Quantifying bird damage to wine grapes in the Western Cape of South Africa: a questionnaire-based approach

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Abstract

Bird-wine grape damage is a globally acknowledged problem that has been the subject of considerable research in many wine growing regions. However, despite the Western Cape of South Africa being a major wine grape growing region, very little research has quantified bird damage in this region and very little is known about the extent of the problem. This research aimed to quantify bird damage to wine grapes in four grape growing regions of the Western Cape, through questionnaires. It also aimed to determine the factors that might explain the patterns of damage observed. 102 questionnaires were sent to the wine farms, and 52 were returned. Of the respondents, 71% reported bird grape damage. The amount of damage per wine farm ranged between 0% and 15% of the total rows of vines across a farm. When exploring the factors associated with whether a wine farm experienced bird damage, it was found that the border habitat of a farm was a significant factor. The composition of the border habitat greatly influenced the probability of bird damage. The PCA showed that tall trees, Fynbos and residential areas specifically increased the probability of bird damage. Within farms that experienced damage, it was found that in different vineyard blocks the areas closer to the edge of a vineyard and to trees were significantly more susceptible to bird damage. The most common reported damage-causing bird species were Red-Winged Starlings (*Onycognathus morio*) and White-Eyes (*Zosterops lateralis*). Damage was reported to occur mostly one month before harvest and at harvest time. This research provides a baseline for understanding the nature of bird damage in these regions and will aid future quantitative studies aimed at the management of the problem.

Introduction

The conflict between wildlife and agricultural producers is a problem that has been around since humans started growing crops (Brook, 2009; Bruggers *et al*., 2002). This conflict is widespread and can be locally severe (Brook, 2009; Moran, 2003; Brook 2009). Research has attempted to understand the nature of this conflict with various quantitative studies. Many of these studies focus on a singular crop and the damage it experiences, or a singular animal and the damage it causes (Elk-Brook, 2009; Bears-Stowell & Willging, 1991; Badgers-Moore *et al*, 1999; corn-Wywialowski, 1993; apples-Tobin *et al*.; 1989; Deer-Putman & Moore, 1998). Research has also focused on extensive surveys that look at an entire array of wildlife in a country or region across different crop types (Wywialowski, 1996; Moran, 2003; Johnson & Timm, 1987). Another major focus of research on agricultural damage examines the stakeholder's perspectives on the levels of damage and the species responsible (Reiter *et al*., 1999; Conover, 1994; Wywialowski, 1994). Considering this range of research worldwide there is a need for a better understanding of local patterns of agricultural damage so that farmers can effectively manage the problem (Wywialowski, 1996; Brugger *et al.*, 2002; Nelms *et al.*, 1990; Wywialowski, 1994; Stone *et al.*, 1972; Tracey & Saunders, 2003; Fall & Jackson, 2002).

Wildlife damage of agriculture is often defined as the loss of economic productivity due to the damage of produce (Bruggers *et al.*, 2002). The type of damage caused by wildlife varies across different crop types and across different animals. Types of damage can include standing crop damage, removal of or damage to fruits and predation of livestock (Brook, 2009; Virgo *et al*., 1987; Tobin *et al*., 1989; Stowell & Willging, 1991). One example of animal damage occurs in Manitoba, Canada where Elk have been in conflict with cereal crop growers since the 1880s (Brook, 2009). The damage caused by Elk ranges from fence damage, to stored hay damage and the eating of oilseed crops (Brook, 2009). The economic losses from Elk damage can be greater than $240 000 per year, and for this reason farmers have tried to mitigate this loss through the hunting of Elk on agricultural land (Brook, 2009). This mitigation technique has had little success and Brook (2009) emphasises the need for continuous quantification of the problem, so that stakeholders and management can establish long term solutions to this issue.

Birds are commonly acknowledged for their widespread destruction of agriculture (Moran, 2003; Coleman & Spurr, 2001; Dolbeer, 1981; Nelms *et al*., 1990; Salmon *et al*., 1986; Rodriguez *et al*., 2004; Avery *et al*., 2005). The foraging behaviour of birds in agricultural fields can cause various types of damage, but mostly it is the removal of fruits, corn and rice, or the destruction of fruit skins resulting in secondary rot (Tracey & Saunders, 2003; Bridgeland & Caslick, 1983; Avery *et al*., 2005). Bird damage has been quantified in many different crops: pistachios (Salmon *et al*., 1986), corn (Stone *et al*., 1972; Dolbeer, 1981), blueberries (Nelms *et al*., 1990; Conover, 1982), rice (Avery *et al*., 2005) apples (Tobin *et al*., 1989) and cherries (Tobin *et al*., 1991; Virgo, 1971). The major effects of damage to these crops are a downgrade in fruit quality, a reduction in yield as well as an early harvest (Tracey & Saunders, 2003). These factors reduce the monetary value of the crops and as a result there is a loss in economic productivity (Tracey & Saunders, 2003; Conover, 1994).

A consistent finding of bird damage research is that it is a highly variable and patchy phenomenon across regions and farms as well as spatially within a farm (Bomford, 1992; Weatherhead *et al*., 1982; Tracey & Saunders, 2003; Tracey *et al*., 2007; Hermann & Anderson, 2007; Avery *et al*., 2005). This finding creates problems when applying generalisations to the amount, extent and prevalence of the damage caused by birds (Tracey & Saunders, 2003; Dolbeer, 1981; Tracey *et al*., 2007; Salmon *et al*., 1986). It further complicates the application of consistent and repeatable preventative techniques because of the highly variable nature of the damage. There is a need to understand the spatial and temporal patterns of bird damage so as to ensure the effective implementation of preventative techniques (Tracey & Saunders, 2003).

The wine grape industry, just like many other agricultural industries, suffers from bird damage. Losses in yield have been reported in most major wine regions of the world; Canada, California, Australia and New Zealand (Somers & Morris, 2002; Tracey & Saunders, 2003; DeHaven, 1973). This study is restricted to literature in English and Afrikaans. As expected bird damage to wine grapes has been found to be an extremely variable phenomenon, exhibiting patchiness across regions, across farms and within vineyards (Tracey & Saunders, 2003; Somers & Morris, 2003).

Despite the variability exhibited in bird damage to grapes, research has revealed some consistent trends. The three main consistencies are 1) edge damage; 2) species differentiated damage or removal of grapes, and 3) temporal damage occurring during the peak ripening times (Tracey & Saunders, 2003; Somers & Morris, 2003; Coleman & Spurr, 2001). Birds tend to damage the edge of vineyards. This has been attributed to the reduction in the distance they need to fly from surrounding perches and protective cover (Stevenson & Virgo, 1971; Somers & Morris, 2003; DeHaven, 1974; Saxton *et al*., 2004). Different bird species have been found to damage the grapes in different ways either by pecking the grapes – causing secondary rot – or removing the entire grape (Saxton *et al*., 2004; Rodriguez *et al*., 2004; Stevenson & Virgo, 1971; Tracey & Saunders, 2003). In a field experiment done by Saxton *et al*. (2004), the European Blackbird (*Turdus merula*) was shown to remove entire grapes, while the White-Eye (*Zosterops lateralis*) was shown to peck the grape to get to the seeds inside. An explanation for the third consistency is that the fruits often exhibit the highest sugar levels at peak ripening times. Consequently the highest amount of damage tends to occur when the grapes are ripening, resulting in a consistent temporal pattern of damage (Tracey & Saunders, 2003).

