Managing Bird Damage to Fruit and Other Horticultural Crops Managing Bird Damage to Fruit and Other Horticultural Crops


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to Fruit and Other Horticultural Crops

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DEPARTMENT OF AGRICULTURE, FISHERIES AND FORESTRY

Bird damage is a significant problem in Australia with total damage to horticultural production estimated at nearly $300 million annually. Over 60 bird species are known to damage horticultural crops. These species possess marked differences in feeding strategies and movement patterns which influence the nature, timing and severity of the damage they cause.

Reducing bird damage is difficult because of the unpredictability of damage from year to year and a lack of information about the cost-effectiveness of commonly used management practices. Growers therefore need information on how to better predict patterns of bird movement and abundance, and simple techniques to estimate the extent of damage to guide future management investment.

This book promotes the adoption of a more strategic approach to bird management including use of better techniques to reduce damage and increased cooperation between neighbours. Improved collaboration and commitment from industry and government is also essential along with reconciliation of legislation and responsibilities.

Whilst the focus of this review is pest bird impacts on horticulture, most of the issues are of relevance to pest bird management in general.

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Foreword

Bird damage is a significant problem for many horticulturists in Australia with over 60 bird species known to cause damage to horticultural crops. These species possess marked differences in feeding strategies, breeding behaviour and movement patterns. There is high variability in, and uncertainty about, bird movements and subsequent damage levels between and within seasons.

Horticulturists are also faced with increasing social, environmental and legal issues that further restrict the techniques that can be used to reduce bird impacts. Of the techniques that are available, few have been subjected to rigorous scientific assessment, and management solutions are seldom suited to all bird species, crops and situations. As a result, the management of pest birds is one of the most difficult and challenging tasks facing horticulturists.

Despite these concerns, many industry and government organisations have been reluctant to invest in research to reduce the damage caused by birds. This may be partly due to a lack of information on the severity and distribution of the problem.

As indicated by the priority issues identified in this review, effective management of pest birds requires: improved ability to predict patterns of bird movement and damage; the development of simple techniques for estimating the extent and severity of damage; adoption of strategic management using improved damage reduction techniques; reconciliation of legislation and responsibilities; and increased cooperation, collaboration and commitment from industry and government. Whilst the focus of this review is pest bird impacts on horticulture, most of the issues are of relevance to pest bird management in general.

Horticulturists need to have a strategic approach to managing pest birds which involves careful planning, consideration of the species involved, and estimation of the extent of damage before and after control. This approach is the basis of a series of pest management guidelines prepared by the Bureau of Rural Sciences over the past decade through its administration of the National Feral Animal Control Programme — a Natural Heritage Trust initiative. Others in the series include guidelines for managing feral horses, rabbits, foxes, feral goats, feral pigs, rodents, carp and wild dogs.

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Key priorities to reduce pest bird impacts

Unlike most other pest animals in Australia, there are fundamental deficiencies in our knowledge of pest bird species, their impacts, and the costs and efficacy of commonly used management practices. These deficiencies must be addressed as a priority before best practice management strategies can be recommended or promoted or new techniques investigated. Improved knowledge of the ecology, behaviour and movements of the species involved and the patterns of damage will increase the effectiveness of management and enable growers to optimise the timing of management. Improvements in the adoption and extension of recommended management strategies is important to ensure that effective, humane and environmentally acceptable management techniques are applied.

There are also a number of policy issues that must be addressed. Legislation and responsibilities between States and jurisdictions are either not in place or are inconsistent and unclear, and as a result pest bird management has not received the level of investment that the size of the problem requires. Improved cooperation between, and an increased commitment by, national and State agencies, industry organisations and end-users is essential to address these deficiencies. Whilst the focus of these priorities is pest bird impacts on horticulture, most of them are of relevance to pest bird management in general.

1. Improve knowledge of pest bird ecology, diet and patterns of movements and damage.

Problem: There is a paucity of relevant ecological data on pest bird species. This information is required to develop control techniques and management strategies. It is difficult for growers to predict when their crops will suffer significant bird damage. This is because of the high variability of damage and a lack of understanding of why this occurs. Hence, each season, growers often wait until damage becomes obvious, bird numbers are high, and the birds have developed a feeding pattern. This is usually too late for effective damage control. There is anecdotal evidence of large spatial and temporal variation in bird species, abundance and damage within crops and within properties and among crops, properties, and regions. There have been few attempts to predict these patterns. To implement effective strategic management or adequately evaluate management options, more baseline information is needed.

Research need: Determine the causes of underlying patterns in bird movements and damage to increase the predictability of damage. Existing control techniques need to be evaluated in relation to the ecology and biology of the main pest bird species. Improved understanding of population dynamics, movements and biology will allow targeted control of populations. Improved predictions of the movements of species will allow management to be targeted during seasons when damage is more severe or more likely.

Benefits: Bird damage control that is more cost efficient and effective, and damage reduction through the application of sound ecological principles to manage pest species. The use of existing controls can be combined with management of the crop and the local environment.

2. Estimate the extent, timing and costs of damage to horticulture

Problem: There is inadequate knowledge of damage caused by birds at farm, regional and national scales. There are few techniques available for measuring damage in horticulture. Methods for measuring damage are time-consuming, complex and difficult to apply for growers and land managers.

Research need: Simple field techniques need to be developed to accurately assess damage caused by birds. These techniques need to be quick and simple to be of use to growers. Techniques to estimate social and environmental costs also need to be investigated. Estimates of damage at the farm scale will enable growers to decide the optimal course of action. Improved estimates of damage are also needed at regional and national levels to allow improved allocation of resources to industries and regions most at risk from bird damage. Realistic economic assessments of damage and of social and environment costs are required before investments are made to manage perceived problems.

Benefit: Simple and accurate techniques for estimating damage and costs at the local, regional and national scales. Better information on the extent, pattern and cost of bird damage and the effectiveness of control techniques and strategies. These data are essential for assessing the benefits of bird control; identifying industries and regions most at risk; identifying the main species involved; and allocating resources and establishing priorities for research and management.

3. Assess existing control techniques on the main pest bird species

Problem: Current techniques used for managing birds in Australia have not been rigorously evaluated in terms of their ability to reduce abundance or damage.

Research need: Better quality data are required for even the most commonly used techniques for managing birds. Studies overseas provide baseline information on the efficacy of some techniques. However, this is no substitute for the need for rigorous evaluations in Australia. Little objective or scientifically sound advice is available for current management techniques, including shooting, trapping, netting and acoustic and visual deterrents. Improved support for economic decision-making and more detailed information on the costs and relative effectiveness of management techniques are required. For example, more information is needed to compare the costs and effectiveness of various kinds of netting, including the type and life expectancy of netting, construction and labour costs, application techniques and changes to management practices. The relative humaneness and non-target effects of current techniques should also be evaluated. Case studies that demonstrate 'best practice' management are lacking in scientific rigour and in many instances rely only on anecdotal measures of damage and effectiveness. Credible evaluations of these methods under Australian conditions and on Australian bird species have rarely been conducted. The environment, the species involved and the patterns of damage are markedly different from those overseas, and scientific evaluation of existing techniques is required. Investigation of the optimal timing of control will enhance the effectiveness of current bird management techniques.

Benefit: Reliable advice for growers on the efficacy and humaneness of current bird management techniques and when to apply them.

4. Improve adoption of effective existing techniques

Problem: Each season growers often wait until damage becomes obvious before they take action. Growers may then initiate limited control, usually a single method like a gas gun, and leave it operating without checking whether it is effective. In this instance there is little account taken of habituation by birds exposed to a frequently repeated stimulus. Growers are also often unaware of the bird species responsible for damage and the need for different management approaches for different species. This is in contrast to their attitude to weed and insect pests, where they distinguish between species and adjust their pest control actions accordingly.

Research need: Investigations are needed to explain why farmers do not implement bird control early enough and then often implement ineffective controls. For example, the use of less expensive measures such as decoy food (either from revegetation programmes, specially cultivated crops, pasture management or alternative foods such as grain) and other habitat manipulative approaches to bird damage may offer effective alternatives to conventional control. However, these measures are poorly accepted by growers, and potentially ineffective techniques such as electronic 'scaring' devices and shooting to kill are popular. It is critical to understand the barriers to adoption of some techniques and 'best practice' and also the perceptions farmers have of bird damage and the relative effectiveness of control techniques. These studies need to be conducted by social scientists trained in the investigation of social attitudes and behaviours. Once these impediments to improved bird management are identified, new advisory strategies need to be developed for growers so that they are well informed and motivated to implement more effective bird control strategies. Such extension strategies may involve demonstration sites to compare integrated management approaches and provide 'real world' evidence of the extent to which damage can be reduced.

