damage to wine grapes.

Type of assessment	Accuracy measured	Source
Counting	NA	Askham, 1992
Counting	NA	Toor and Ramzan, 1974
Weighing	NA	Porter and McLennan, 1995
Ranking scale, counting and weighing	No, NA	Hothem and DeHaven, 1982
Percent estimate	No	Chambers, 1993
Percent estimate	No	Curtis et al., 1994
Percent estimate	Yes ($n = 594$, 8 observers)	This Study
Ranking scale	Yes	Martin and Crabb, 1979
Ranking scale	No	DeHaven, 1974a
Ranking scale	No	Bailey and Smith, 1979
Ranking scale	Previously tested	Martin and Jarvis, 1980
Ranking scale	Yes ($n = 10$, 85% of bunches scored within the damage class)	Stevenson and Virgo, 1971
Ranking scale	No	Yim and Kang, 1982
Ranking scale	Yes ($n = 400$, 2 observers)	DeHaven and Hothem, 1979
Ranking scale	Previously tested	DeHaven and Hothem, 1981
Ranking scale	Previously tested	Hothem et al., 1981
Ranking scale	Yes ($n=104$)	Somers and Morris 2002

be even greater in larger blocks, and where there is a highly skewed spatial distribution of damage. This is commonly observed in bird-crop conflicts (corn: Dyer, 1967; wine grapes: DeHaven, 1974b; apples: Halse, 1986; cherries: Sinclair and Bird, 1987; rice and sunflowers: Subramanya, 1994). We suggest that the progressive sampling strategy would provide similar or increased improvements in efficiency in most bird-crop situations. With an average cost of sampling a block under \$AUS6, we recommend this strategy be routinely implemented to improve bird damage management decisions in viticulture and other agricultural crops.

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