Various techniques are used by farmers to deter birds from vineyards, so as to reduce grape damage (Hothem & DeHaven, 1982; Brugger *et al*., 1993; Kross *et al*., 2012). These techniques include raptor-mimicking devices, acoustic devices, netting, reflective items and the introduction of raptors (Jarvis & Heyl, 1989; Fuller-Perrine & Tobin, 1993; Kross *et al*., 2012; Berge *et al*., 2007). The threatened New Zealand Falcon (*Falco novaeseelandiae*) was introduced into vineyards where damage was occurring (Kross *et al*., 2012). The presence of these raptors reduced the number of grapes removed by 95% compared to vineyards without introductions (Kross *et al*., 2012). Acoustic devices mimicking bird distress calls have been used in combination with other preventative methods, like reflective tape and shot guns (Berge *et al*., 2007). This combination of methods was also found to reduce the bird damage to wine grapes (Berge *et al*., 2007). Raptor-mimicking devices exploit the bird's fear of raptors and Hothem & DeHaven (1982) showed that the use of raptor-mimicking kites, hung on poles in the vineyards, reduced the amount of damage over two consecutive years. Even though there is some research on the efficacy of these techniques, they can only be effectively applied when the pattern of bird damage is understood (Tracey & Saunders, 2003).

The Western Cape Province of South Africa contains 98% of all wine vineyards grown in the country (SAWIS, 2012). The wine industry of the Western Cape contributes 7.3 percent of the total provincial Gross Domestic Product (GDP), and this contributes to almost 2% of the overall national GDP (Conningarth Economists, 2009). The Western Cape's Mediterranean climate creates optimal conditions for the growth of wine grapes and, as such, vineyards have been planted and wine has been produced since the 1650s (Bruwer, 2003). Considering the importance of the wine industry in South Africa, very little quantitative research has taken place on the patterns and extent of bird damage. Cape Nature, an established conservation institution in the Western Cape Province, has undertaken some studies on the use of mist nets as a means to reduce pest birds in vineyards (Jarvis & Heyl, 1989); however this work was not based on any quantitative studies of the damage by birds.

In the only empirical study of bird damage to grapes in South Africa, Le Riche (1981- in Afrikaans) undertook a study on a single farm in the Stellenbosch region. He worked on six different grape varieties: Chenin Blanc, Pinot Noir, Riesling, Cinsaut, Clairette Blanche and Cabernet Sauvignon. The two bird species identified to cause the most damage were the Cape Sparrow ('Mossies') *Passer melanurus*, and the European Starling (*Sturnus vulgaris)* although many other bird species were also observed causing damage. Findings by Le Riche (1981) were consistent with the trends found in global bird wine-grape damage studies. Bird damage was found to be most prevalent on the edge of the vineyards. Examination of individual bunches of grapes showed that different birds caused different types of damage by either removing the whole fruit, or piercing the skins. There was also a temporal pattern, where significant damage only occurred once the grapes had started to ripen, which was approximately four to six weeks before harvest. The similarity of these trends to global trends suggests that the nature of the damage does show some level of predictability (Le Riche, 1981). Although Le Riche's study revealed important observations of local bird damage on a specific farm, it is difficult to know whether this farm is representative of the surrounding farms, or even the wider region of Stellenbosch.

Considering the variable nature of wine-grape damage by birds worldwide there is a need to understand, in more detail, potential patterns and trends of damage in specific regions. Understanding these patterns of damage can assist with future management efforts. The lack of quantitative research into this issue in a South African context means that if there is a bird damage problem, very little is known about the nature of the damage and even less is known about how to manage it. This study endeavours to provide a regional analysis of the pattern of bird damage to wine grapes, in the Western Cape of South Africa. The study has two main aims: 1) Quantify the level of bird wine-grape damage in vineyards across the Western Cape to determine if bird damage is a real problem for producers in the region. 2) To determine which factors explain whether and how much bird damage occurs, at two scales; a) the farm scale and b) the individual vineyard block scale. This will provide the basis for understanding the patterns of damage, which can assist in future management of the issues.

Methods

Regional and Farm Scale Information

A questionnaire was compiled (Appendix A). The questions addressed the main issues that had been identified from previous global bird damage research. The questions included whether or not damage takes place on a farm, the amount of damage (calculated as a percentage of the total rows on a farm), and the estimated financial loss. Border habitats and surrounding land use were examined through the ranking of categories such as 'Tall trees' or 'Buildings' that would be found on the borders of farms or in the surrounding areas. Other questions also addressed the prevalent bird species causing damage to the grapes and any temporal patterns in damage. Respondents were also asked about their use of preventative techniques. This study did not deal with the efficacy or the monetary benefit of the techniques, but simply identified which techniques were being used by the farmers.

Questionnaires have been used in other wildlife damage scenarios to attain information and perceptions on the extent and patterns of damage in a region (Salmon *et al*., 1986; Reiter *et al*., 1999; Conover & Decker, 1991; Conover, 1998; Wywialowski, 1994; Tracey & Saunders, 2003; Dawson & Bull, 1970; Crase *et al*., 1976; Bridgeland & Caslick, 1983; Brook, 2009; Tobin *et al*., 1989; Coleman & Spurr, 2001; Reiter *et al*., 1999; Moore *et al*., 1999). Because questionnaires are mostly sent by mail or done telephonically, data can be collected over large regions, without the additional costs of site visits. Questionnaires also give a general overview, from the perceptions of respondents, on the level of agricultural damage and may highlight general trends.

The questionnaire distribution area was limited to the geographical unit of the Western Cape of South Africa, with a further focus on the Coastal Wine Region, as defined by the Areas of Origin Legislation of South Africa (Vinpro 2012). This legislation pertains to the designation of certain farms to certain areas to ensure accuracy of wine labelling (Vinpro, 2012). Within this region, wine farms were contacted from Constantia, Stellenbosch, Wellington and Paarl from March to April 2013, during the harvest season. Stellenbosch and Paarl represent approximately 33 percent of the vines farmed in South Africa (SAWIS, 2011), making these areas some of the largest wine producing areas in the country. A collection of farms from each region was selected randomly. This random selection did not apply to Constantia, because it is a ward that contains fewer farms, and so all the farms were contacted. Of the 102 farms contacted, 9 were from Constantia, 33 from Stellenbosch (20% of vineyards in this region), 29 from Wellington (74%) and 31 from Paarl (22%) giving a total of 102 farms contacted.

The wine farms were contacted by phone to establish the exact contact details of the appropriate person with whom to speak (the winemaker, viticulturist, farm manager or owner). All future correspondences were then carried out with this person. The questionnaire was sent by e-mail to all the farms, except for two farmers who preferred to answer the questionnaire verbally. After giving the farmers a week to respond, follow up calls were made to those farms who had not returned the questionnaire. Another call was done 4 days later if there was still delay in their replies. If there was still no response after a third call, the questionnaire was considered as unreturned. In addition to phoning farms directly, an article was published in the May edition of the Winelands Magazine (Appendix B). This article promoted the research, and also potentially increased the likelihood that a questionnaire might be returned.

Some data was then modified for ease of analysis. One modification pertained to data from a question that addressed the area of each variety farmed. There were 35 different varieties identified by the respondents. Some varieties were more prevalent than others in terms of area used, and so the average percentage area for each variety was calculated so as to narrow down the number of varieties. Any variety that had an average overall coverage of less than 4% was grouped into the category 'Other'. Subsequently, there were six varieties that had an average coverage of over four percent; these were Sauvignon Blanc, Cabernet Sauvignon, Merlot, Shiraz, Chenin Blanc and Chardonnay.

Farmers were asked to rank the extent of certain border habitats and surrounding land usage, according to the relative amounts present on i) the borders or ii) in the surrounding areas of their farms. Initially there were six categories for 'Border habitat', farmers could select: 1) tall trees, 2) vineyards, 3) Fynbos, 4) residential areas, 5) farms (other than vineyards) and 6) industry. These were reduced to five because the category 'Industry' almost never featured. Five categories were also used for surrounding land usage. Initially there were seven categories for surrounding land usage: 1) Tall trees, 2) vineyards, 3) Nature reserve, 4) residential areas, 5) farms (crops), 6) farms (grazing) and 7) industry. Again 'Industry' was eliminated from this analysis as it rarely featured. Two categories, 'Farms (crops)' and 'Farms (grazing)', were combined and averaged to form a new category, 'Farms other than vineyards'. This was done because the distinction between the two (due to high proportion of mixed farming) was not evident and they could easily be classified as one group.