Benefits: Bird damage control that is more cost-efficient and effective.

5. Develop additional effective, species-specific and humane techniques and products that can be used by land managers

Problem: There is a lack of effective and humane solutions for addressing the diversity of pest bird problems.

Research need: A variety of practical solutions are required for growers and land managers to effectively manage pest birds in the range of situations in which they occur. Growers are facing increasing restrictions on available techniques and require alternatives that are effective, humane, and socially and environmentally acceptable. For example, providing alternative foods and decoy plantings — such as pasture management near crops — could be investigated. In some situations the development of benign and cost-effective repellents, or humane and environmentally safe toxins, for introduced species could also be justified. There is also a need to investigate whether an alternative food source in a crop increases or decreases damage to the crop: the alternative food source could be a decoy food, produced through habitat manipulation such as pasture management (either height or species). For example, does the manipulation of inter-row pasture in a vineyard to produce an alternative food alleviate damage or attract more birds to the crop?

Benefit: A variety of techniques and solutions available to allow land managers to effectively and responsibly manage pest birds.

6. Reconcile legislation and responsibilities for pest birds

Problem: Growers are frustrated when attempting to obtain advice from government organisations. Objective advice is not always available and responsibilities are often passed from one organisation to the next.

Research need: Responsibility for pest birds is unclear. Agreed responsibilities and improved policy mechanisms to manage the impacts of pest birds are required between agencies. For example, consistent guidelines are needed for local councils to deal with conflicts arising from the use of scaring devices. Landholders and land occupiers are not required to manage any pest bird species, unlike the case with other pests of agriculture. Consultation and investigation are required to determine responsibilities, shared obligations and benefits.

Benefits: Smoother management processes.

7. Improve cooperation between, and commitment from, national and State agencies, industry and horticulturists

Problem: There is an improvised approach to investment in the research and management of pest birds.

Research need: A national approach incorporating pest bird researchers, managers and industry is necessary to avoid duplication of research, increase the relevance of research for growers; and provide growers with an avenue to contribute to the direction of research and development. Engaging industry in setting priorities for bird pest research is a challenge. For example, the Western Australian table grape industry believes that pest bird problems can best be solved by netting crops, whereas the Western Australian Government would like to see greater industry involvement in preventing the arrival of starlings (*Sturnus vulgaris*) in Western Australia through eradication programmes conducted near the border with South Australia (Andrew Woolnough, Department of Agriculture, Western Australia, pers. comm. 2005). Longer-term projects and a coordinated direction for research and development are required.

Benefits: Outcomes that address issues of direct relevance to horticulturists, thus improving the rate of adoption of new control techniques. A clear direction of research that will provide growers with effective, humane and environmentally acceptable strategies for the management of pest birds.

8. Conduct risk assessments for captive birds

Problem: Introduced non-native birds pose major threats to Australian agriculture. In addition to the 20 exotic bird species already established in the wild on the Australian mainland (Appendix G; Bomford 2003), over 240 exotic species are known to be legally held in captivity (Vertebrate Pests Committee 2006), including many species held in low-security cages in private aviaries. Governments have a responsibility to ensure that risk assessments are conducted to identify species that pose a high threat of establishing pest populations if they should be released from captivity, and to ensure that such species are either kept out of Australia, or, if they are kept here, are held with appropriate levels of security. To support governments in this role, the Vertebrate Pests Committee has published 'Guidelines for the Import, Movement and Keeping of Exotic Vertebrates in Australia' (Natural Resource Management Standing Committee 2004). In some situations, translocated native birds may also pose threats to agriculture. A national approach is necessary to ensure that birds that have significant pest potential in one part of Australia are not kept under low security in other regions, where they could escape, establish and spread.

Research need: A significant element of the Vertebrate Pests Committee Guidelines for the Import, Movement and Keeping of Exotic Vertebrates in Australia is the risk assessment model developed by the Bureau of Rural Sciences (Bomford 2003) which is being continually refined. Bomford's model evaluates a range of factors for an exotic bird species, including its climate match to Australia, its history of establishing exotic populations elsewhere, and its pest status overseas, to calculate a risk score of low, moderate, serious or extreme. To date only a small number (approximately 50) of the exotic bird species that are held in captivity in Australia have been assessed using Bomford's model (see http://www.feral.org.au/content/policy/risk_assess_list.cfm).

All exotic bird species currently held in Australia need to be assessed, with the highest priority being given to species considered to be pests in their overseas range. Risk assessments of priority translocated native species may also be necessary in some circumstances. Increased security may be required for species that score a serious or extreme risk, as discussed in the Vertebrate Pests Committee Guidelines (Natural Resource Management Standing Committee 2004). Bird keepers, landowners and the general public also need to be educated about the importance of promptly reporting any escapes of exotic aviary birds or sightings of unusual birds in their area.

Benefits: Governments can use the risk assessment scores to assist in regulating the import, trade and keeping of exotic or translocated native bird species to reduce the risk that new agricultural pest species will establish wild populations in Australia.

Introduction

Why produce a pest bird manual?

Crop damage caused by pest birds is a significant problem for many horticultural industries in Australia. Many growers seek advice on how to address this problem. New types of horticultural crops are being grown, growing practices are changing, values for horticultural products are increasing, and the geographical range of production is expanding. These changes often result in expansion of the range and impact of pest birds. There is a lack of Australian-based advisory material to provide growers with the information they seek, particularly with regard to the costs and likely benefits of damage-reduction strategies. These guidelines aim to address this need.

Bird damage is an issue that frustrates many growers because of the lack of reliable information. There are many control techniques, and pest bird control can be expensive. In 2000, a survey of 30 local grape growers by Sydney University in the Central Ranges of New South Wales found that bird control was costing on average $500 per hectare per year, with most techniques failing to adequately protect crops. The killing of birds does not necessarily reduce crop damage, and associated animal welfare and native species conservation concerns make the practice controversial and politically sensitive. Exclusion netting is usually the most effective strategy, but it is expensive and often is either not practical or cannot be justified given current prices for some crops. As a wide range of netting options and application techniques is available, selection of the most appropriate combination can be difficult.

Growers also face high variability in, and uncertainty of bird movement and damage. This makes the resolution of bird problems complex. Without estimates of probable damage, it is difficult to estimate how much effort should be put into pest bird control.

Good decision-making requires the costs and benefits of different strategies to be estimated and compared. Estimates vary because of: variations in the species of pest birds; seasonal variations in bird movements and numbers; variations in land uses in surrounding areas; differing economic circumstances of individual growers; variations in the type and value of the crop; and differences in growing practices. These guidelines provide rural managers and advisers with best practice approaches to managing damage to horticulture caused by pest birds. They provide scientifically-based information that State and Territory Government agency staff can use to develop extension materials. Such materials can be used to advise growers on how to resolve specific bird problems affecting horticultural industries, using approaches that are humane and cost-effective.

‘Growers need reliable information on how to assess bird damage in their crops and which pest bird control techniques will work best to reduce damage.’

These guidelines consist of a main document of general principles linked to a series of factsheets and appendices. They have been written by scientific experts in pest bird management who have been selected from agencies around Australia. The authors include experienced field officers who are familiar with the practical problems faced by producers.

Although these guidelines focus specifically on the management of bird damage to horticulture, the approaches and techniques discussed are also relevant for addressing other pest bird problems.

We define ‘pest birds’ as birds that have a negative impact on a valued resource. In some situations this may include local populations of native species.

What these guidelines cover

These guidelines cover approaches to addressing bird damage to horticultural crops, including tree, vine and berry fruit crops, nursery stock and vegetable crops. Chapter summaries are presented below.

Part A of the guidelines contains the general principles of pest bird control:

1. **Introduction to 'Strategic Approach' —** outlines the strategic approach for best practice management of pest bird problems in horticulture. The four key steps of this approach are outlined.

2. **Damage caused by pest birds to horticulture —** describes the bird species involved and the type, severity and cost of damage caused.

3. **Techniques for measuring and monitoring damage and abundance —** details techniques for measuring and monitoring bird damage. It is important to estimate the percentage crop loss, the value (dollars) of damage caused by birds and the cost of their control, because this enables sound decisions to be made on the appropriate level of investment to reduce bird damage economically. It is also important to determine which bird species cause damage, as well as when and where damage occurs, to enable sound decisions to be made on the most appropriate management strategy.

4. **Assessment of control techniques —** including: scaring, population reduction (poisoning, shooting, trapping and fertility control), habitat manipulation and decoy feeding, netting (and other forms of exclusion), chemical repellents and biological control. This information will assist growers to select the pest bird control techniques most appropriate for their circumstances.

