

**FINAL REPORT TO THE
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**Bio-economic evaluations of management
strategies for pest birds**

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1. PROJECT OUTLINE

1.1 PROJECT INFORMATION

1.1.1 Project Name

Bio-economic evaluations of management strategies for pest birds

1.1.2 Details of Applicant

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1.1.3 Project Aims and Objectives

1. An evaluation of the costs and benefits of pest bird management strategies.
2. Development of efficient sustainable best practice management strategies for birds.
3. Through participatory learning and education, ensure adoption of modified strategies by pest bird managers.

Outcomes and Outputs

- Recommendations of effective pest bird management strategies
- Provide pest bird managers with advice on the most effective management strategy in a range of conditions
- Reduced impacts and improved management of pest birds
- Changes to existing management practices for pest birds
- Reduced use of in-effective methods and improved adoption of effective and environmentally responsible bird management approaches.

1.1.4 Project Location

This project provides an evaluation of pest bird management strategies using case studies and information collected in the Orange Region NSW and Harcourt Region Victoria.

The Orange region (149.3° E, 33.3° S) falls within the Central Ranges zone which spans an elevation from 245m at Forbes to 1100m at Oberon and also includes the viticultural regions of Cowra, Mudgee and Forbes. The zone has a variety of soils suitable for viticulture and horticulture. The other main agricultural enterprises in the region are merino wool, prime lamb and beef cattle production and winter cereal cropping.

Orchards of Orange surround Mount Canobolas at 990m above sea level and are interspersed with scattered eucalypts (*Eucalyptus macrorhyncha*, *E. seeana*, *E. tereticornis*, *E. viminalis*), pine (*Pinus radiata*) plantations, mixed farming, apple and stone-fruit orchards and sheep and cattle grazing country. The area has a cool climate

with medium to high rainfall. 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, with cabernet sauvignon, cabernet franc, merlot, shiraz, pinot noir, sauvignon blanc and chardonnay the primary varieties grown. Many varieties of apples (Jonagold, Sun-Downer, Pink Lady, Braeburn, Granny Smith and Fuji) and cherries (Lapins, Sweetheart, Sunburst, Chelan, Merchant, Rons, Kordia, Simone, Regina) are also grown.

The Harcourt Region (144.3° E, 37.0° S), central Victoria is at the foot of Mount Alexander, has fertile granite soils and a temperate climate, which is ideally suited to fruit growing. The major apple varieties grown in Harcourt are Granny Smith, Gala, Cripps Pink (sold as Pink Lady™), Fuji and Cripps Red (sold as Sundowner™). Pear varieties are Packham, Williams (WBC) and Beurre Bosc.

2. COSTS AND EFFECTIVENESS OF MANAGEMENT STRATEGIES FOR PEST BIRDS

2.1 INTRODUCTION

Pest birds cause direct losses to agriculture of in excess of \$290 million each year (Tracey et al. 2007), and adversely impact on biodiversity and social amenity. Over 60 bird species are known to damage horticulture crops in Australia (Tracey et al. 2007), including many native species, such as cockatoos and corellas (ENRC 1995), crows and ravens (Sinclair 1998), silvereyes (Rooke 1983), lorikeets (Paton and Reid 1983; Temby 2002), rosellas (Fisher 1991) and honeyeaters (Tracey et al. 2001). Of the introduced species in Australia, starlings are regarded the most serious pest to horticulture (Tracey et al. 2007). Starlings also cause significant damage to cereal crops (Dolbeer et al. 1978), feedlots and grain storage areas (Feare 1975); they usurp native hole-nesting birds (Green 1983; Pell and Tidemann 1997); and are potential hosts of parasites and diseases (Weber 1979). The ecology, breeding and behaviour of all these species, which are markedly different, influence the timing and severity of damage, and are important to consider in implementing effective controls.

While significant losses from birds are commonly reported, bird damage is rarely measured directly (Bomford and Sinclair 2002; Tracey et al. 2007 for review), and few attempts have been made to estimate pest bird impacts on a national level (Bomford and Hart 2002; Tracey et al. 2007; Gong et al. 2009). Surveys of land managers (Bomford 1992; Graham 1996; Graham et al. 1999; Chapman 2007) are an efficient way of providing information on perceived impacts and control of pest animals over large areas. However, there are several well-known biases associated with these surveys (Tracey et al. 2007). For example, landholders may over- or underestimate damage (MacDonald and Dillman 1968), or those with higher levels of damage may be more likely to respond (Dawson and Bull 1970). Accurate measures of damage are important for effective decision making at a local and national level.

The most commonly used methods to reduce impacts of birds include netting, scaring, shooting, trapping, and poisoning (Tracey et al. 2007 for review). Netting is

increasingly used to protect orchards, despite high up-front and on-going costs (Slack and Reilly 1994). Assuming nets offer complete protection, netting can be cost-effective in vineyards where bird damage exceeds 15% (Tracey and Vere 2007). While scaring with visual or acoustic devices, is usually in-effective (Bomford and O'Brien 1990; Bishop et al. 2003; Tracey et al. 2007 for review).