Principal Component Analyses (PCAs) were used for a number of variables of interest in order to condense them into fewer explanatory variables. There was a specific interest in establishing whether the presence of bird damage was associated with the grape variety farmed. Consequently, the first PCA was constructed using the area of each of the varieties for each farm (52 farms). The first two axes of this PCA (PC 1 and PC 2) had eigenvalues of 1.59 and 1.32 respectively, and explained a cumulative 41.5% of variation in the data (Table 1). Axis 1, which explained 22.73% of the variation, differentiated between the white varieties (Chenin Blanc, Sauvignon Blanc and Chardonnay) and the red varieties (Merlot, Cabernet Sauvignon and Shiraz) (Figure 1). Axis 2, which explained 18.79% of variation in the data differentiated Sauvignon Blanc, Chardonnay and Merlot from Chenin Blanc. The smaller amount of variation explained by this axis could mean that this separation is not too relevant. The PC Scores (PC 1 and PC 2) were used for future analysis as a measure for variety area.

Table 1: Principal Component scores (PC1 and PC2), Eigen percentages and Cumulative variance for the areas of 6 grape varieties as well as the 'Other' category for each wine farm that responded.

Grape Variety	PC1	PC2
Sauvignon Blanc	-0.358	0.635
Cabernet Sauvignon	0.406	0.013
Merlot	0.59	0.464
Shiraz	0.646	-0.172
Chenin Blanc	-0.321	-0.752
Chardonnay	-0.502	0.316
Other	-0.427	0.05
Eigen Percentage (%)	22.73	18.79
Cumulative Variance (%)	22.730	41.520

There was an additional interest in the effect the different categories of bordering habitats and surrounding land use would have on the probability of damage. For this reason two additional PCAs were constructed using the ranks of the different categories of border habitats and surrounding land usage given by the respondents. The first two axes of the border PCA explained 50.82% of the variation in the data (Table 2). The first axis differentiated between the extremes of residential areas and other vineyards, while the second axis differentiated between tall trees and farms other than vineyards (Figure 2A).

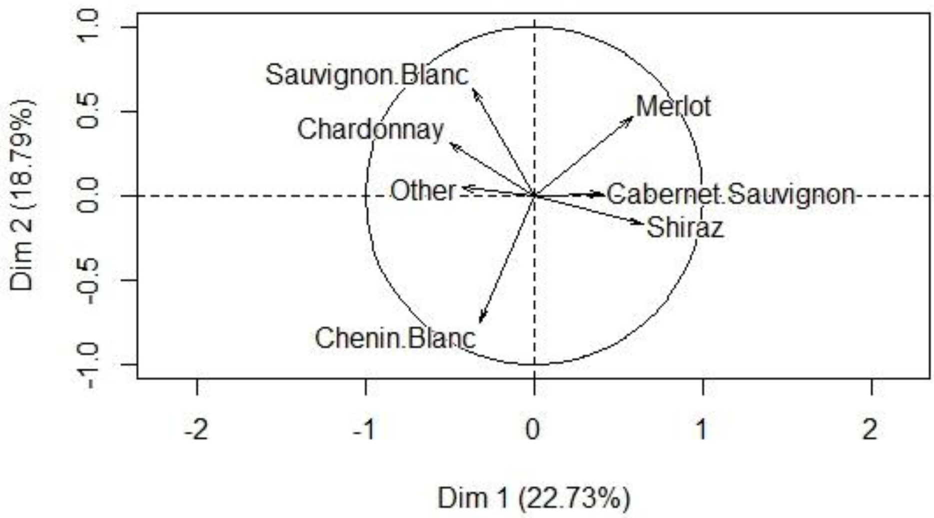

Figure 1: PCA Plot for the 6 grape varieties and the 'Other' category showing the relative 2D spatial relationship of the PCA scores. Dim 1= PC Axis 1; Dim 2=PC Axis 2.

The first two axes of the surrounding land use PCA explain 57.33% of the variation in the data (Table 2). The first axis shows a similar differentiation to the border habitats PCA1, between residential areas and other vineyards, whereas the second axis doesn't show a very strong differentiation amongst the categories (Figure 2B). The PC scores from the first two axes from both the border analysis and the surrounds analysis were used in future analysis as a measure for the amount of border or surrounding habitats.

Table 2: Principal Component scores (PC1 and PC2), Eigen percentages and Cumulative variance for the various border habitat and surrounding land use categories that were assessed through a ranking system in the questionnaires.

	Border		Surrounds	
Habitat Category	PC1	PC2	PC1	PC2
Tall trees	0.073	0.782	0.543	0.63
Other vineyards	-0.675	-0.290	-0.664	0.303
Fynbos/Nature reserve	-0.239	0.421	0.639	-0.076
Residential areas	0.774	0.133	0.723	0.108
Farms other than vineyards	0.438	-0.584	-0.211	0.807
Eigen Percentage (%)	26.193	24.631	34.2	23.137
Cumulative Variance (%)	26.193	50.824	34.2	57.333

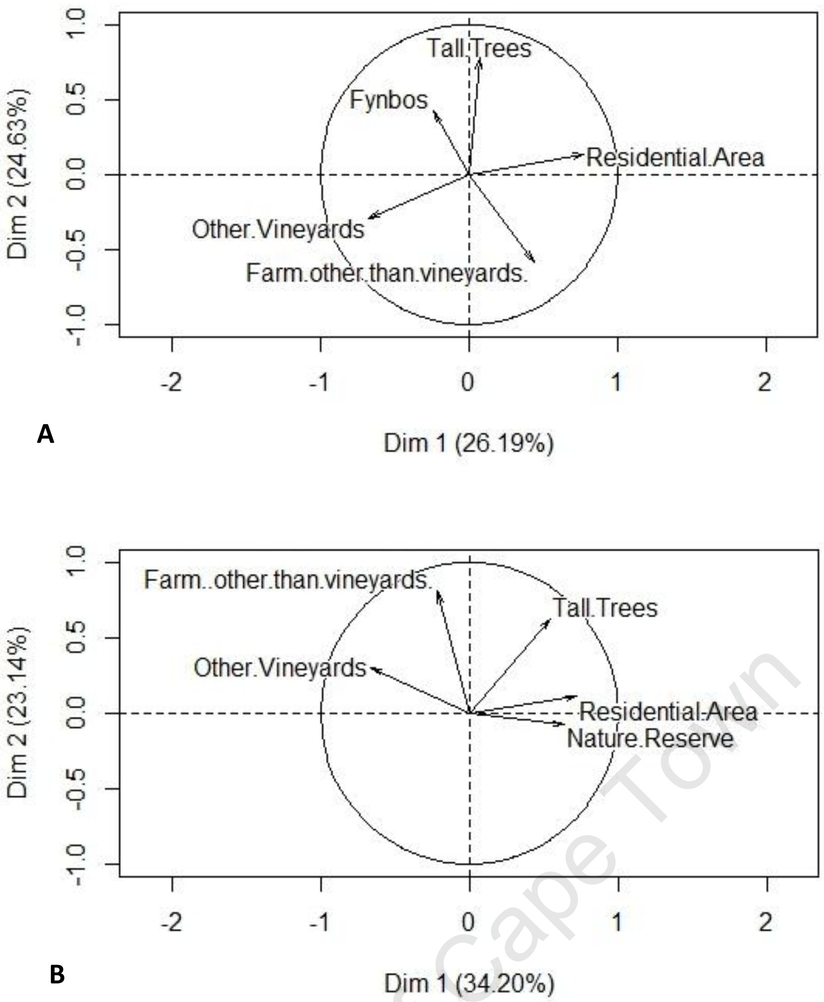

Figure 2: Principal Component plots for (A) the bordering habitat and (B) the surrounding land use of the wine farms.