5. **Economic decision-making —** describes the economic principles of pest bird control. This chapter provides economic tools for selecting alternative management strategies and deciding when to implement them. A practical step-by-step guide is presented; it allows horticulturists to consider the benefits and costs of particular activities.

6. **Legislation —** outlines the current legislative controls relating to pest birds. This chapter considers the implications of legislation for horticulturists in making management decisions for pest bird control.

7. **Social and environmental factors affecting bird management options —** examines the practice of pest bird control in Australia and related legal, social and environmental issues. This chapter addresses some of the more controversial issues relating to current and proposed approaches to pest bird control, such as animal welfare, culling of native birds, threats to non-target species from lethal control techniques and noise pollution from scaring. Some of the social and practical issues facing horticulturists are also considered.

8. **Extension —** examines the extension of knowledge about pest bird control to growers so that best practice strategic approaches are adopted. This chapter considers the practicalities of dealing with pest bird issues amongst other management priorities. The impediments to best practice management and ways of improving communication between researchers, advisors and growers are discussed.

9. **Case studies —** illustrate the principles of the strategic approach to best practice pest bird management. They include examples of successful local and regional approaches to managing pest bird issues.

10. **References** — contains references to the material in Part A.

Part B of these guidelines consists of factsheets for growers:

Factsheets on pest birds — describes the major species that may be pests in some situations. Includes for each species: a photograph and description to aid identification; a distribution map; description of each species' habits and movements, breeding, social organisation, preferred habitats and foods; types of damage caused; and references for further reading.

Factsheet on managing the impacts of birds in horticulture provides an overview of the principles and control techniques for managing bird pests, and a sample management plan.

Part C contains the appendices and source materials:

Appendix A — lists State and Territory contacts responsible for pest bird management.

Appendix B — describes random and systematic sampling methods.

Appendix C — lists some of the native plants that attract birds.

Appendix D —describes the roles of government agencies and legislation relating to pest birds.

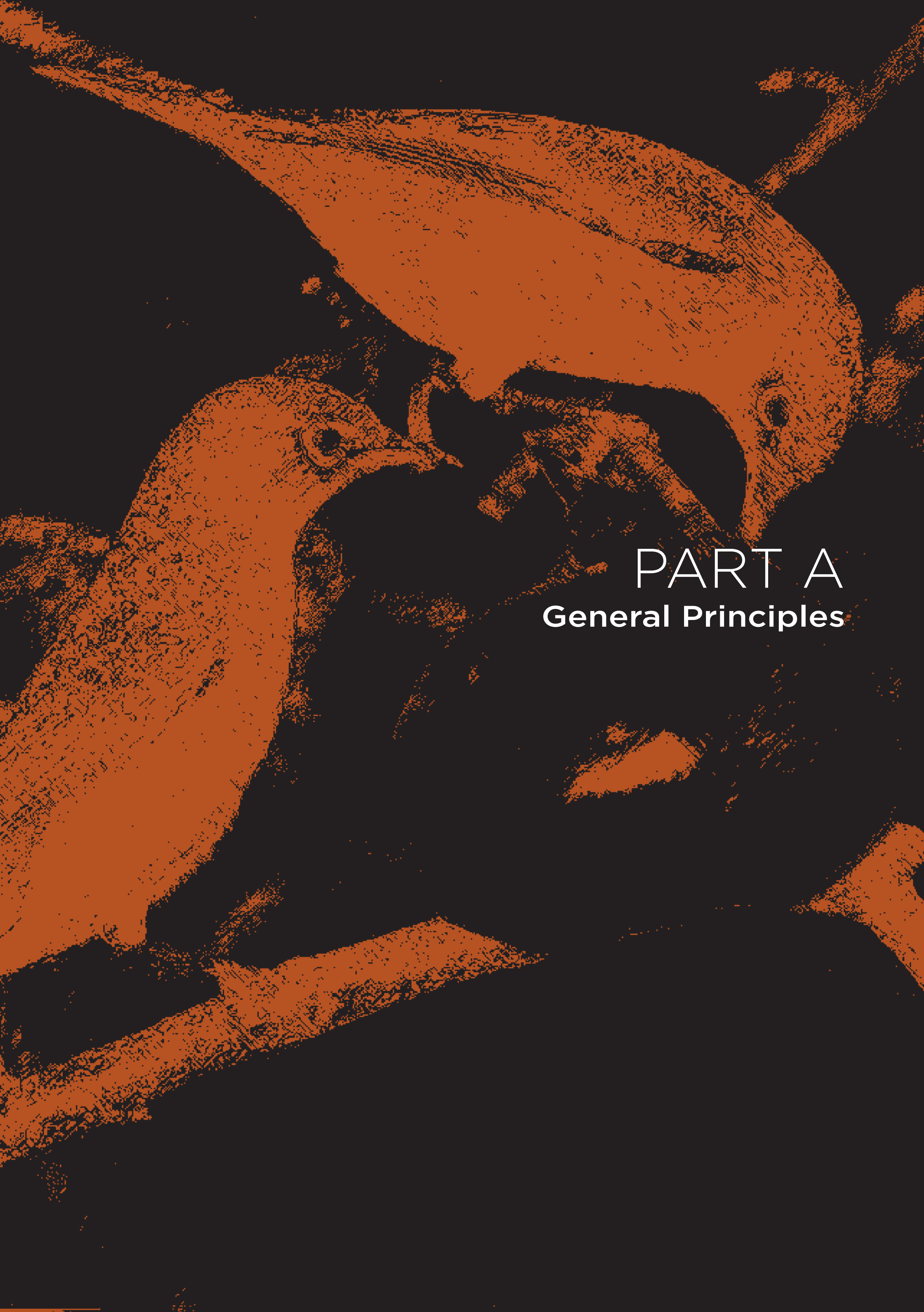
Appendix E — lists the legislation and conditions relating to the destruction of native birds.

Appendix F — lists chemicals available for bird control.

Appendix G — lists the scientific names of the birds discussed in this manual.

Finally, at the end of the manual there is a **glossary**.

Note: All money values throughout these guidelines are in 2007 Australian dollars.



PART A
General Principles

1. The 'strategic approach'

General principles for an optimal approach to the strategic management of pest birds are presented in this chapter. It is unrealistic to be too prescriptive for best practice bird control in horticultural crops, because of constraints imposed by a lack of basic knowledge about pest birds and their behaviour. Experience also indicates that every bird damage situation is different and requires local knowledge for individual growers to make the best management decisions.

Best practice pest bird management involves four basic activities:

- define the problem
- develop a management plan
- implement the plan
- monitor and evaluate the results.

Evaluation may then feed back to redefine the problem and/or modify the management plan.

1.1 Define the problem

In strategic management, pest bird problems are defined by:

- the damage caused
- the risk of damage occurring
- any associated costs
- the species of pest bird present.

It is necessary to estimate the percentage crop loss and value (in dollars) of the damage caused by birds, because this enables sound decisions to be made on how much effort and/or money it is reasonable to spend on bird control. Problem definition also requires finding out what species cause damage and when and where damage occurs. This information enables good decisions to be made about where, when and how to target control efforts.

Table 1.1: *Strategic approach to managing bird pest damage.*

Problem definition (Section 1.1)	**Management plan (Section 1.2)**	**Implementation (Section 1.3)**	**Monitoring and evaluation (Section 1.4)**
• Who has the problem? • Who else is involved? (that is, list all stakeholders) • Is problem real or perceived? • Define and measure pest impacts: – economic – environmental – social • Prepare information in a form that can be understood by all stakeholders (graphs, maps etc)	• Define objectives • Performance criteria • Management options: – precautionary management – local eradication – sustained management – targeted management – one-off management – no management • Allocate management units (what scale is required for effective management?) • Select management techniques • Assign stakeholder responsibilities	• Involve all stakeholders and coordinate activity	• Monitor regime (techniques, responsibility, timing, reporting) • Assess against performance criteria • Compare techniques over time • Evaluate outcomes and reconsider problem definition, management plan and/or implementation, as appropriate

1.1.1 Damage

Techniques for assessing damage are described in Chapter 3.

What — Define what crop (variety) and what parts of a crop are damaged (for example, buds, flowers, fruit, shoots), the level of damage, and the effect on crop yields and value of the loss.

When — Define when damage occurs. Find out when damage first starts and at what stage of ripening most damage occurs. For example, bird damage to cherries is often most severe on early-ripening varieties (Tobin et al. 1991). Information on how damage varies between years is also important.