Lethal controls for pest birds are often used, but most attempts fail to reduce pest bird populations or damage in the long-term. For example, shooting to reduce wood pigeon impacts in Cambridgeshire UK (Murton et al 1974), organophosphate for controlling quelea in Africa (Ward 1979), PA-14 to control starlings and blackbirds in Tennessee, North America (White et al. 1985), and explosives to reduce starling damage to cherries (Tahon 1980) failed to cause long-term reductions in pest bird population or the damage they cause. Feare (1991) suggests two main reasons for this, (1) that pest birds usually have a wide geographic range and much of the population is inaccessible to control and (2) that control attempts can be counter-acted by compensatory increases in breeding and survival.

In comparison the use of lethal control where most of the population is accessible, where the species has low reproductive rates (e.g. laughing gulls, Dolbeer 1998), or where they are highly concentrated can result in large population reductions in the short- (West 1968; Besser et al. 1967; Besser et al. 1984; Blanton et al. 1992) and long-term (Porter et al. 2008).

The Bureau of Rural Sciences (BRS)' national guidelines for pest birds identified major deficiencies in the costs and efficacy of commonly used control techniques for pest birds. This is a fundamental problem for managers of pest birds that should be addressed before sustainable best practice management strategies can be recommended. The problem for pest bird managers is deciding on an appropriate technique or combination of techniques to use, and the level at which to apply them.

An evaluation of the costs and benefits of pest bird control strategies and combinations is required that incorporates the high variability of pest-agriculture systems. This project has taken into account the variables known to influence populations, damage and costs and benefits of management over time; and

investigates how and when a range of biological and economic factors will influence pest bird populations, the impacts they cause to agriculture, and the success of strategies for their management.

This chapter will compare cost and benefits of methods to reduce pest bird populations and damage, including poisoning, trapping, shooting and netting.

2.2 METHODS

2.2.1 Bird abundance

Bird abundance was estimated at each site using variable circular plots (Bibby et al. 2000). Bird observers counted all species seen or heard for 10 minutes from fixed locations at each site (n=2,295 bird counts on 62 sites). Numbers of individuals, distance, habitat and activity were all recorded to allow estimation of detection probabilities in different conditions. An additional area search method was used to monitor starling populations over time. This method involved recording the number and location of all starlings during a standardised route of the study area, the presence of other species was also recorded. were used for the analyses.

2.2.2 Bird damage sampling techniques

Bird damage was estimated in wine grapes and cherry, apple and pear orchards using methods described by Tracey and Saunders (2010) with the following differences. For cherries the number of damaged and undamaged cherries were counted in three cherry clusters, selected from one of 16 randomly allocated selected zones each selected tree. Trees from each block were systematically selected, with outside stratum sampled more intensively. To assess different types of damage, sampling occurred at various stage of flower, bud and fruit development. In apple orchards the number of damaged and undamaged apples were counted from one of six randomly allocated zones on each selected tree, with trees from each block systematically selected. To account for damage caused early in the season (especially by Sulphur-crested cockatoos), old fruit on the ground under the tree was inspected for signs of damage. Cockatoo damage is distinct from damage by other species as they split the fruit in half to retrieve the seeds in the core.

2.2.3 Control techniques

Methods for shooting, netting and trapping for the Orange Region case study are described in Tracey *et al.* (2008). Detailed information was collected to determine the ongoing and upfront costs of each technique. For shooting, this included the number of shooters, time and duration of shooting activities, the number of shots fired, cost of ammunition, cost and type of firearm, number of birds shot, bird species, age and sex (where possible), costs of vehicle (if applicable), location and habitat.

Labour costs were also estimated for the intensive control site, where two people spent 30 hours (60 person hours) to complete the initial search. Labour was recorded for all activities, including subsequent checking of natural nest hollows (127 natural hollows marked, 2 people for 12 hours, 24 person hours), nest boxes (43 boxes, 1 person for 1 day per week for 6 hours, 12 times between 15/10/2007 and 16/1/2008, 72 person hours) and nest box traps (daily checks for 55 days between 5/10/2008 and 20/12/2008, 27.5 person hours), and time spent shooting. On the intensive control site, three shooters at different times spent approximately 925 minutes (over 15 hours) shooting. The duration of shooting at the intensive site ranged between 30 minutes and 180 minutes.

Methods for the cage and field bait acceptability trials are described in Tracey *et al.* (2006). In the bait trial, bird abundance was estimated per day at each site using methods described in section 2.2.1, conducted after every hour of observation through-out daylight hours. Time of day was classified into Morning (6:00-10:00), Midday (10:00-14:00) and Afternoon (14:00-18:00) for analyses. Bird observers counted all species seen or heard for 10 minutes from fixed locations at each site. The proportion of birds feeding was estimated using (1) the number of unique birds feeding per day by excluding all repeated observations of the same flock, divided by (2) the maximum number of unique birds seen during point counts.

2.2.4 Analysis

Bait trials

The effects of bait type, abundance, number of days of feeding, site, time of day on the number of birds visiting feeding trays were examined using ASREML (Gilmour et al. 2006) in Program R. ASREML estimates variance components under a general linear mixed model by residual maximum likelihood. Wald tests for fixed and random effects (Gilmour et al. 2006) were used to test the significance of variables after first removing effects of other significant variables in the model. Analyses were conducted separately for each of the 3 species; starlings, corvids (Australian and little ravens) and magpies. The Poisson distribution was used in all analyses, and a dispersion argument included for the starling model, as this data was over-dispersed. Errors bars in all figures show 95% confidence intervals. Costs of labour (1 hour/ day/ site @\$15/hour) and feed (\$9 / day/ site) during bait trials were used to estimate costs of poisoning per site.