Vineyard Block Scale Information

Personal visits were made to 28 (76%) of the farms who said that they experienced bird damage. Using a Google Earth (http://earth.google.com) map of the individual farms, the respondents were asked to mark out the areas within the blocks that had been damaged by birds, as well as the variety of the blocks. In addition to this, where necessary, the farmers indicated the boundary fence of the area they managed. The information pertaining to the damaged areas was transferred onto Google Earth by placing points 20m apart within the corresponding areas that had been shown on the map. Random points within the farm were also generated in Google Earth for comparison. The number of random points was equal to the number of damage points for each farm. From each point, both damaged and random, distances were measured to the edge of the block, to the closest trees, to the closest buildings and to the closest large water body.

Statistical analysis

General Linear Models (GLMs) were used to analyse the various explanatory variables and their effects on the probability of damage occurring. Initially univariate GLMs were constructed with damage as a binary, response variable and all other factors as explanatory variables. These explanatory variables were: Variety area (PC scores 1 and 2), Border habitats (PC scores 1 and 2), Surrounding land use (PC 1 and 2), the proportion of red grapes, Region (Constantia, Wellington, Stellenbosch and Paarl) and Farm size. All these variables were used in separate GLMs to establish which ones might determine the probability of damage occurring on certain farms. A second Linear Model (LM) was constructed using the same explanatory variables, but the amount of damage, as a percentage, was used as the response variable. To normalise percentage damage, the data was transformed using a Square-root-Arcsine transformation. Additionally, another LM was constructed; however this one had the percentage damage for all farms, excluding those that had zero percentage damage. This enabled an accurate view of whether or not the amount of damage could be explained by the various explanatory variables.

GLMs were also constructed to examine the effect of border categories on the probability of damage occurring on farms. The border categories were ranked by respondents, and in order to analyse this effectively, the categories were converted to binary information. If a certain border category was given the values 0, 1 or 2 by the respondents, it was assigned a zero. If it was given values 3, 4 or 5, it was assigned a one. These parameters were chosen because if a farmer scored a habitat category between 0 and 2, this meant that the border category was not very dominant. This method was applied to the main border components identified in the PCA, which were residential areas, tall trees, farms other than vineyards and other vineyards. This information was used in GLMs with damage as a binary, response variable.

Generalised Linear Mixed Models (GLMMs) were run on the distance data for the damaged and random points which were of a binary nature. The farm name was used as a random effect in this case, because points from the same farm were not independent and this ensured that comparisons were made at the appropriate scale. This analysis explored if the probability of damage occurring at a point could be explained by the distance to any of the four features: 1)Trees, 2) the edge of the block, 3) the nearest water body and 4) buildings. All statistical analyses were carried out in R-Studio version 1.9.0. (R Core Team, 2013)

Results

Out of 102 wine farmers contacted, 52 returned the questionnaires (51 %). Of the 52 farms who responded, 37 (71 %) of them indicated that they experienced bird damage. The average percentage grape damage of all the farms that responded was 2.92%, ranging from 0% to 15% of the total rows within a farm. The average percentage damage for only those farms that experienced damage was 4.11%. The average perceived cost of the damage was R1670 per ha, ranging from R18 per ha to R16 500 per ha.

Regional and farm scale Information

The farms that responded represented 2553 ha of productive vineyards with an average farm size of 49 ha. There were no differences in the probability of damage or the percentage of damage that a farm experienced between the regions (probability of damage: χ^2=2.07, p=0.56; % damage: F value=1.89, p=0.14). There was also no significant effect of size of farms (χ^2=0.29, p=0.59)

Table 3: Summary of the regional information for the 52 farms that responded from Constantia, Stellenbosch, Paarl and Wellington. It includes the probability of damage, the average percentage damage reported from each region (±standard deviation) and the average size of the farms (±standard deviation), with the corresponding χ^2 statistic and F values.

Region	Pr of Damage	Average Damage (%)	Average size (ha)
Constantia n=9	0.89	5.06(±4.9)	35.22(±33)
Stellenbosch n=20	0.70	3.27 (±4.2)	71.70 (±45.5)
Paarl=12	0.64	2.21(±3.7)	54.26 (±97)
Wellington=11	0.67	1.33 (±2.2)	26.49 (±21.6)
	χ^2 Statistic: 2.07	F value: 1.89	χ^2 Statistic: 0.29

Bird Species

Farmers identified the birds that were perceived to cause the most damage to the grapes. White eyes (*Zosterops lateralis*) and Red-Wing Starlings (*Onycognathus morio*) were both reported to cause the most damage, and were identified as being the most abundant bird species in 15 farms.

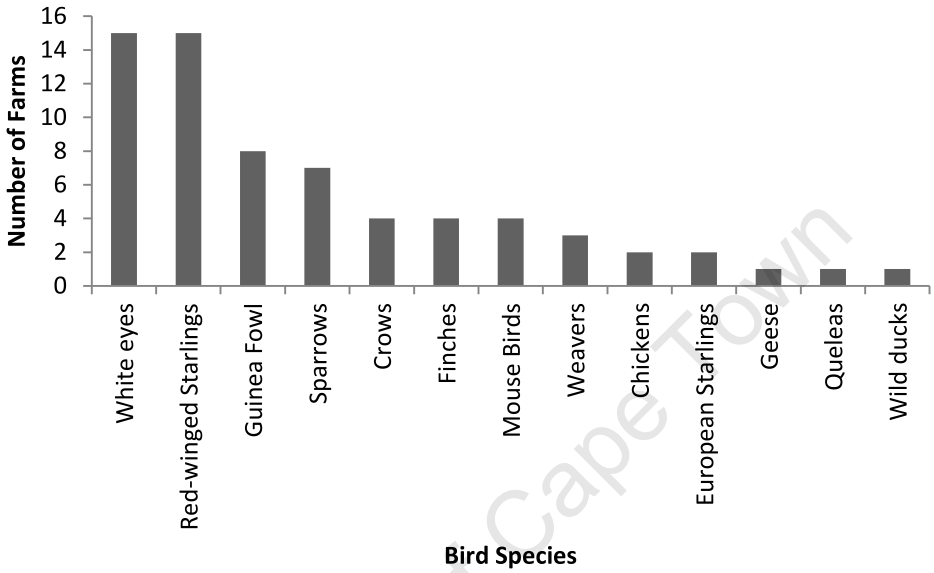

Figure 3: The number of farms that reported wine grape damage by different bird species. ‘Sparrows’ will include both Cape Sparrow (*Passer melanurus*) and introduced house sparrow (*Passer domesticus*).

Preventative techniques

A variety of preventative tactics were used by the farmers to either reduce or eliminate bird damage. 11 out of the 31 farms (35%) that experienced bird damage used some form of preventative technique. Of the 15 farms that did not experience damage, no farms utilised any bird preventative techniques. Reflective tape and CDs (Reflective items on Fig. 4) were used on 10 farms, netting was used on 4 farms, ands birds of prey stands and manual scaring tactics were used on 3 farms.

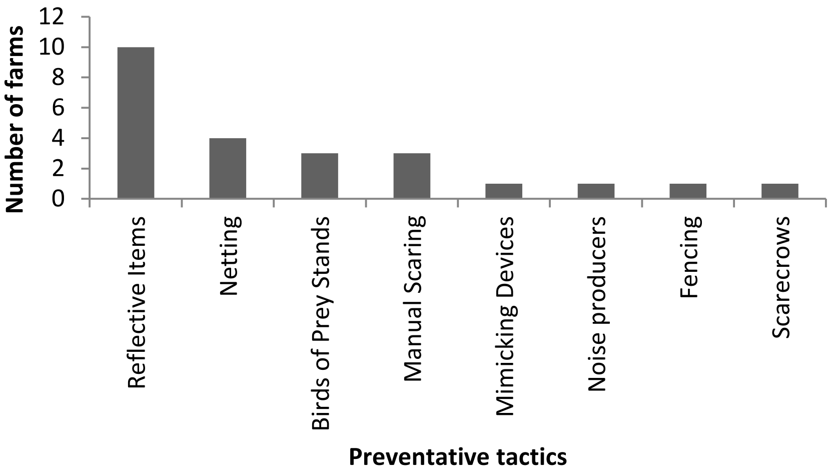

Figure 4: The preventative tactics used by the farmers to reduce bird damage, and the number of farms that reported use of each tactic. Reflective items group all reflective tapes, CDs and Eagle Eye devices (rotating reflective units). Manual scaring refers to the use of people to scare away the birds, and mimicking devices are items made to look like raptors to frighten the birds.