Where — It is important to find out the spatial pattern of damage. For example, whether damage occurs uniformly throughout a crop, is patchily distributed over a crop, or is most severe on the outside edges. Observations on where damage occurs in relation to specific habitats, for example proximity to windbreaks or structures such as powerlines, can help in making good management decisions.

Who — Deciding who owns a bird damage problem is important, because this is the person or agency that has responsibility for managing it. Generally it will be the grower whose crop is damaged, but when a mobile bird species is involved it may be best for a group of neighbours to jointly address a problem, or birds may simply be moved from one property to another. Both government and private extension officers may help growers to coordinate control actions. Growers may believe that the government should do more to help with control of bird damage, but governments rarely have such legal responsibility. Exceptions include when rare or endangered species damage crops and are potentially targeted for control: in such cases government will have a responsibility to protect these birds. State government agencies regulate the use of lethal control techniques such as shooting and any avicides that may be developed in the future. State agencies are also involved in preventing the spread of some species, such as common starlings in Western Australia. Local government is involved in restrictions on some control techniques, such as the use of noise generating scaring devices.

1.1.2 Costs

In addition to crop losses, costs associated with pest birds may include:

- the cost of control techniques;
- negative impacts of control measures — for example, animal welfare concerns or killing of non-target species (particularly those that benefit production);
- opportunity costs — if a crop is not grown (or a less profitable type of crop is grown) because of bird damage risk, or if a crop has to be harvested early due to heavy bird predation resulting in loss of quality and quantity of produce;
- disease or weed establishment or spread by birds (Figures 1.1; 1.2); and
- off-site effects — for example, complaints about noise pollution from scaring devices, or an increase in problems on neighbouring properties when there is poor bird control on one property, or poor management on a property attracting pest birds, which then move onto neighbouring properties.

Figure 1.1: *Silvereye feeding on small-leaved privet (*Ligustrum sinense*) in the NSW central coast region. Birds contribute to the spread of privet, which is declared in New South Wales, Queensland, Western Australia and the Australian Capital Territory.*
Photo: N. Lazarus.

Figure 1.2: *A feral olive in fruit. Birds feed on the fruit, contributing to the spread of olives as a weed in Australia.*
Photo: R. Sinclair.

1.1.3 Species

It is necessary to identify which bird species cause damage, so that control can be directed at those species (see Part B for information on identifying bird species, and Chapters 2 and 3 for information on monitoring damage). Not all bird species present will damage fruit, and no control techniques will be effective against all species. Similarly, different bird species may cause damage in different years, depending on environmental factors such as pollen production in native trees or fluctuations in food resources because of drought. Information on types of damage, such as whether small pecks are taken from fruit or whether whole fruit or whole bunches are removed, will often help identify the bird species responsible.

1.2 Develop a management plan

Once the problem has been defined, there are three steps in developing a management plan:

- define management objectives and performance indicators;
- select an appropriate management option; and
- formulate a management strategy.

1.2.1 Define management objectives and performance indicators

The objectives of pest bird control are to:

- prevent damage caused by pest birds or reduce bird damage to an acceptable level;
- produce economic benefits; and
- use the most effective, least objectionable and safest methods.

These objectives are best described in terms of outcomes that can be measured against milestones or target dates, as defined by performance indicators.

Defining the objectives in terms of measurable performance indicators enables the assessment of whether the objectives of control are being achieved. Objectives should not be defined solely in terms of the effort made to control birds. This is because there is no guarantee that increased effort actually results in reduced levels of bird damage. Case studies (Chapter 9) provide examples of useful performance criteria. Appropriate performance indicators are those that are measurable and are related directly to the problem, such as 'reduce damage to less than 5%'. Inappropriate performance indicators are those that solely measure control effort, such as 'the number of days spent shooting', 'the number of birds killed' or 'the number of control devices put in a crop'. These are poor choices, as the control effort or the number of birds killed may have no relationship with the reduction in damage (but a lot to do with the feeling of 'doing something').

'Appropriate performance indicators are those that are measurable and are related directly to the problem, such as reducing damage to less than 5%.'

Factors such as safety and social acceptability need to be considered. For example, noisy or dangerous control methods can cause injury or poor relationships with neighbours. Measures to prevent such potential negative impacts may be considered.

1.2.2 Select a management option

The next step is to decide on the best management option to meet the objective(s). There are six possibilities to consider:

- **Eradication** — permanently eliminating the entire population of the pest species in a defined area. This option is inappropriate for native bird species. Eradication of exotic pest bird species is rarely feasible because of factors such as mobility, abundance, widespread distribution, ability to breed prolifically and (most importantly) cost. In assessing eradication as a management option it is necessary to consider the law of diminishing returns. The first 70%–80% of birds might be relatively easy to remove, but the last 20%–30% will be much harder. The last 1%–10% may be impossible to remove, or (if they can be taken) the cost is likely to be prohibitive. In addition, when bird numbers are low, they will cause less damage and there may be little incentive to get the last few. Eradication of established populations of pest species is often prohibitively expensive and impractical (Bomford and O'Brien 1995). However, limiting the spread of exotic species can be an effective way of preventing serious future impacts. Refer to Chapter 9 — Case studies 9.1 and 9.2 for examples of this management option.
- **Strategic one-off control** — implementing a single management action that has a long-term effect. A good example relevant to birds is the erection of permanent netting (Chapter 9 — Case study 9.8). This is expensive and requires careful cost–benefit calculations (Chapter 5), but it is often worthwhile for high-value crops. Another example is the release of a biocontrol agent, but none is currently available for birds (Section 4.6).
- **Strategic sustained control** — a management strategy that requires a sustained effort over an extended period of time to reduce crop damage. For example, the objective might be to reduce birds to low numbers and keep them low by regular culling. Significantly reducing numbers of mobile bird species may not be a practical choice, for the same reasons that eradication is rarely achieved. If, however, control is aimed at a resident population of a species that is not very mobile, it might be possible to lower numbers sufficiently to reduce crop damage to acceptable levels. Population reduction may need to be achieved over a large area to make it worthwhile. Cooperation with neighbours may be necessary if property sizes are small. An example of strategic sustained control may be a culling programme throughout the year for locally sedentary species such as European blackbirds (*Turdus merula*) or house sparrows (*Passer domesticus*). Another example is the use of scaring techniques at all times when the crop is vulnerable to bird damage, irrespective of whether it is a 'good' or a 'bad' bird season (Case study 9.7).

- **Strategic targeted control** — control implemented only when conditions indicate that it is desirable. Birds are controlled only when the risk of damage is high. Applying 'drape-over' or 'side' exclusion netting (Figure 1.3) when damage is expected to be severe, or using scaring devices strategically as fruit is reaching maturity, are examples of strategic targeted control (Case studies 9.3, 9.4, 9.5 and 9.9).
- **Crisis management** — control applied reactively with no forward planning. This is the most common form of pest bird control, with little or no action taken until damage reaches an unacceptable level. Unfortunately, by this time pest birds have usually developed behavioural feeding patterns and damage control is often difficult.
- **Do nothing** — a viable economic option if the cost of control exceeds the benefits achieved. An example is an orchard situated close to a residential area where damage is low and scaring devices cannot be used. The only technical solution available is permanent netting, which costs more than the savings it would bring from reduced damage (Case study 9.9). Another example is where a vineyard or orchard is so large that bird damage is insignificant compared with the amount of fruit harvested. This occurs in the large apple-growing areas of Hawke's Bay, New Zealand, or in large vineyards in the Murrumbidgee Irrigation Area of New South Wales, which typically suffer insignificant levels of bird damage compared with isolated orchards (Case studies 9.6 and 9.9).

Figure 1.3: *Side exclusion netting in a vineyard, an example of strategic targeted control. Photo: R. Sinclair.*

When selecting the best management option from the list above, consider the following:

- crop type, value, location and size;
- levels and pattern of expected bird damage (risk);
- bird species causing damage and their numbers;
- neighbouring land uses and bird numbers;
- control techniques available and their effectiveness, cost, legality, humaneness and social acceptability (Section 1.2.3; Chapter 4); and
- available expertise in the use of control techniques.

If native species are involved, the grower is generally required to obtain a destruction permit (Appendix E). This permit will allow the grower to reduce bird numbers when the crop is most vulnerable to damage, and to improve the effectiveness of scaring devices. However, the permit most likely will not allow the grower to destroy protected species beyond the property boundary. Issues such as this are likely to restrict the management options available to growers who have infestations of native pest birds.