Empirical-based predictive model

A linear modelling approach (Crawley 1993) was used to investigate the effects of 18 variables on percent block damage (logit transformation), including harvest date, variety, variety colour, vineyard size (square root transformation), block size (square root transformation), area of vegetation (a separate covariate was included for the area of native, pine, other exotic, adjacent vineyard within 1 kilometre of the vineyard boundary), distance to landscape features (dead trees, powerlines, buildings), pest bird density, pest bird species, diversity (number of bird species observed). Habitat variables were estimated using spatial and proximity analysis in Arcview 3.2. The procedure used was typical of linear models and followed a step-wise progression from the maximal (full) model through a series of simplifications and deletions to the minimal adequate model. The maximal model contained all 18 factors and covariates. Higher-order interactions were progressively removed if they were not significant ($P < 0.05$) using an analysis of variance (Crawley 1993). A monotonic logit transformation of the response variable was used to remove heterogeneity of variance (Snedecor and Cochran 1989). Standard residual plots (e.g. Cochran 1951) on the subsequent data indicated that the variance was homoscedastic. Size was transformed back to distance units using a square root transformation which reduced the disproportional effects of large sized blocks.

An alternative mechanistic or theoretical modelling approach was also used, which required use of data collected on the underlying biology. This type of approach is especially useful in more variable environments (Mangel et al. 2001). A power analysis conducted indicated the existing data of 94 sampling occasions in vineyard blocks over two seasons was sufficient to detect structural elements using generalised linear modelling (step I). The subsequent mechanistic and system modelling phase included factors according to available data and level of significance.

Evaluation of management techniques

Linear mixed models and analysis of variance were used to test for the effects of treatment (Nil, Shooting, Netting), orchard size (0.25 – 500 ha), year (2000-2008) and crop type (grapes, apples, cherries) on percent bird damage by property (response variable). Models were also used for netting and shooting separately, to test the effects of net type (single black extruded, green extruded, side, and single, double, triple and quad drape-over) (netting model), number of birds shot (shooting model), crop type, year, orchard size, ongoing cost (including labour), capital cost and total cost per hectare on percent bird damage by property. Square root transformations were applied to orchard size to linearise the response. ASReml (Gilmour et al. 2002) in Program R (Venables and Smith 2004) was used for the analyses, which estimates variance parameters using Residual Maximum Likelihood (REML) (Patterson and Thompson 1971). Wald tests were used to examine fixed effects and terms were added sequentially; adjusted for those above. Total costs for treatments included all anticipated direct upfront and on-going associated with the technique including labour (\$15/hour), and machine and vehicle hire and running costs (maintenance, fuel, labour). Up-front capital costs of netting were based on 2008 prices (single drape-over \$4356/ha, double row drape-over \$4860/ha, triple row drape-over \$4212/ha, side nets \$3200/ha, extruded netting \$2000), and were depreciated over 7 years. Netting machines were depreciated over 25 years. Other costs included post caps for netting, labour in repairing and removing nets for spraying, and tying nets down where applicable. However, indirect costs associated with netting such as any changes to orchard management, increased pruning or spraying, removal of prunings from between rows etc. were not included. For shooting, vehicle running costs were based

on 60 cents per kilometre for a Ute or 4WD and 20 cents per kilometre for motorbikes. Ammunition was assumed to cost 38 cents per shell (7 ½ shot).

A dynamic bio-economic framework was used to evaluate pest bird management strategies. This is particularly appropriate for pest birds due to the potential carryover effects of management upon populations; high population turn-over of pest birds; and the high variability of pest bird- agriculture systems. For example any bird that escapes control in one period has the potential to reproduce and thus increase populations in later periods. Therefore, it helps to view pest birds as a negative resource stock that needs to be managed over time. This allows a change in the assumption of profit maximisation for pest bird control for a single season or year to an assumption of maximising returns over a longer period.

The objective of this approach was to determine the economic benefits for managing a pest bird population in an agricultural landscape, using starlings in wine grapes as a case study. The state variable is the pest bird population density (starlings/ha) and the decision is the combination of pest bird management options of no-control, netting, shooting, trapping, and intensive control during the starling breeding season. Economic and effectiveness data from field experiments was used for each of these strategies. The transition in the pest bird population (P) was assumed to be a function of the intrinsic growth processes and any management combination. An age-structured model (Leslie matrix) was used. The variable P is a function of the initial population size prior to control and the mortality from shooting, trapping, poisoning and intensive control during the starling breeding season. Detailed costs of management strategies and other economic factors was incorporated into these models. A cost function approach was used for deriving costs of control, which allowed for the cost per pest bird to vary as population declines to reflect the higher marginal costs of control as pest numbers decline (e.g. a power function).

This process first determined the optimal decision for pest bird populations and second determined the effect of implementing the optimal decisions over time for different initial pest bird populations. Results were presented in annual pest bird population, and overall economic performance measures in terms of net present

values and benefit-cost ratio. These models are available from john.tracey@industry.nsw.gov.au. An example is presented in Figure 1.