Temporal factors

The respondents identified the period when the grapes were damaged the most according to four categories. Grapes experienced most damage during harvest time (Figure 5). Damage was also experienced 1 month before harvest. All other periods received negligible damage.

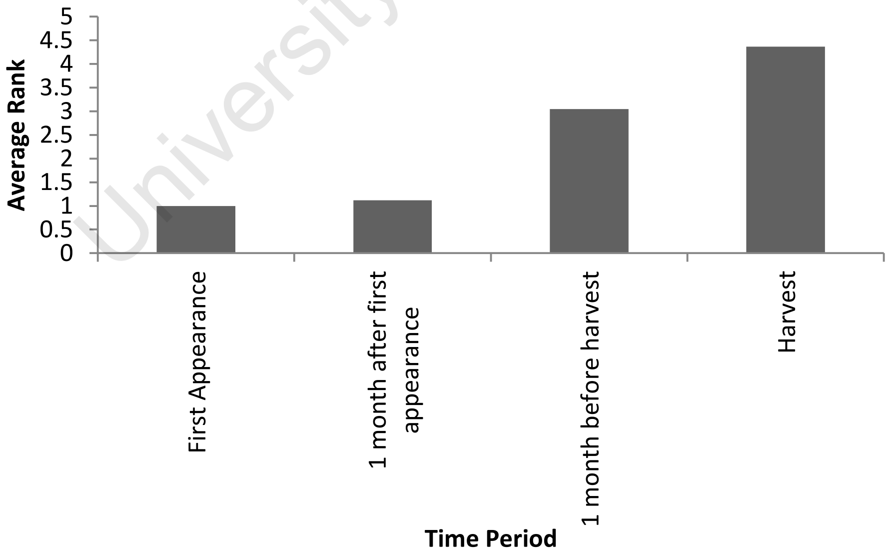

Figure 5: The average rank for each category of time in the grape's development that was reported by the respondents. 1 represents no damage to the grapes, and 5 represents the most damage to the grapes.

Variables associated with whether a farm experienced bird –grape damage

Variety area, surrounding land usage, proportion of red grapes, region and size of farm had no significant effect on the various damage response variables. The immediate border composition had a significant effect on the occurrence of damage (χ^2=6.93, p=0.008). Border composition was marginally non-significant in the amount of damage, and in the amount of damage excluding all those farms which did not experience damage (F-value=3.77, p=0.058 and F-value=0.073, p=0.073).

Table 4: The parameter estimates and test statistics for factors explaining the occurrence of damage (Damage Binary), the amount of damage (%) and the amount of damage for the farms that did not have 0% damage. The symbol '**' shows p value<0.01 and '.' shows a p value<0.1.

	Damage (Binary)		Damage (%)		Damage (Excl 0%)	
Explanatory Variable	Parameter Estimate	χ^2 Statistic	Parameter Estimate	F value	Parameter Estimate	F value
Variety Area (PC1)	-0.053	0.048	-0.158	0.043	-0.071	0.008
Variety Area (PC2)	-0.123	0.201	-1.239	2.34	-1.216	2.53
Border (PC1)	-0.069	0.07	0.883	1.16	1.545	3.41.
Border (PC2)	0.783	6.93**	1.605	3.77.	0.138	0.02
Surrounds (PC1)	0.212	0.79	0.790	1.21	0.550	0.50
Surrounds (PC2)	0.397	1.77	1.104	1.61	0.469	0.26
Grape Type (Red)	0.000	0.0006	-0.019	0.432	-0.027	0.43
Region		2.07		1.89		1.37
Size	0.003	0.294	-0.014	0.76	-0.026	2.82

The relationship between the border 2 PC scores and Binary damage is illustrated in figure 4. With the increase in border PC scores there is a corresponding increase in binary damage.

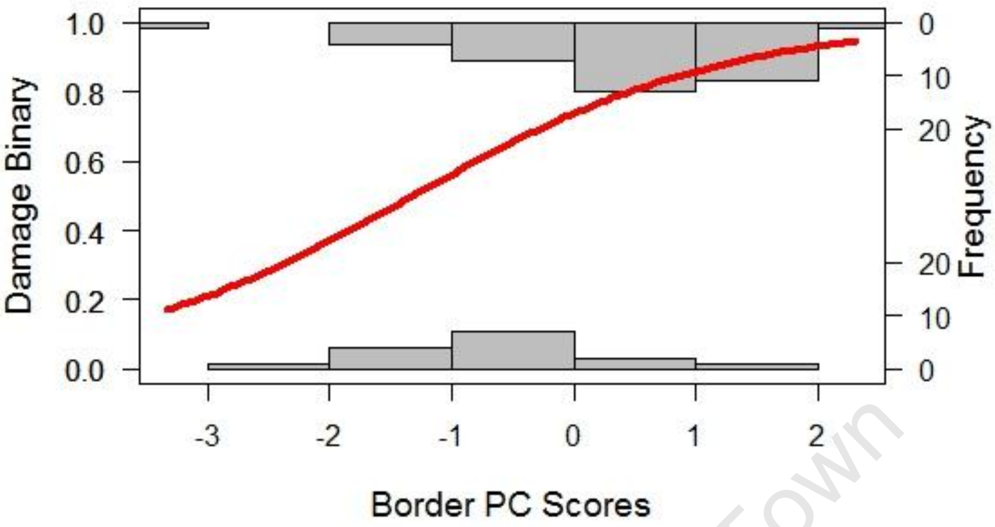

Figure 6: An illustration of the relationship between 1st Border Principal Component (PC1) Scores and damage (farms recording damage =1, farms without damage =0). This figure also shows the frequency of the different PC scores.

The border categories that were identified as showing the extremes in the variance from the PCA were Tall trees, farms other than vineyards, residential areas and other vineyards (Table 2). Tall trees had a significant effect on the probability of damage occurring (χ^2=3.99, p=0.045) and farms other than vineyards had a marginally significant effect (χ^2=3.19, P=0.074,).

Table 5: This table shows the significance of certain border categories, identified from the Principle Component Analysis, with their corresponding parameter estimates and test statistics. The tests for 'Other Vineyards' and 'Residential Areas' could not be done due to the high number of zero in the data. The symbol '*' shows p value<0.05 and '.' shows a p value<0.1.

	Damage (Binary)	
Explanatory Variable	Parameter Estimate	χ^2
Tall trees	1.283	3.99*
Farms other than vineyards	-1.236	3.19.
Other vineyards	na	na
Residential areas	na	na

Variables associated with damage at the vineyard block scale

Damage points were significantly closer to the edge (χ^2= 84.49 p=2.2e-16) and to trees χ^2=79.85, p=2.2e-16) than random points. The distance to the nearest water body had a marginally significant effect on the probability of damage to points in a vineyard block (χ^2=3.19, p=0.074). When Trees and Edge were modelled together, they both had a significant effect on the probability of damage at points in the vineyard blocks (χ^2=36.23, p=1.75e-09 and χ^2=31.86, p=1.66e-08 respectively).

Table 6: This table shows the significance of border features and their influence on the probability of damage experienced at different points within vineyard blocks. The symbol '***' shows a p value of p<0.0001 and '.' shows a p value of p<0.1.