In orchards and vineyards, the best management option for high-value crops sustaining consistently high levels of damage may be investment in 'drape-over' netting or the use of permanent netting as a strategic one-off control option. For lower-value crops, or for crops unsuitable for netting, the best option is usually strategic targeted control. This involves implementing control when damage risk is high. If the main pest species are resident species, such as sparrows or common mynas (*Acridotheres tristis*), then strategic sustained control to reduce resident populations may be appropriate. The process of selecting management options and strategies for a range of situations is demonstrated by the case studies in Chapter 9.

1.2.3 Select control techniques and formulate a management strategy

This step requires selecting the most appropriate control techniques to suit the circumstances and devising when and how they will be used. A wide range of control techniques is available (Chapter 4). These rely mainly on deterrence (scaring), population reduction, habitat and/or crop management, and exclusion. They are used either alone or in combination. To select the most appropriate techniques to use, consider the following factors (see Table 1.2 for an example of a selection matrix):

Is it technically possible? For example, habitat manipulation to deter birds from roosting or sheltering might not be feasible in crops adjacent to native vegetation. Shooting, for lethal control or deterrence, requires the use of a registered firearm and the operator must have an appropriate gun licence, but many farmers have neither.

Will it work? The effectiveness of control techniques varies greatly. For example, testing has shown that many scaring devices are largely ineffective in the longer-term, whereas permanent netting can be 100% effective (Chapter 4).

Is it economically feasible? What level of damage can be sustained and how do the costs and benefits compare (Chapter 5)?

Is the scale of the control programme feasible to achieve the desired outcomes? Considering the scale of a control or management programme for pest birds is essential for success. For example, a habitat restoration programme to offer alternative food for honeyeaters (Meliphagidae) will require a regional approach; or preventing the establishment of starlings in new areas will require a State or national programme.

Is it environmentally acceptable? Control techniques may have significant non-target impacts, especially if poisons are used. Chemical repellents can leave residues in fruit (Chapter 7).

Is it legally and socially acceptable? What are the legal implications of the control method with respect to the destruction of native species, use of firearms, animal welfare, chemical registration, or pollution and noise control? What are the possible impacts on neighbours (Chapters 6 and 7)?

Is expertise available to use the preferred control techniques effectively? Some techniques require expert assistance or considerable training to ensure cost-effectiveness.

An example of the decision-making process used in formulating a management strategy is provided in Table 1.2. The feasibility of different management strategies may vary considerably over time; with changing public attitudes; with additional information; and between individual growers, locations and industries.

At this point, reassess the objectives and performance indicators to see if it will be feasible and practicable to meet them using the selected techniques. If this is not the case, it will be necessary to redefine the performance indicators or consider the use of alternative control techniques.

If more than one technique is to be used, the management plan needs to specify how they are to be integrated and the areas and times to

Table 1.2: *Example of a matrix used to examine management techniques against feasibility and acceptability criteria in horticultural crops (after Bomford 1988). Note that this table is an example only: the feasibility of different management strategies may vary considerably over time; with changing public attitudes; with additional information; and between individual growers, locations and industries. Question marks highlight uncertainties associated with some techniques due to a lack of rigorous experimental studies.*

Control option	Feasibility/acceptability criteria						
	Technically possible	**Will it work?**	**Practically feasible (growers' resources)**	**Economically desirable (cost–benefit)**	**Environ-mentally acceptable**	**Politically/ legally acceptable (State/ Federal)**	**Socially accept-able (local)**
Grow another crop	Yes	Yes	No	No?	Yes	Yes	Yes
Grow decoy crop	Yes	Yes?	Yes	No?	Yes	Yes	Yes
Predators and disease	No	?	?	?	?	?	?
Harvest date	Yes	Yes?	Yes	No?	Yes	Yes	Yes
Harvest technique	Yes	Yes?	Yes	?	Yes	Yes	Yes
Alternative foods	Yes	?	No?	No?	Yes	Yes	Yes
Shooting	Yes	No?	Yes	No?	Yes?	No?	Yes?
Prevent access, netting	Yes	Yes	Yes	?	Yes	Yes	Yes
Repellents	Yes	?	No	?	?	?	?
Deterrents, acoustic	Yes	Sometimes	Yes	?	Yes	Yes	Yes?
Deterrents, visual	Yes	Sometimes	Yes	?	Yes	Yes	Yes
Poisons	No	?	Yes	?	?	?	?
Replanting or transplanting	Yes	No?	No?	No?	Yes	Yes	Yes
Exclusion netting	Yes	Yes	?	?	Yes	Yes	Yes

be targeted by each technique. Similarly, if more than one crop or more than one property is to be treated, the management plan needs to give details of which techniques will be used, when, where and how they will be combined, and who will implement them.

1.3 Implement the management plan

When the management plan is complete, implementation can start.

If more than one person is involved in implementing the management plan, good communication among all participants is essential. Each person needs to know what their roles and responsibilities are. Measures are needed to ensure that participants maintain commitment and enthusiasm. For example, good communication and regular monitoring (Chapter 3) will ensure that the rewards for efforts are seen, and this, in turn, will help to maintain high levels of motivation.

Cooperative action with neighbours may be required to effectively implement a management plan. The type and scale of a pest bird problem and the management option selected will determine the level of cooperation required. Scaring of birds in one crop will usually just move them to a neighbouring crop unless cooperative action is taken. Manipulation of habitat (for example, by decoy feeding) or population reduction by shooting will often need to be taken on by a group of neighbouring properties to be effective.

1.4 Monitor and evaluate

Monitoring and evaluation are often the most forgotten aspects of management programmes. Once performance indicators have been set to define the desired level of achievement against the management objectives, the programme needs to be monitored to determine how well the performance indicators are being met. This gives an opportunity to evaluate the level of success, estimate the costs and benefits, and then modify the management plan or control actions if necessary (Figure 1.4).

1.4.1 Monitoring

The ultimate goal of pest bird management should be to achieve the most cost-effective reduction in impact on a valued resource. This means that best practice pest bird management is about maximising the economic returns from an investment in control effort. Determining whether this goal is being reached requires monitoring on a number of levels. The ultimate measure of the success of a pest management programme is its cost–benefit relationship (Chapter 5). Measuring control costs is a relatively straightforward exercise; measuring benefits in the form of reduced damage is usually more difficult (Chapter 3).

Figure 1.4: *Estimating and recording bird damage to grapes. Bird damage must be monitored so that control programmes can be evaluated. Photo: B. Mitchell.*

Some specific issues associated with the two main levels of monitoring are discussed below. Monitoring is a fundamental part of the strategic approach, rather than something that is tacked onto the end of a management programme. Monitoring is required to define the problem. An ongoing monitoring strategy should be a key component of the management plan. Because our understanding of birds and reducing their impact is incomplete, management approaches will often be a 'best guess'. Monitoring provides the information needed to reduce the guesswork in determining how and when to repeat control and constantly improve the effectiveness of management.

There are two components to monitoring: operational monitoring and performance monitoring.

Operational monitoring aims to evaluate the efficiency of the control programme. Labour, materials, transport and any other control costs need to be recorded. For example, records are needed of the costs of purchasing netting, setting it up and maintaining and storing it. This information is used to assess whether the operation is running smoothly and efficiently and whether or not the costs compare favourably with the economic returns.

The costs of bird control include the costs of planning, purchase, construction and running of equipment and materials, and labour time. Pest managers often leave out an important component when assessing the cost–benefit relationships of different management approaches: their time, existing equipment and running costs like fuel. Even if a person conducting bird control is not on a salary, there is an opportunity cost if time is spent on bird control activities at the expense of alternative activities that have financial benefits. Hence it is usually appropriate to estimate a dollar value for time spent on bird control. Some pest control strategies are cheap in terms of equipment and materials, but very labour intensive. For example, a grower needs to consider whether the benefit derived from driving around shooting and scaring birds is greater than that derived from alternative activities. It may be more cost-effective overall for a grower to select a technique with high up-front costs but minimal ongoing labour requirements: for example, the use of permanent netting rather than an apparently cheaper but more labour-intensive and less effective approach, such as scaring, or even temporary netting. The time saved over the life of the permanent netting may be spent on other activities that bring greater benefits.

Monitoring and comparison of the annual costs of different management approaches are also complicated by the differing service lives of the various equipment and materials involved (for example, different net types). There is a resultant need to consider the discount rates (see glossary) associated with current costs, which are averaged out over a number of years into the future. Chapter 5 explains this issue in more detail.

Performance monitoring aims to determine how well the implemented management plan performs in meeting the objectives as defined by the performance criteria. This is usually a measure of damage levels and lost production caused by birds (Chapter 3). When comparisons are made in damage levels before and after a management plan is implemented, or between places with and without bird control, it is important that the same methods are used to measure damage levels.