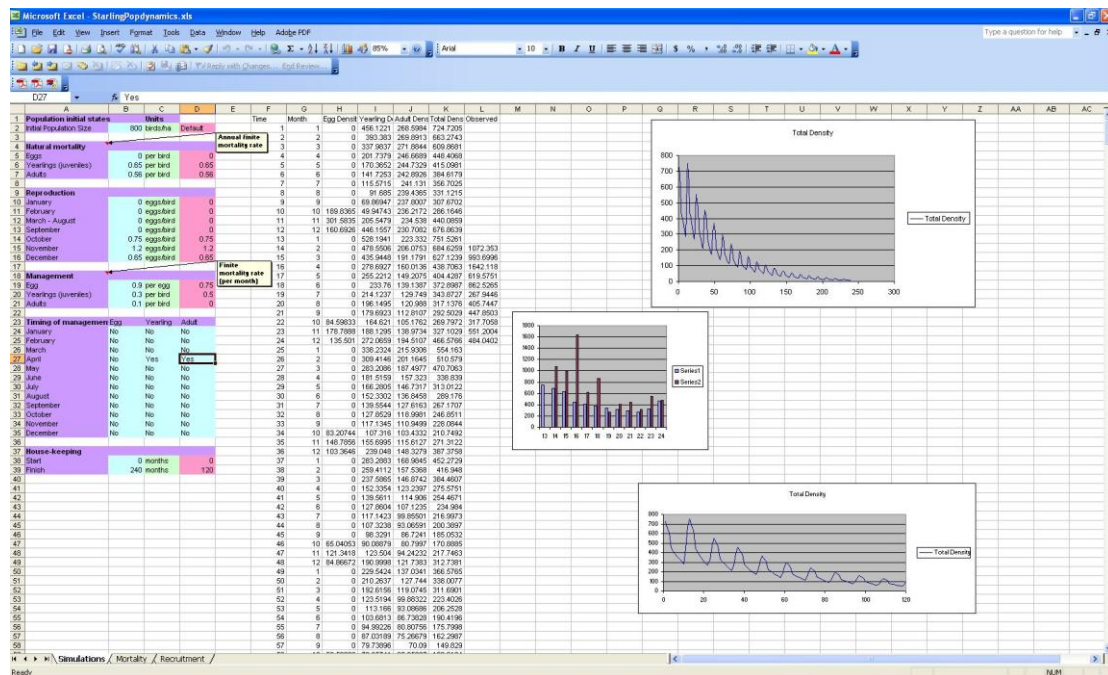


Figure 1: A population model to identify the optimal timing, cost and effectiveness of pest bird management strategies.

2.3 RESULTS

2.3.1 Poisoning

Sultanas, dog biscuits and bread and dripping were preferred food items for starlings during the cage trial, with approximately equal proportions consumed. Table grapes and poultry pellets were occasionally consumed, and wheat was avoided. The overall mean quantity consumed per starling per day was 19.90 ± 1.72 grams. Slight changes in diet were observed over the cage trial period, with starlings switching preferences from dog biscuits to sultanas (A power function, $y = 0.17 x^{0.30}$, $r^2 = 0.66$ for sultanas, and a log function, $y = -0.12 \ln(x) + 0.52$, $r^2 = 0.71$, for dog biscuits showed a good fit to the data, where y is the proportion of bait media consumed and x is the time in captivity). Consumption of the other food types was constant during this period.

Overall starlings were most abundant on field sites (Tracey et al. 2006) and the most common species to visit (60%, n=1609) and feed from (53%, n=1564) bait trays.

Magpies (23%, n=1564), corvids (12%, n=1564), magpie larks (5%, n=1564), and white-winged choughs (4%, n=1564), sulphur-crested cockatoos, crested pigeons and pied butcherbirds were the other species observed feeding from trays. Other native species present (Table 7.1) did not consume food from trays.

Starlings, corvids and magpies showed clear preferences for particular bait types. Bread and dripping was the preferred feed type overall, particularly for starlings, corvids, magpies and magpie larks (n=1564 feeding visits during 318 hours of observation). Starlings also regularly fed on sultanas and dog biscuits. Sultanas were the most target specific for starlings, with 96% (n=322) of the total feeding visits made by starlings. Australian ravens and magpies were the other species that fed on sultanas. However, this occurred on only 7 and 6 occasions respectively.

For starlings, bait type, free-feed days and abundance were significant ($P < 0.0001$) in the final model. Bread and dripping, sultanas, and dog biscuits were preferred, while poultry pelts and wheat were avoided. Feeding activity and consumption increased after 15 days, and was highest after 24 days. The mean proportion of starlings feeding from trays after 21 days (3 weeks) was 0.5 ± 0.34 (95% confidence interval, n=4).

For corvids, bait type and free-feed days were significant ($P < 0.0001$) in the final model. Corvids displayed a clear preference for bread and dripping over other bait media presented, and visits increased gradually with days of free-feeding (Poisson: size of effect for free-feed days = 0.0213). For magpies, bait type and property were significant ($P < 0.0001$) in the final model, with an obvious preference for bread and dripping (Fig. 3x c). A higher number of starlings visited trays (4.46 ± 0.85 per hour, n=194 observations), than corvids (1.08 ± 0.85) and magpies (2.01 ± 0.85).