	Damage (Binary)	
Explanatory variable	Parameter Estimate	χ^2 Statistic
Edge	-0.168	84.49***
Trees	-0.112	79.85***
Building	-0.0004	1.04
Water body	-0.0009	3.19**.**

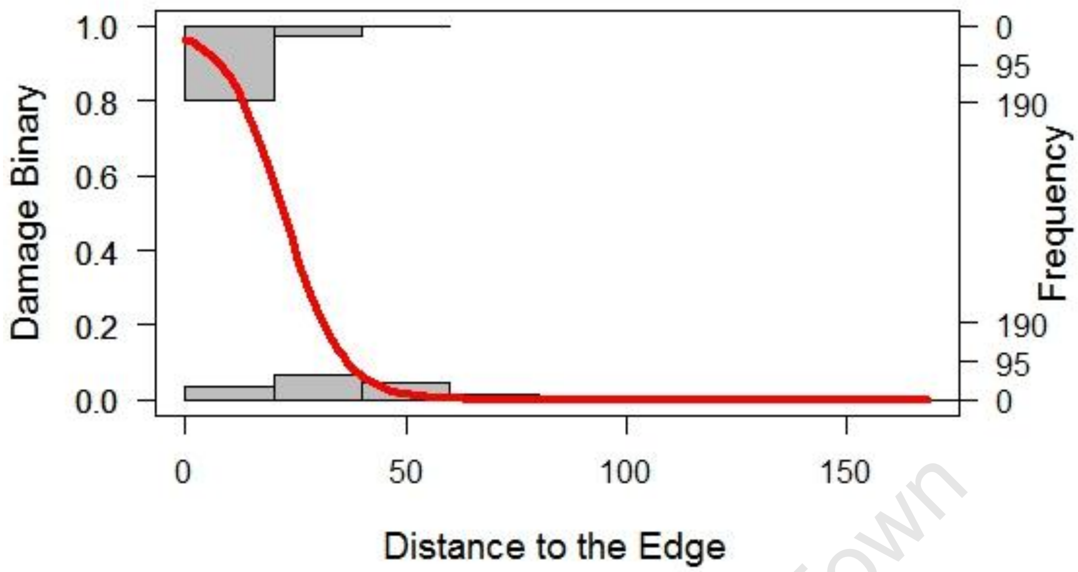

Figure 7: Relationship between the distance to the edge of a vineyard block (in meters) and damage (1= damage points, 0=random points). Each block shows the frequency of the distance scores in various categories.

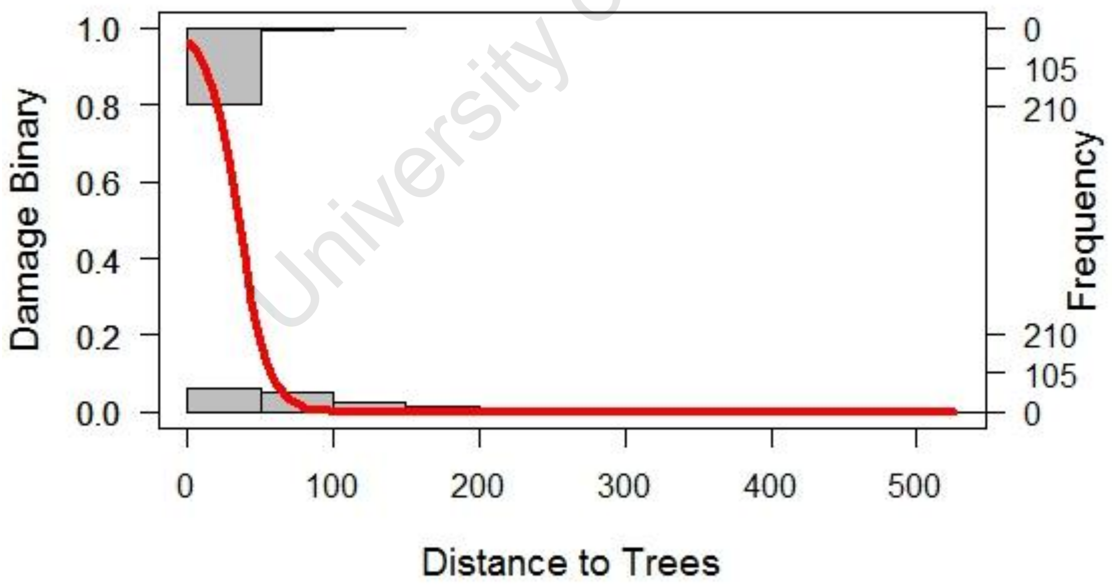

Figure 8: Relationship between the distance to trees (in meters) and the damage (1= damage points, 0=random points). This graph also shows the frequency of the distance scores within various categories.

Discussion

A large proportion of the farms that responded indicated that they experienced some degree of bird damage. However, on average, the amount of damage was relatively low. Despite this low average, there was a large range in the amount of damage experienced by farms as well as the estimated monetary loss per hectare. Some farmers were experiencing severe damage while others experience none at all. This suggests that bird damage occurrences are extremely variable across the study area, which is consistent with bird damage reports worldwide (Tracey & Saunders, 2003; Somers & Morris, 2002; Tracey *et al*., 2007; Stevenson & Virgo, 1971; Saxton *et al*., 2004).

Region was expected to play a role in the prevalence of bird damage. However, this was not the case, and the models suggested no significant effect of region on the probability of damage. Although not significant, the results showed that more farms in Constantia experienced damage relative to other regions, and that Constantia also experienced the greatest percentage damage on average. This result might suggest that region has an effect on damage. However, the results suggest that region does not play a role in the prevalence of bird damage thus damage will take place no matter what region the grapes are farmed in. This has been reported in other wine grape growing regions, where one farm may experience a lot of damage, but the one right next to it doesn't sustain any damage (Tracey & Saunders, 2003; Bridgeland & Caslick, 1983).

The sizes of the farms were also tested as a potential explanation for the pattern of damage in the different regions but once again, farm size was found to have no significant effect on the probability of damage. Farm size has not been frequently reported as a factor in worldwide bird damage research, but size was mentioned by Tracey & Saunders (2003). They found that in Australia, smaller farms were damaged more, due to the higher edge to area ratio (Tracey & Saunders, 2003). This pattern does not appear to be prevalent in this study which may indicate that the farms in South Africa are not isolated but rather contiguous, which negates the edge to area ratio. In the Tracey and Saunders (2003) study there is no mention of the isolation or density of farms, however in the Western Cape wine regions, farms are densely concentrated next to each other. This might explain why there is little effect of size, as the edge to area ratio is negated.

A factor that can assist in explaining the patterns of bird damage, are the birds themselves. Knowing which birds are responsible for the damage to grapes can also explain the type of damage and the measures needed to reduce the damage (Somers & Morris, 2002; Tracey & Saunders, 2003; Tracey & Saunders, 2009). The birds reported by the respondents in this study as the most common pests in their vineyards were the Red-winged Starling (*Onycognathus morio)* and the White-Eye (*Zosterops lateralis)*, although there was a range of other species also reported. These birds fall in the order Passeriformes, and birds of this order appear to be the most common pest species, not only to wine grape growers but also to other horticultural farmers (Moran, 2003; Kross *et al*., 2012; Somers & Morris, 2002; Saxton *et al*., 2004). Starlings, specifically the European Starling (*Sturnus* vulgaris) have been reported as causing damage to grapes in Canada, North America, Australia and New Zealand (Somers & Morris; Stevenson & Virgo, 1971; Crase *et al*., 1976; Tracey & Saunders, 2003; Dawson & Bull, 1970). White eyes (*Zosterops lateralis*) are a less common pest species but also cause damage to grapes in Australia and New Zealand (Tracey & Saunders, 2003; Dawson & Bull, 1970). It appears, therefore, that the damage-causing birds in these regions of the Western Cape are also predominant in other areas of the world. Knowing which species of birds are the pests can assist with targeted management techniques and interventions, because farmers can put in place the appropriate mitigation measures for the specific birds.