It is important to consider which bird species are causing the most damage on a property (Sections 2.2 and 2.3). This allows growers to focus appropriate monitoring and management strategies on these species. A count of the number of birds can also be used instead of monitoring damage, although there are a number of issues that need to be considered (Chapter 3). The factsheets in Part B describe the main pest bird species and their potential impacts.

Chapter 3 describes in detail the techniques used for measuring and monitoring damage. Random or systematic sampling (Appendix B) of crops for damage may provide a good assessment, particularly if the damage occurs mainly when the crop is nearly mature and measurements represent actual losses rather than losses that may be compensated for during development or ripening. There must be sufficient random sampling to account for the patchiness of bird impact. Measured reductions in damage that occur as a result of bird control allow the benefits of the control activity to be quantified.

1.4.2 Evaluation

Evaluation of monitoring information allows management changes to be made both within and between seasons. At the most reactive level, monitoring the effect of scaring devices on bird activity will allow immediate changes to be made to improve or maintain effectiveness. At a more strategic level, the option of purchasing netting is an expensive and long-term decision. Therefore, impact evaluation over several seasons may be required to determine whether the expense will be justified.

Evaluation of the 'Strategic Approach' will give rise to one of the following possibilities:

The perceived problem was correct. The management plan and its implementation were cost-effective and optimal given the range of control techniques currently available.

Action: Continue with current strategy but continue to monitor bird activity and damage to determine whether the control effort needs to be changed (increased to increase or maintain effectiveness; or decreased to save money and/or time). To see whether the management strategy can be further improved, consider new control techniques as they become available.

The perceived problem was correct and the management plan appropriate, but implementation was poor.

This is a common problem with pest animal management, and the control techniques are often blamed when it is their implementation that is actually at fault. Note, however, that some commercial pest bird control products are fundamentally ineffective, despite manufacturers' claims that implementation is the problem (Chapter 4). Poor implementation can sometimes result from unforeseen events or catastrophes (for example, nets may collapse or blow away), even though the current strategy is basically sound.

Action: Obtain expert independent advice on the implementation of control techniques. When something unforeseen has happened, the current strategy may need adjusting to encompass the new information. Alternatively, the current strategy can be kept on the assumption that the catastrophe will not happen again.

The perceived problem was correct but the management plan was not cost-effective.

This may occur either when the costs of an effective control are not justifiable, given the value of the protected crop, or when the actions did not achieve the desired management goals.

Action: Obtain expert advice to determine whether there are likely to be cheaper and/or more effective approaches. In some cases, if damage is low and/or sporadic or the value of the crop is low, the most cost-effective option may be to do nothing. Consider new control techniques as they become available, and decide whether they are likely to improve the cost–benefit of management.

The perceived problem was incorrect.

This may occur when the most obvious or numerous birds are targeted but they are not the species doing the most damage.

Action: Focus monitoring to clarify which birds are causing the most damage and revise the management plan accordingly.

The problem with pest bird management, in contrast to the management of some other pest animals in Australia such as rabbits, is the large number of species that can become a problem, as well as their mobility (Figure 1.5) and the unpredictability of their activity within and between seasons. Hence a management strategy that is appropriate now may not be appropriate in following seasons. This may occur if there

Figure 1.5: *A flock of starlings in flight. Starlings, like many bird species, congregate in large, very mobile flocks, making control more difficult than for other pest animals. Hence adaptive management is even more important for pest bird management than for other pest species. Photo: J. Tracey.*

are changes in surrounding habitat or seasonal conditions that change bird activity. Permanent exclusion netting avoids this uncertainty but may not be cost effective unless monitoring has shown that bird impact is usually high. For other control techniques, ongoing monitoring and evaluation is essential, even if the initial strategies are successful. The concept of 'adaptive management' (Walters and Holling 1990) is more critical for pest bird management than for management of other pest animals. Adaptive management is where different management options can be implemented so that their effectiveness can be monitored, evaluated and compared and the knowledge gained can be used to improve future management.

2. Damage caused by pest birds to horticulture

2.1 Susceptible crops

Many horticultural crops in Australia are susceptible to bird damage (Table 2.1). Almost all fruit crops are potentially at risk, and significant levels of damage have been reported to table and wine grapes; apples, pears and other pome fruit; stone fruit and cherries; mandarins and other citrus; blueberries, strawberries and other soft fruits, bananas, pineapples, paw paws, lychees, carambolas and other tropical fruits. Damage is also reported to walnuts, hazelnuts, almonds, chestnuts, macadamias and pistachios, although the level of damage is mostly unknown. Locally significant damage is recorded to some vegetable crops, including sweet potatoes, peas, beans and lettuce. Locally significant bird damage can also be caused to floriculture, particularly proteas and banksias grown for the cut flower market.

Table 2.2 outlines the production value of some of these industries. Figure 2.1 illustrates the key areas of horticultural production in Australia. Figure 2.2 illustrates the key areas of viticultural production.

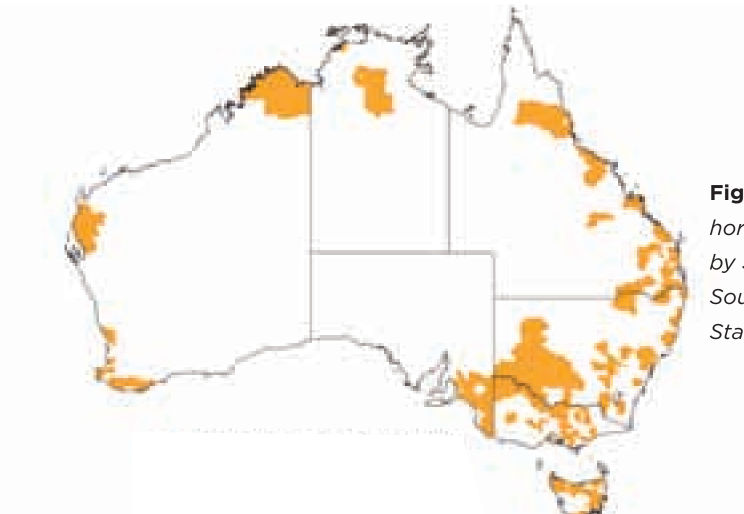


Figure 2.1: *Key areas of horticultural production in Australia by Statistical Local Area. Source: Australian Bureau of Statistics 2001.*

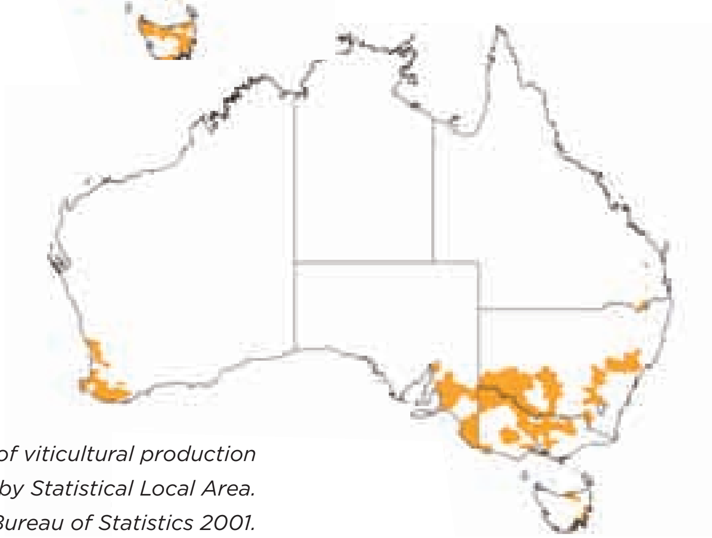


Figure 2.2: *Key areas of viticultural production in Australia by Statistical Local Area. Source: Australian Bureau of Statistics 2001.*

Table 2.1: *Levels of damage to horticulture and main bird species causing damage. Level of damage is classified as Low (L), Medium (M), Serious (S) or Very Serious (VS), derived from information in HANZAB, Sinclair and Bird 1987, Fleming et al. 1990, Massam 1990, Bomford 1992, Lim et al. 1993, Porter et al. 1994, St John 1994, ENRC 1995, Curtin and Kingsford 1997, Olsen 2000, Bomford and Sinclair 2002, Forshaw and Cooper 2002, Tracey and Saunders 2003, the National Pest Bird Survey and information in Section 2.3. Superscripts indicate legal status: Endangered or Threatened (t), Protected (p), Locally Unprotected (lup) and Introduced (i). State is where damage has been reported.*