2.3.2 Comparison of management strategies

Treatment (Nil, Shooting, Netting), Year (2000-2008), and their interaction were significant in the overall model. Bird damage was significantly less on netting and shooting treatments than nil treatments after taking out the effects of other factors. Orchard size (0.25 – 500 ha), crop type (grapes, apples, cherries) and other interactions were not found to be significant. For the netting model, net type (single

black extruded, green extruded, side, and single, double, triple and quad drape-over), crop type, year, orchard size, ongoing cost (including labour), capital cost and total cost per hectare were not significant ($P > 0.05$, log likelihood = -80.4536, sum of squares = 132.8514, $df = 26$). For the shooting model, the total cost was the only significant co-variate ($df = 1$, Sum of squares = 123.645, Wald statistic = 15.271, $P < 0.0001$). The number of birds shot, crop type, year, orchard size, ongoing cost (including labour), capital cost and total cost per hectare were non-significant ($P > 0.05$). Bird damage on shooting sites was lower than nil treatments by 11.4%, on average (Nil mean damage = 23.9%, $SE = 4.6$, $n = 31$; Shooting mean damage = 12.5%, $SE = 2.7$, $n = 41$). While bird damage on netting sites was lower than nil treatments by 12.4% (Netting mean damage = 11.5%, $SE = 1.8$, $n = 43$). The mean total investment in shooting (Capital + on-going costs including labour) was \$538 + 278 ($n = 41$) per hectare per property, while the mean total investment in netting was \$1,903 + 601 ($n = 43$) per hectare per property.

For trapping population modelling indicated that long term reductions in starling populations would have been achieved in only 3 of the 28 site/ years that trapping was conducted. Population models developed using fecundity and immigration data predicted changes to the resident population without control. The population on the intensive control site was estimated to have reached 275 birds if no control was implemented, which is more than three times as high as the population was after breeding with control.

The relative abundance of bird species observed in the intensive site was consistent with other sites, with starlings the most common species followed by eastern and crimson rosellas. Bird damage to blocks ranged between 0% and 57% in the Orange Region, with an average of 2.55% + 1.44 ($n = 78$ blocks), which is lower than recorded in other years (Tracey et al. 2008). The damage recorded at the intensive control site was considerably lower than the other sites (Figure 2), with all blocks suffering less than 1% damage.

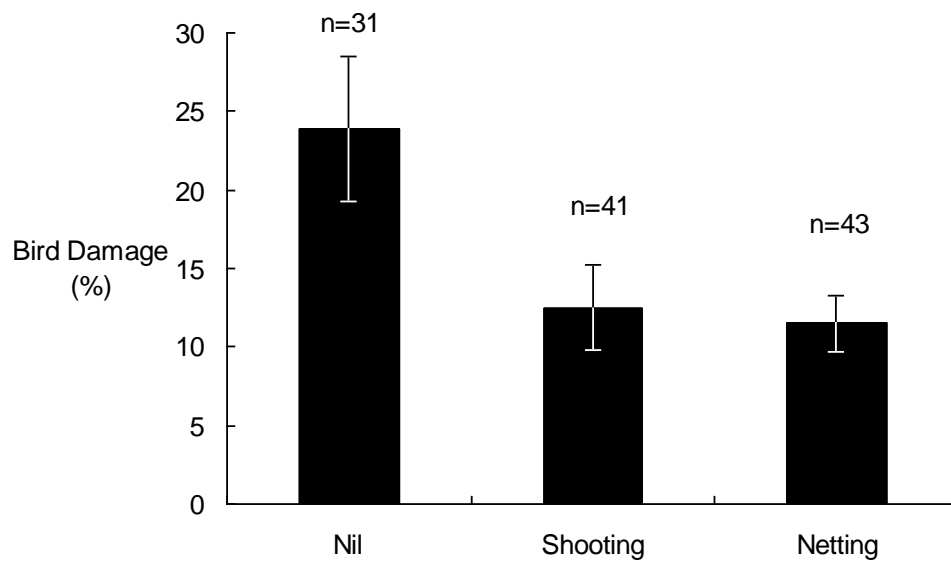


Figure 2: Mean bird damage (%) by treatment. n=115 properties. Errors bars show standard error.

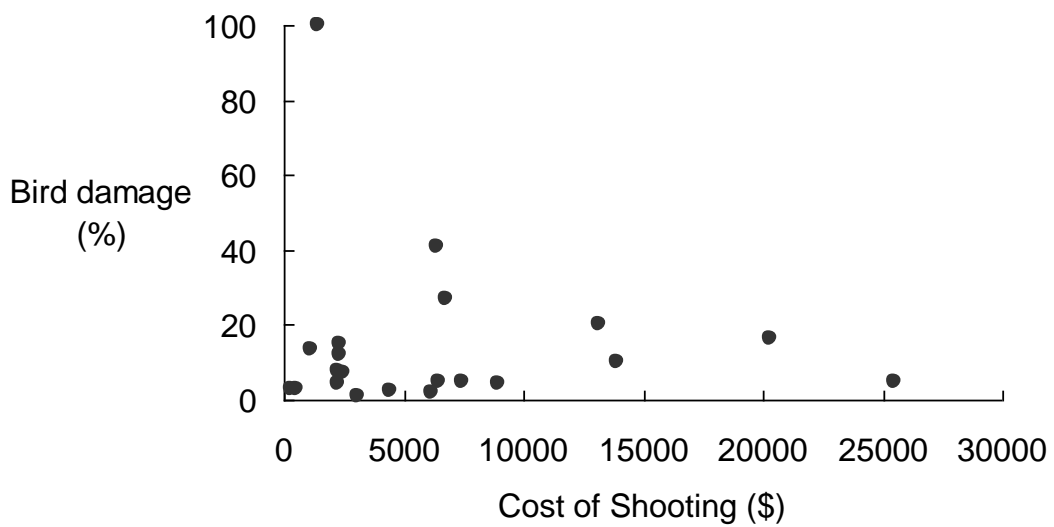


Figure 3: Bird damage (%) versus overall investment (\$) in shooting per property.