Although the questionnaires did not cover the type of damage the various birds were causing, farmers were able to describe the type of damage seen on the grapes (pers. coms.). The Red-winged Starlings would remove whole grapes from bunches, whilst the White-eyes pecked the grapes to get to the seeds inside (Appendix C and D). This is consistent with one of the trends in bird grape damage (Tracey & Saunders, 2003; Stevenson & Virgo, 1971; Somers & Morris, 2002; Saxton *et al.*, 2004). Knowledge on the type of damage that birds cause can assist in identifying which birds are causing the most damage and further assist in targeted management practices (Tracey & Saunders, 2003; Stevenson & Virgo, 1971).

A temporal trend in damage was observed where the most amount of damage occurred one month before harvest and at harvest time. Examining the development of the grapes, gives some insight into why this might occur. Grapes exhibit a two-phase pattern of development, with the ripening occurring in the second phase (Robinson & Davies, 2000; Coombe &

Mccarthy, 2000). The term used for the onset of ripening is *verasion*, and during ripening there are changes such as the decrease in acids, accumulation of sugars, the onset of colour and berry softening (Robinson & Davies, 2000; Coombe & Mccarthy, 2000). This could explain why most of the damage occurs during the peak ripening times where sugar levels are increasing, and the grapes are more attractive to the birds. This temporal trend has been reported in other wine grape damage studies (Tracey & Saunders, 2003; Somers & Morris, 2002; Stevenson & Virgo, 1971), however only Tracey and Saunders (2003) linked it directly to sugar levels. Others only observed the trend, and Stevenson and Virgo (1971) state that it is not due to sugar level at all but other variables such as bird abundance and behaviour. This trend of peak damage occurring at ripening times has also been reported in other types of crops such as cherries, apples and corn (Virgo, 1987; Tobin *et al*., 1989; Bridgeland & Caslick, 1983). The sugar levels were not addressed in the questionnaires for this study, but whether or not the trend is linked to sugar levels, there does appear to be this distinct pattern of damage over the ripening periods. This knowledge can assist in implementing effective management strategies, because famers know that the birds will not be a problem throughout the grapes development, but only once the fruit starts to ripen. This knowledge can increase effective temporal targeting of any management interventions.

Exploring the variables which were associated with whether a farm experienced damage showed that variety area, surrounding land usage, proportion of red grapes farmed, region and size had no significant effect on the likelihood of damage occurring on a farm. Only the 'Border Habitat' category had a significant effect on the presence and amount of damage within a vineyard. Habitats bordering a vineyard have been highlighted in other bird grape damage research, and have also been acknowledged as one of the most important factors in determining the occurrence and amount of bird damage (Tracey & Saunders, 2003; Somers & Morris, 2002; Tracey & Saunders, 2009; Stevenson & Virgo, 1971). There was a positive relationship between the likelihood of damage and Border PC 2 scores. This means that if a farm has large amounts of 'Fynbos', 'Tall Trees' or 'Residential Areas', the probability of bird damage occurring on that farm increases. This highlights the importance of border habitat as a determining factor in the presence of damage and the amount of damage within a vineyard.

Further analysis of the border habitats revealed that the presence of 'Tall Trees' on the border of a wine farm increased the probability of damage occurring on that farm. Interestingly, the findings in this paper also show that if a farm is surrounded by farms other than vineyards, there is a decrease in the probability of damage. The presence of vegetation, especially tall trees, adjacent to vineyards is a major determining factor because birds do not tend to live in vineyards, but rather in the vegetation that surrounds the vineyards (Tracey and Saunders, 2003; Somers & Morris, 2002). Consequently if there is a lot of vegetation around a vineyard, this provides living spaces for the birds that can easily forage in the nearby vineyards (Somers & Morris, 2002; Stevenson & Virgo, 1971). When farms are surrounded by farms other than vineyards, these other farms may be farming different fruits, that may be more attractive to the birds and so the amount of damage to the wine grapes is reduced slightly. This may cause the spread of the damage across the different farms, rather than being concentrated on the wine grapes.This has not been shown in other studies specifically, however it is certainly something worth investigating further.

Analysis on an even smaller scale was carried out, looking at the points within an individual vineyard block. The probability of damage occurring at specific points within a block was found to be significantly affected by the distance to the edge of the block and the distance to the nearest trees. Damage points were nearer to the edge than random points, suggesting that damage was more likely to occur around the edges of the blocks. This also applied to damage points that were closer to trees, once again suggesting that damage is more likely to occur in areas that are closer to trees. This is consistent with the above mentioned importance of adjacent vegetation to vineyards. The adjacent vegetation provides perches and shelter for birds, and behavioural studies suggest that the birds will not fly too far from their protection to get to the grapes (Tracey & Saunders, 2003; Somers & Morris, 2002; Tracey & Saunders, 2003; Stevenson & Virgo, 1971).

Another important aspect of managing bird damage to grapes is the preventative techniques used by farmers to prevent or reduce damage (Tracey & Saunders, 2003; Somers & Morris, 2002; Kross *et al*., 2012). All the patterns found in bird grape damage assist in establishing the most effective preventative techniques as the target areas can be identified (Tracey & Saunders, 2003; Tracey *et al*., 2007). The most commonly used preventative techniques used by the respondents were reflective items and netting. A relatively low number of farmers reported the use of any technique and this could suggest two things. Firstly, farmers do not see the damage caused by birds as a significant problem and so do not make an effort to reduce what little damage does occur. Secondly, farmers may not know which methods to utilise or which ones are the most effective and so they do not use any. With generally low average percentage damage experienced by farmers (2.92% of the total rows) the first reason may be the most probable in this case. However, one must not disregard the farmers that are on the higher end of the damage scale that may still be trying to reduce damage. There needs to be accurate information available to farmers so they can implement effective preventative techniques (Tracey & Saunders, 2003). In South Africa, there is very little research on the efficacy of preventative techniques in agriculture, asides for a study done on the use of mist netting by Cape nature (Jarvis & Heyl, 1989). This appears to be a problem not only in worldwide grape damage, but also in wildlife agricultural damage (Fall & Jackson, 2002; Bruggers *et al.*, 2002; Tracey & Saunders, 2009). This study shows that farmers and managers are attempting to reduce damage to their wine grapes, but the lack of information on the patterns of damage as well as methods to deal with it are lacking.

Habitat management is often advocated for managing human-wildlife conflicts; however the results in this study might suggest that eradicating border habitats of trees and vegetation will decrease the occurrences of bird wine-grape damage. Considering that many of the vineyards within the Western Cape fall adjacent to natural Fynbos vegetation (a highly diverse vegetation type and of high conservation importance), any modification of border habitats of wine farms would not be beneficial for conservation. Therefore, there appears to be a management conflict between decreasing bird damage within vineyards and maintaining the biodiversity in the vegetation surrounding the vineyards.

Considering that vegetation removal was not mentioned as a preventative technique by any of the respondents in this study, suggests one of three things. Firstly, the amount of bird damage does not call for the removal of vegetation surrounding a farm. Secondly, the farmers may not be allowed to remove vegetation in neighbouring land because the land may fall within a conservation area or nature reserve. Thirdly, farmers may not remove large patches of vegetation within their farms because they are part of the Biodiversity & Wine

Initiative (BWI). The BWI is an initiative that was started in 2004, which acknowledged that a large proportion of wine farming in South Africa takes place in a biodiversity hotspot. To prevent the loss of natural vegetation to expanding vineyards, land owners can commit to giving back certain areas of land to conservation. In addition to this, land owners commit to certain farming practises and maintain biodiversity within the boundaries of their own farms, if appropriate. The BWI aims to combine conservation with agriculture development (Biodiversity and Wine, 2013). This makes habitat management slightly more difficult when trying to reduce bird damage of wine grapes. It is a perpetual conflict that famers face; the balance between conservation and preventing damage to valuable crops (Brook, 2009).