Common name	Fruit[1]	Cherries	Stone fruit	Pome fruit	Citrus	Grapes	Tropical fruit	Berries	Nuts	Flowers	Olives	Vegetables	State
Anatidae (ducks)													
Grey teal [p]												L	NSW
Pacific black duck [p]									M			L	National
Australian wood duck [p]	L					L						L	National
Black swan [p]												L	TAS, VIC
Anseranatidae (magpie geese)													
Magpie goose [p]							M			L		L	NT, QLD, WA, NSW, VIC
Cacatuidae (cockatoos)													
Sulphur-crested cockatoo [lup]	VS	S	VS	VS	M	S	S	S	VS	M		M	NSW, ACT, TAS, VIC, QLD, SA
Major Mitchell's cockatoo [p]	M		M	M					M				VIC
Little corella [lup]	S		S	S	M	S			VS				NSW, QLD, SA, VIC, WA
Long-billed corella [lup]	S			S		S			M				VIC, SA, NSW, ACT, WA
Gang-gang cockatoo [p]	M		M	M					M				VIC, TAS, NSW, ACT
Red-tailed black-cockatoo [p]	L									L			NSW, ACT, NT, QLD
Baudin's cockatoo [t, p]	S			S						M			WA
Yellow-tailed black-cockatoo [p]	S			S						M			NSW, ACT, TAS, SA
Short-billed black-cockatoo [p]	M			M						M			WA
Galah [lup]	S		S	S		S			VS				NSW, ACT, SA, VIC, QLD, NT
Corvidae (crows and ravens)													
Crow/raven [lup]	VS	S	S	S	S	S	S		VS		S	S	National
Cracticinae (currawongs)													
Pied currawong [p]	S	M	M		M	VS	M		M		S		NSW, ACT, TAS
Black currawong [p]	M	L	M			M	M		M		L		NSW, TAS
Grey currawong [p]	M	M	M			M	M		M		L		NSW, TAS, SA

1 A combined classification for cherries, stonefruit, pome fruit, citrus, grapes, tropical fruit and berries.

Common name	Fruit[1]	Cherries	Stone fruit	Pome fruit	Citrus	Grapes	Tropical fruit	Berries	Nuts	Flowers	Olives	Vegetables	State
Dicaeidae (mistletoe birds)													
Mistletoe bird [p]	L					L							NSW
Fringillidae (finches and allies)													
European goldfinch [i]	L					L							NSW, ACT
European greenfinch [i]	L					L							VIC, SA, TAS, NSW, ACT
Megapodiidae (brush turkeys)													
Australian brush turkey [p]	L				L		L	L				M	NSW, QLD
Meliphagidae (honeyeaters)													
Spiny-cheeked honeyeater [p]	L					L							NSW
Red wattlebird [lup]	VS	S	S	S		VS		S			S		NSW, ACT, QLD, SA
Blue-faced honeyeater [p]	S		M			M	S						NSW, ACT, QLD
Yellow faced honeyeater [p]	S					S							NSW, ACT, WA
White-plumed honeyeater [p]	L					L		M					NSW, ACT
Yellow-throated miner [p]	S					S							National (except TAS)
Noisy miner [p]	VS					VS							VIC, NSW, QLD, TAS, SA
Lewin's honeyeater [p]	L		L			L	L						QLD
Noisy friarbird [p]	VS	S	S	S		VS	M	S					NSW, QLD
New Holland honeyeater [p]	L					L				S			NSW, SA
Muscicapidae (Old World flycatchers)													
Common blackbird [i]	VS	S	M	M		VS		M			M	M	NSW, ACT, TAS, SA
Song thrush [i]	L					L							VIC
Oriolidae (orioles)													
Yellow oriole [p]	M					M							QLD, NT, WA
Olive-backed oriole [p]	S					S							QLD, NSW, ACT, VIC, NT, WA
Figbird [p]	S												QLD, NSW, ACT, NT, WA, VIC, TAS
Pachycephalinae (cuckoo shrikes)													
Black-faced cuckoo-shrike [p]	S					S		M					National
Passerinae (sparrows, grassfinches)													
House sparrow [i]	S	M	M	M		S		S				S	NSW, ACT, TAS, VIC, SA, QLD
Zebra finch [lup]	L		L										SA

Common name	Fruit[1]	Cherries	Stone fruit	Pome fruit	Citrus	Grapes	Tropical fruit	Berries	Nuts	Flowers	Olives	Vegetables	State
Psittacidae (parrots)													
Australian king parrot [p]	L			L								L	NSW, QLD, VIC
Australian ringneck [p]	S	M	S	S		S		M		M	L		WA, SA, NT
Pale-headed rosella [p]	M	M	M			M	M	M					QLD, NSW
Green rosella [p]	M	M		M		M		M					TAS
Adelaide rosella [p]	VS	S	S	VS		M		S	M	M			SA
Crimson rosella [p]	VS	S	VS	VS		VS	M	M	M				NSW, ACT, VIC, QLD
Yellow rosella [p]	M	L	M	L		M	L	M					NSW, SA, VIC
Eastern rosella [p]	VS	M	S	S		VS		M					NSW, ACT, TAS, VIC, QLD, SA
Western rosella [p]	S	M	S	S		S		M					WA
Regent parrot [p]	L		L			L							WA, SA, VIC
Red-capped parrot [p]	L		L	L						M			WA
Superb parrot [t, p]	L	L											NSW
Red-winged parrot [p]	L			L		L							NT
Scaly-breasted lorikeet [p]	VS	S	S	S	M	VS	S						QLD, NSW
Rainbow lorikeet [lup]	VS	S	S	S	L	VS	VS		S	M		M	NSW, SA, VIC, QLD, NT, WA
Musk lorikeet [p]	S	M	M	M		S			L	L		L	VIC, NSW, ACT, SA, TAS, QLD
Ptilinorhynchidae (bowerbirds)													
Spotted bowerbird [p]	L		M			M		M					QLD
Great bowerbird [p]	S						VS	S				M	NT, QLD, WA
Satin bowerbird [p]	M		L		L	S		S				M	NSW
Regent bowerbird [p]	L		L			L		L					QLD
Rallidae (rails, coots)													
Purple swamphen [p]	M											S	QLD, WA
Sturnidae (starlings and allies)													
Common myna [i]	S					S		S					VIC, NSW, ACT, QLD
Metallic starling [p]	L						M						QLD
Common starling [i]	VS	VS	VS	VS		VS		VS			VS		ACT, NSW, TAS, VIC, SA, QLD
Zosteropidae (white-eyes)													
Silvereye [lup]	VS	VS	VS	VS		VS	VS	VS					VIC, NSW, ACT, WA, TAS, SA, QLD

Table 2.2: *Gross value of horticultural and wine grape production ($million) in Australia.*

Item	Total Australia		
	2002-03	2003-04	2004-05
Fruit and nuts	2,216.1	2,183.8	2,546.9
Table grapes and dried vine fruit grapes	225.3	197.7	219.6
Nursery production	787.8	800.8	768.2
Vegetables	2,125.6	2,355.5	2,133.5
Horticulture total value	5,354.8	5,537.8	5,668.2
Wine grapes	1,145.5	1,491.1	1,288.6
Wine grape production (kt)	1,329.6	1,816.6	1,818.4

Source: Australian Bureau of Statistics (ABS).

2.2 Bird species

Many bird species, including both native and introduced species, are responsible for damage to horticultural crops (see factsheets in Part B). Of the introduced birds in Australia, starlings are the most serious and widespread agricultural pest, causing high levels of damage to fruit, particularly grapes, olives and stone fruit. Other serious introduced pests of horticulture are European blackbirds, sparrows and the myna. Native species, including silvereyes (*Zosterops lateralis*), honeyeaters and several psittacine (cockatoos, corellas, galahs and rosellas) and Corvidae (crow and raven) species, can also cause severe damage to a range of horticultural crops.

'Over 60 bird species are regarded as pests to horticulture in Australia.'

Table 2.3 lists over 60 bird species that are regarded as pests to horticulture in Australia. These species have varied movements, distribution, breeding seasons and feeding strategies (Table 2.3), all of which are important to consider when implementing management. Management strategies targeted to particular species will be more effective. For example, control impacting on insectivorous birds may be counterproductive, and control not only when the crop is susceptible to damage may be more appropriate for resident species. With few exceptions, native bird species are protected by legislation (Chapter 6) and most may be destroyed only under a permit (Section 6.1).