2.4 DISCUSSION

2.4.1 Poisoning

Although avicides are currently used in some states of Australia (alphachloralose, 1,4-aminopyridine and fenthion) for specific purposes (Tracey et al. 2007), this occurs on a small scale and the extent they reduce impacts is unknown. Effectiveness (Porter et al. 2008), community attitudes (Tracey et al. 2007), impacts on non-target species (Bruggers et al. 1989; Cummings et al. 2002; Custer et al. 2003), animal welfare concerns (Ministry of Agriculture Fisheries and Food 1997); and residual or secondary effects in the food chain (Cunningham et al. 1979; Schafer 1984) require careful consideration before avicides are considered.

In North America and New Zealand avicides are currently applied to cereals, cereal pellets, bread and dripping, sultanas, nuts and potato chips for controlling pest birds including starlings, red-winged blackbirds, corvids, ravens and gulls, and magpies (Bull 1965; Besser et al. 1967). Preferences of non-target species to different food types are an important consideration as most avicides are toxic to all bird species. DRC-1339 is an exception, where starlings, corvids and gulls are highly sensitive (United States Department of Agriculture 2001; Eisemann et al. 2003), while mammals (except cats) and many native North American birds are not susceptible (Eisemann et al. 2003).

Target specificity, bait uptake and acceptability were used in considering the costs and benefits of poisoning for starlings, corvids and magpies. Information on the acceptability of novel food types by pest birds and other non-target species is valuable to improve the effectiveness of management and research programs involving poisoning or trapping.

Grain-based pellets using either poultry layer mash (Johnson 1994), corn (Knittle et al. 1980) or rice (Linz et al. 1995) are the recommended and most commonly used bait media for starlings and blackbirds (red-winged blackbirds, *Agelaius phoeniceus*,

yellow-headed blackbirds, *Xanthocephalus xanthocephalus*, and grackles, *Quiscalus quiscula*). While poultry pellets were consumed by starlings in the current study, bread and dripping, sultanas and dog biscuits were consumed in preference in both field and/or cage trials. Sultanas were the most target-specific for starlings, with corvids and magpies commonly consuming bread and dripping and occasionally dog biscuits. Familiar food types are usually preferred, for example, poultry feed at feedlots, grain at grain storage areas, fruit in vineyards, almonds in nut orchards, corn in corn growing areas, bread or dog biscuits in residential areas.

Diluting poison bait with untreated feed is recommended for reducing non-target impacts, for example 1:25 (Linz et al. 2002), or up to 1:200 is recommended (West et al. 1967). However starlings in the current study were less abundant (e.g. mean 260 this study versus 77,000 Knittle et al. 2002), required longer periods of free-feeding (23 days vs 1-4 days Johnson 1994), consumed less (gms per starling per visit) and were less likely to feed from feeding stations compared with these other studies (West et al. 1967; Linz et al. 2002). High dilution rates in the present study may reduce effectiveness for starlings, while still exposing ravens and magpies, which fed more consistently and for longer periods than starlings. Magpies, corvids and magpie larks would be the main non-target species at risk from a starling baiting program. However, a small number of white-winged choughs, sulphur-crested cockatoos, crested pigeons and pied butcherbirds may also be exposed. Other non-target species may be at risk in other areas for example along watercourses or near dams. Coots, mallards, Pacific black ducks, wood ducks, and grey teal are easily attracted to grain or bread, and anatids are susceptible to DRC-133 (Eisemann et al. 1999), as well as other toxins.

Knittle et al. (1980) suggests that bait consumption estimated using cage and field trials is the most reliable method of estimating overall effectiveness of baiting compared to other methods, including using change in population estimates and/ or numbers of dead birds recovered during systematic searches. In the present study the estimated abundance and visitation of bait by starlings indicates that a mean reduction of 50% could be achieved after 3 weeks of free-feeding. While this period of free-feeding is longer than recommended in other studies (1-4 days Johnson 1994), differences in the familiarity with food types, varying feeding rates, and therefore efficacy are expected in different locations.

Increased baiting efficacy and higher feeding rates by starlings were recorded where there are larger numbers of birds (77,000 Knitte et al. 1980), larger amounts of food presented (23kg), and where baiting occurred during winter, when alternative foods are likely to be limited. In comparison, the current trial sites are located in productive agriculture area with medium to high uniform rainfall (mean annual rainfall: 920 mm), where alternative food, including grasshoppers and other insects, ground invertebrates, and food scraps are regularly available. In arid and semi-arid rangelands during dry periods, where pasture growth is limited and food availability is lower, starlings may be more easily attracted to novel foods, or water. Starlings in the present study were regularly observed probing the soil and foraging for invertebrates, their preferred food source.