Future Research

Managing the problem of bird damage to grapes entails understanding the trends, which this paper has endeavoured to do, and then applying a methodology that uses this knowledge and assesses the most effective techniques to reduce damage. The literature pertaining to bird damage of wine grapes repeatedly calls for studies that examine the efficacy of different preventative techniques (Tracey and Saunders, 2003; Somers and Morris, 2002; Tracey et al., 2007; Tracey and Saunders, 2009; De Grazio, 1978). There is an opportunity in the Western Cape wine region to apply a similar methodology to that seen in Berge *et al.* (2007). Here a variety of different preventative methods (reflective tape, shot guns, bird distress calls and netting) were tested in different areas of a vineyard, targeting three main pest bird species. In South African vineyards, different methods could be tested, such as those identified in this study, while considering the different trends of bird damage, and targeting the two most prevalent bird species; Red-Winged Starlings and White-Eyes. Compared with this study which quantified damage over a large area, testing the preventative techniques would be on a much smaller scale on one or two farms. However, it will assist farmers with information on targeted management techniques and further assist them with understanding where damage is most prevalent on their farms.

Conclusion

The first aim of this paper was quantify the level of bird grape damage in the Western Cape and to establish whether or not it is a problem for wine grape farmers. The data suggests the nature of the problem to be extremely patchy. Bird damage to wine grapes is not an issue for every farm, and there are some farms that are experiencing substantial damage. Where bird damage to grapes was taking place, this study established what the trends were and where damage was most prevalent. Understanding the nature and pattern of damage is the first step towards putting in place effective mitigation measures. This study can inform management practises on these farms because it suggests, based on the trends, that preventative techniques should be placed near the edges of vineyards, close to vegetated areas and mainly one month before harvest time. Further research into the efficacy of certain preventative techniques will supplement management practises and ensure that where there is a conflict between birds and wine grape farmers, it is effectively managed.

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Appendices

Appendix A: The Questionnaire that was distributed to the wine farm viticulturists, managers or owners for data collection.

<u>Questionnaire for Biological Science Honours Project-University of Cape Town</u>

<u>Bird Damage to Wine Grapes (Ward: Constantia)</u>

1. Farm name:

2. What area of land (Ha) do you manage or cultivate for grape growing?

3. What grape varieties do you farm and what is the area of each (Ha)?

4. Do you experience any bird damage of grapes on the areas you manage? (Damage defined as: any plucking or piercing of the grapes that cause them to rot)

   Yes ☐ No ☐

5. What is the estimated number of rows that get damaged by birds across your entire farm?

6. Approximately how many rows do you farm in total?

7. What is the estimated cost of the loss of yield from bird damage?

8. What species of birds are involved in grape damage on your farm? (Please list)

9. Do you employ any tactics to reduce the amount of damage by the birds (e.g. Nets, shooting of birds, mimicking devices eg. Kite of raptor)?

10. What is the main habitat immediately bordering your vineyards? Please rank each habitat listed below, between 1 and 5, according to how much of the border fence it takes up. (1=hardly any border and 5=large amounts of the border)

Tall trees (forest)	Other vineyards	Fynbos	Residential Areas	Farm (other than vineyards)	Industry

Other (please describe):

11. What is the main land use surrounding your farm (beyond the boundary)? Please rank each surrounding habitat listed below, between 1 and 5, according to how much of the surrounding area it takes up. (1=hardly any area and 5=large areas)

Trees (forest)	Vineyard	Nature Reserve	Residential areas	Farm (crops)	Farm (grazing)	Industry

Other (please describe):

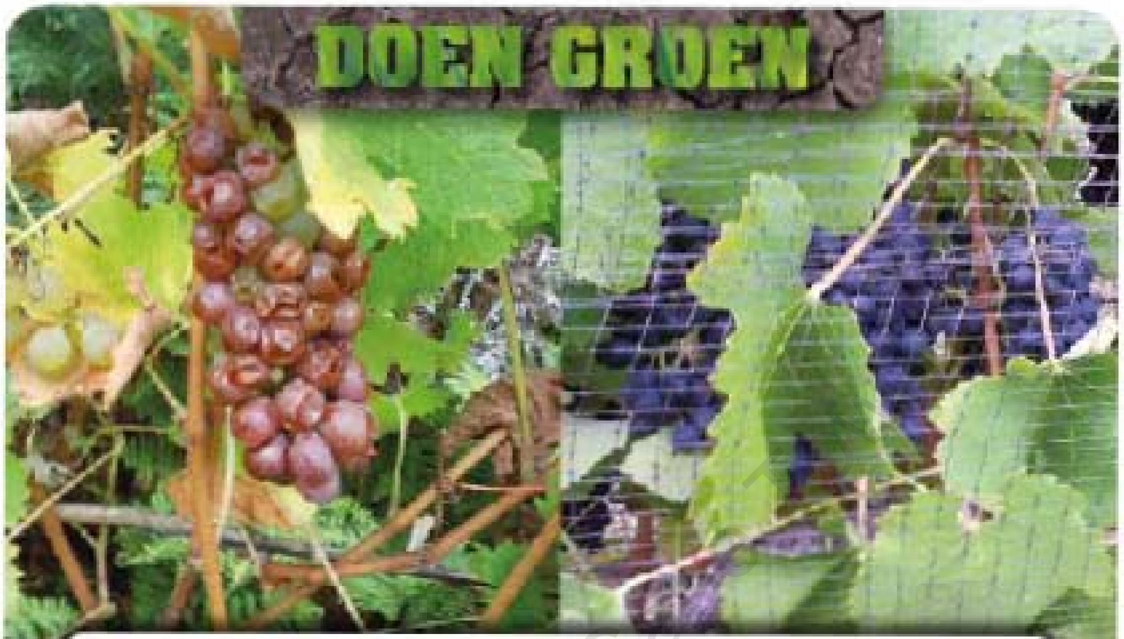
12. At what stage in the grape development is the damage the highest? Please rank each category below between 1 and 5, according to how bad the damage is at each stage of the grapes development (1=no damage, 5=the most damage)

Appearance of first grapes	1 month after first appearance of grapes	1 month before harvest	Harvest time

Appendix B: The article published in the May edition of The Winelands magazine to advertise the bird grape damage research.

DOEN GROEN

deur [illegible]



Voëlskade in die navorsingskollig

[illegible] meer as die plaaslike navorsing daar[illegible]. Daar is talle [illegible] van [illegible], musiek en [illegible] wat voëlskade beperk, terwyl meer drastiese stappe – soos om die voëls met haelgewere te skiet – ook algemeen toegepas word.

Maar kennis oor hierdie onderwerp behoort egter ook meer en [illegible] omgewingsvriendelike oplossings na vore te bring. Niki [illegible] 'n honneurs-navorsingsprojek wat die omvang van voëlskade in die wynlande sal bepaal. [illegible] studie word onder die leiding van Dr Arjun Amar by die Percy FitzPatrick Instituut vir Afrika Ornitologie gedoen.

Volgens [illegible] uitgebreide studies oor voëlskade reeds in ander wynlande soos Australië en die VSA behartig, maar plaaslike navorsing is beperk ten opsigte van die omvang van die skade, [illegible]

Die eerste stap van die navorsing sal 'n vraelys aan wingerdkundiges en wynmakers insluit, om onder andere te bepaal watter voëlsoorte die verantwoordelik is, waar in die blok die meeste skade aangerig word en ook watter kultivars die meeste geteiken word. Niki [illegible] speel in die mate van skade wat aangerig word.

Niki [illegible] – veral diegene wat ly onder buitengewone voëlskade. Wingerdkundiges of wynprodusente wat graag die vraelys sal wil voltooi kan kontak maak by die onderstaande e-pos adres.

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Appendix C: A photograph showing the type of damage that can be done to grapes by birds. This image shows the pecking of grapes, which results in secondary rot.

Appendix D: A photograph showing the type of damage that can be done to grapes by birds. This image shows the removal of whole grapes from the bunches.