Bread and dripping was the preferred bait type for corvids and magpies. These species often feed on carrion (Higgins et al. 2006); and meat baits, offal, small mammal carcasses or eggs are regularly used to poison or capture them (Johnson 1994). However, other non-target species are also likely to be attracted to meat baits, including wedge-tailed eagles, little eagles, whistling kites, black kites and other raptors, butcherbirds, currawongs, grey shrike thrush (eggs), and mammals such as quolls, feral pigs, dogs, foxes, cats, antechinus, and native and introduced rodents. Other food types are also used for corvids and magpies, such as crumbed cheese, butter, corn, milo heads, watermelon, and poultry feed (Johnson 1994).

2.4.2 Comparison of management strategies

Netting and shooting treatments were equally effective in reducing bird damage (12.4% and 11.4 % lower than nil treatments respectively), despite the cost of netting (\$1,903/ha/property) being almost three times higher than the cost of shooting (\$538/ha/property). The significance of the interaction between Year: Treatment indicates that shooting and netting was more successful in years where damage was higher.

The benefits of shooting reported here, are most likely to be a result of scaring birds from the crop, as the number of birds shot was unrelated to the extent of damage caused.

Lethal control is often found to be ineffective for reducing populations of pest birds in the long term (Tahon 1980; Murton et al. 1974) and there are no other known experimental studies that have reported reduced crop damage as a consequence of shooting. In contrast a study of wood pigeons and damage to brassica crops showed that an intensive shooting campaign in the experimental area did not result in less damage than at control sites (Murton and Jones 1973). The current study investigates the efficacy of existing techniques using currently used methods of application; it does not represent a best case scenario for techniques used, and control efforts weren't balanced between treatment sites. So while increased shooting effort may result in lower damage, growers are also likely to increase effort where damage is high. It is not possible to separate these effects.

Bird damage was consistently evident under bird netting, which may have been a result of: delayed placement of netting, breaches in the net as a result of nets catching on posts and wire, birds consuming fruit through nets, birds breaching nets - through holes or underneath netting, smaller species (silveryeyes, yellow faced honeyeaters) entering through large mesh sizes, or placement of nets by orchardists where damage was likely to be greatest. The labour costs to put out and take in drape over netting decreases the effectiveness of this method. In addition orchardists may delay net placement until after the final spray, or until bird damage is evident. This emphasises some of the difficulties of netting and the need for improved applications.

Trapping was labour intensive and therefore expensive and, with the exception of 3 of 28 occasions, would not have resulted in a reduced starling population in the following season. In comparison, starling population size and damage to wine grapes was markedly less on the intensive control site than other treatments. While the intensive control of starlings during the breeding seasons appears to effectively limit the resident population and reduce damage, immigration during ripening is still occurring, limiting the benefits of control. Bait trials and analysis indicate that poisoning is cost-effective (50% reduction in the resident population @ \$240/site) in some cases. However, bait uptake by target and non-target species was highly variable between sites, which will limit its application in agricultural areas.

3. ECONOMICS OF BIRD NETTING: A TOOL FOR HORTICULTURISTS

Managing the impacts of pest birds is difficult as damage is highly variable between seasons and few techniques have been shown to be cost-effective. Permanent netting is effective in reducing damage but involves significant up-front costs. Careful consideration of costs and long-term benefits of netting is required. The purpose of this chapter is to develop a simple tool to allow horticulturists to compare the costs and benefits of permanent bird netting over time. The tool is flexible for value of production (\$/tonne), bird damage levels, and upfront costs of net. These can be entered by each grower (Figure 4, program available from john.tracey@industry.nsw.gov.au). The Harcourt apple growing region was used as a case study. Birds, particularly musk lorikeets (*Glossopsitta concinna*), are a serious problem for apple growers in Harcourt, Victoria. Harcourt growers have reported combined losses of up to \$1.5 million in a season.

Benefits and Costs of Netting Apples in Harcourt				Production			
Inputs				Tonnes/Ha (without bird damage)	Year	Tonnes/Ha	
4	Tonnes/Ha without bird damage	35.2		35.2	1	30.624	
5	Price \$/tonne	\$1,254	Critical input value 1	35.2	2	30.624	
6				35.2	3	30.624	
7	Bird Damage (%)	13%	Critical input value 2	35.2	4	30.624	
8				35.2	5	30.624	
9	Costs of Permanent Netting			35.2	6	30.624	
10	Upfront cost: Net + labour of construction (\$/ha)	\$40,444	Critical input value 3	35.2	7	30.624	
11	Annual cost (maintaining net) (\$/ha) Min (Year 1)	\$200		35.2	8	30.624	
12	Max (Year 10)	\$1,000		35.2	9	30.624	
13				35.2	10	30.624	
14	Discount rate (%)	5.00%					
15							
16							
17	Returns and Costs of Netting						
18		Year	Increase in Production	Return (\$)	Cost (\$)	Net Return (\$)	
19		1	4.576	\$5,736	\$40,644	-\$34,908	NPV costs 42,550.71
20		2	4.576	\$5,736	\$200	\$5,536	NPV returns 44,232.00
21		3	4.576	\$5,736	\$300	\$5,436	NPV 1,741.28
22		4	4.576	\$5,736	\$400	\$5,336	BCR 1.04
23		5	4.576	\$5,736	\$500	\$5,236	
24		6	4.576	\$5,736	\$600	\$5,136	
25		7	4.576	\$5,736	\$700	\$5,036	
26		8	4.576	\$5,736	\$800	\$4,936	
27		9	4.576	\$5,736	\$900	\$4,836	
28		10	4.576	\$5,736	\$1,000	\$4,736	
29							
30							
31	Net Present Value		Benefit Cost Ratio				
32		\$1,741	1.04				
33							

Figure 4: Decision support tool to evaluate the costs of bird netting for horticulturists.

Inputs in Blue (production) and Orange (bird damage)

Outputs (Net Present Value and BCRatio) in green:

NPV is the value of the proposition (Permanent Netting) in today's terms.

BCR>1 is profitable

Assumptions:

- This is a marginal Benefit–Cost Analysis, and does not include overall costs and benefits of production.
- Orchard development costs are not included- e.g. how long do trees last?
- Proposition for an established orchard.
- 10 year life for net (Alternative presented for 15 years in 2nd sheet.)
- This analysis assumes that bird netting is 100% effective (i.e. reduce bird damage to 0%) when maintained- this is not always true in practice due to breaches in the net.
- Discount rate of 5%
- Upfront net costs were estimated for netting apples in Harcourt.
- Increasing costs of maintaining net from \$200-\$1000 per hectare

Other considerations (not included):

- Unit costs (\$/t)- handling, processing, freight: Trade-off: without nets less fruit to process (\$ saving) but damaged fruit takes longer to sort (increased \$)
- Tax considerations (depreciation)
- Sensitivity analysis
- Other benefits or costs of netting:
 - decreased wind rub, blemishes, disease considerations etc.
 - trade offs: disease increase because of higher and more constant humidity but more control over spray regime because of less downtime for weather
 - less water because more efficient under nets- longer irrigation intervals
 - more control over ripening- no cracking from water stress and resultant physiological damage
 - Slower ripening depending on variety and region
 - Colour problems if pruning not adequate.
 - insects both pollination and damage

General Conclusions:

Results are strongly dependent on:

1. \$/tonne
2. Average bird damage levels over 10 years.
3. Upfront costs of net.

For example, with the above assumptions, and using figures from Harcourt (\$1,250/tonne) permanent netting would be profitable for growers experiencing greater than 13% bird damage (on average for 10 years). This may be more profitable than for other Victorian apple-growers where average \$/tonne were reported to be \$500-\$850/tonne in 2006 - i.e. bird damage of 20% before netting is profitable.

Further development: Sensitivity analysis, more detailed descriptions of (and testing of) assumptions. Analysis and presentation of graphs to show pay-off periods etc., expand to a web-based decision support tool.

4. EDUCATION AND EXTENSION

A coordinated communication and extension strategy was incorporated in project objectives. Involvement with other government agencies, researchers, and industry at a local, state and national level ensured that applications were well understood and that any proposed activities were not replications of other work. Pest bird experts, managers and industry representatives including vigneron, orchardists and other agriculturists, state and regional industry associations were involved in the project through regular meetings, workshops, phone and email contact and on-going communication of project objectives, methods, results and implementation. The project was a collaborative effort between research institutions and growers, and continual feedback was communicated via existing networks. Key stakeholders were directly engaged in the development and implementation of this project, and in the application of results. This was achieved locally and regionally via on-site orchard visits, and by holding workshops and targeted meetings with the horticulturists in Orange Region of NSW and Harcourt region of Victoria; and achieved nationally by regular communication with the Invasive Animal CRC and industry groups.

Extensive consultation was an integral component of establishing agreed directions for this project. This project has been proposed as it specifically addresses key research

priorities endorsed nationally by Vertebrate Pest Committee and many government and industry partners. This project is part of a highly collaborative initiative, demonstrated by the success of the national adoption of best practice guidelines and agreement to national research priorities for pest birds, and the adoption of economic decision tools by horticulturists. More information available from:

<http://www.dpi.nsw.gov.au/agriculture/pests-weeds/vertebrate-pests>

On-going involvement by landholders, researchers and many other stakeholders was achieved by:

- the development and adoption of a coordinated communication and extension strategy,
- incorporating extension and communication in project objectives
- regular meetings, workshops and on-going communication of project objectives, methods, results and implementation.
- on-site orchard visits,
- holding of workshops and targeted meetings with the Orange Region, NSW and Harcourt Region Victoria,
- regular communication with other state agencies, research and industry organisations and horticulturists.
- seeking continual feedback from research institutions and growers.

The extension and communication strategies were important to ensure this project met the needs of government and industry, that outcomes were adopted, and that subsequently pest birds are more effectively managed.

4.1 TABLE OF OUTPUT MEASURES

Output measures	
Number of awareness-raising event participants in person-days (e.g. 20 participants at a 2-day workshop equates to 40 person-days)	40
Number of written products such as brochures, newsletters, posters or factsheets and estimated number of recipients (if any, please also report on media opportunities)	2, 40

Number of media opportunities resulting in articles in newspapers or on radio or television	
Number of websites developed or significantly enhanced	
Number of training sessions, workshops, seminars or other skills and training events conducted and number of training participants in person days	2, 40
Number of workbooks, course notes or other key materials developed and number distributed	2, 40
Number of new databases developed	
Number of community groups OR projects assisted	2
Area (ha) of pest animal control measures (=properties involved in the development of the economic decision tools)	400
Number of best management practice codes or guidelines completed	
Number of models developed	5
Number of information management systems developed	
Number of other decision support tools developed	2

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