Table 2.3: *Pest birds of horticulture: preferred foods, feeding behaviour, movements, breeding times and legal status: For consistency, the categories of Loyn (1985) and MacNally (1994) were used where possible for preferred food and feeding behaviour. Movements: Sedentary (S), Nomadic (N), Migratory (M). Superscripts indicate legal status: Endangered or Threatened (t), Protected (p), Locally Unprotected (lup) and Introduced (i).*

Common name	Preferred food	Feeding behaviour	Movements	Breeding
Anatidae (ducks)				
Grey teal [p]		Dabbling	S, N	Jan-Dec
Pacific black duck [p]	Aquatic plants; seeds, pasture, invertebrates	Dabbling, grazing	S, N	Mar-May, Jul-Oct
Australian wood duck [p]		Grazing	S, N	Jan-Mar, Aug-Oct
Black swan [p]	Aquatic plants & pasture	Dabbling, grazing	S, N	Feb-Apr, Jun-Sep
Anseranatidae (magpie geese)				
Magpie goose [p]	Aquatic plants & pasture	Dabbling, grazing	N	Mar-May
Cacatuidae (cockatoos)				
Sulphur-crested cockatoo [lup]	Seeds, fruits, invertebrates	Granivore	N, S	July-Dec
Major Mitchell's cockatoo [p]	Seeds of grasses; shoots, flowers, invertebrates	Granivore	S	May-Nov
Little corella [lup]		Ground granivory	N, S	May-Oct
Long-billed corella [lup]	Seeds close to ground; some invertebrates	Ground granivory	N	Aug-Oct
Gang-gang cockatoo [p]		Granivore	S, N	Nov-Jan
Red-tailed Black-cockatoo [p]	Seeds, fruits, invertebrates	Granivore	N	Mar-Dec
Baudin's cockatoo [t, p]		Granivore	N	Sept-Dec
Yellow-tailed black-cockatoo [p]	Seeds of trees & shrubs, invertebrates	Granivore	N	May-Jan
Short-billed black cockatoo [p]		Granivore	N	May-Jan
Galah [lup]	Seeds close to ground; some invertebrates	Granivore	N, S	Feb-May, Aug-Nov
Corvidae (crows and ravens)				
Crow/raven [lup]	Grain, fruit, insects, small animals, eggs, refuse, carrion	Extensive	N	Jul-Oct

Common name	Preferred food	Feeding behaviour	Movements	Breeding
Cracticinae (currawongs)				
Pied currawong [p]	Fruit, insects, small animals, eggs, refuse, carrion	Extensive	N	Sep-Nov
Black currawong [p]		Extensive	N	Sep-Nov
Grey currawong [p]		Extensive	N	Sep-Nov
Dicaeidae (mistletoe birds)				
Mistletoe bird [p]	Fruit, nectar and invertebrates	Foliage searcher	S?	Oct-Jan
Fringillidae (finches and allies)				
European goldfinch [i]	Seeds close to ground; some invertebrates	Ground searching	S	Sep-Nov
European greenfinch [i]	Seeds, fruit, flowers, nectar, invertebrates	Ground searching	N, S	Oct-Jan
Megapodiidae (brush turkeys)				
Australian brush turkey [p]	Grain, fruit, insects, small animals, eggs, refuse, carrion	Ground searching	S	Aug-mid Feb
Meliphagidae (honeyeaters)				
Spiny-cheeked honeyeater [p]	Nectar, invertebrates, plant or insect exudates	Nectarivore	N	Jul-Feb
Red wattlebird [lup]		Nectarivore	S	Jul-Feb
Blue-faced honeyeater [p]	Invertebrates, nectar, fruit, some seeds	Hawker	M	Jul-Jan
Yellow-faced honeyeater [p]	Nectar, invertebrates, plant or insect exudates	Foliage searcher	M	Jul-Jan
White-plumed honeyeater [p]		Nectarivore	N, S	Jul-Jan
Yellow-throated miner [p]	Invertebrates, nectar, fruit, some seeds	Wood & foliage searcher	S	Jul-Jan
Noisy miner [p]		Wood searcher	S	Jun-Jan
Lewin's honeyeater [p]	Fruit, nectar and invertebrates	Wood searcher	N	Aug-Jan
Noisy friarbird [p]	Nectar, invertebrates, plant or insect exudates	Nectarivore	N, M	Aug-Jan
New Holland honeyeater [p]		Nectarivore	M	Mar-May, Jul-Jan
Muscicapidae (Old World flycatchers)				
Common blackbird [i]	Invertebrates from short grass swords, fruit and litter	Ground searching	S	Aug-Feb
Song thrush [i]		Ground searching	S	Aug-Feb

Common name	Preferred food	Feeding behaviour	Movements	Breeding
Oriolidae (orioles)				
Yellow oriole [p]		Foliage searcher	S, N	Aug-Jan
Olive-backed oriole [p]	Fruit, nectar and invertebrates	Wood & foliage searcher	M	Aug-Jun
Figbird [p]		Wood & foliage searcher	M	Sep-Feb
Pachycephalinae (cuckoo shrikes)				
Black-faced cuckoo-shrike [p]	Invertebrates and fruit	Wood searcher	M	Aug-Jan
Passerinae (sparrows, grassfinches)				
House sparrow [i]	Grain and seeds, fruit, insects, refuse	Ground searching	S	Sep-Feb
Zebra finch [lup]	Seeds of trees & shrubs, invertebrates	Ground searching	N	Oct-Mar
Psittacidae (parrots)				
Australian king parrot [p]		Granivore	S	Oct-Dec
Australian ringneck [p]		Granivore	S	Mar-May, Sep-Dec
Pale-headed rosella [p]		Granivore	S, N	Apr-Jun, Oct-Dec
Green rosella [p]		Granivore	S	Nov-Jan
Adelaide rosella [p]	Seeds, fruits, invertebrates	Granivore	S	Oct-Dec
Crimson rosella [p]		Granivore	S	Oct-Dec
Yellow rosella [p]		Granivore	S	Oct-Dec
Eastern rosella [p]		Granivore	S	Sep-Dec
Western rosella [p]		Granivore	S	Sep-Nov
Regent parrot [p]		Granivore	N, S	Sep-Dec
Red-capped parrot [p]	Seeds, fruit, flowers, nectar, invertebrates	Granivore	S	Sep-Nov
Red-winged parrot [p]		Foliage searcher	N	May-Jul, Sep-Dec
Superb parrot [t, p]	Seeds, fruit, flowers, blossom, invertebrates	Granivore	N	Sep-Nov
Scaly-breasted lorikeet [p]		Foliage searcher	N	Jul-Nov
Rainbow lorikeet [lup]	Nectar, pollen, fruit, seeds, insects	Foliage searcher	M, N	Sep-Nov
Musk lorikeet [p]		Foliage searcher	M, N	Sep-Nov

Common name	Preferred food	Feeding behaviour	Movements	Breeding
Ptilinorhynchidae (Bowerbirds)				
Spotted bowerbird [p]	Fruit, invertebrates, herbage	Forest searcher	S	Sep-Jan
Great bowerbird [p]		Forest searcher	S	Oct-Feb
Satin bowerbird [p]		Forest searcher	S	Oct-Feb
Regent bowerbird [p]		Forest searcher	S	Oct-Jan
Rallidae (Rails, coots)				
Purple swamphen [p]	Diverse vegetation and invertebrates	Ground searching	N	Jan-Dec
Sturnidae (Starlings and allies)				
Common myna [i]	Grain and seeds, fruit, insects, refuse	Ground & bush searching	S	Aug-Mar
Metallic starling [p]	Fruit, nectar and invertebrates	Foliage searcher	M	Aug-Jan
Common starling [i]	Insects, grain and seeds, fruit, refuse	Ground & bush searching	S, N	Aug-Apr
Zosteropidae (White-eyes)				
Silvereye [lup]	Fruit, nectar and invertebrates	Wood & foliage searcher	M, N	Aug-Feb

2.3 Types and costs of damage

Birds cause losses to horticulture by damaging or removing shoots, stems, foliage, buds or fruit; by damaging infrastructure (Figure 2.3), including irrigation systems; or by secondary spoilage through infection with moulds, yeasts or bacteria or through insect damage (Figure 2.4). Some secondary diseases (which occur after the skin of the fruit is damaged), such as 'sour rot' or *Botrytis cinerea* infection (Figure 2.5), can devastate fruit, particularly in cool climates. The presence of pecked and partly damaged fruit can result in significant penalties for quality downgrades and can add considerable labour costs during harvesting, when growers try to remove individual damaged fruits. Bird damage can also make it necessary to harvest early, resulting in a downgrading of both the quality and quantity of fruit.

Figure 2.3: *Sulphur-crested cockatoo damage to oregon picnic table, Bundoora Park, Victoria. Photo: I. Temby.*

Figure 2.4: *Insect damage can increase once the sweet flesh of the fruit is exposed following bird damage. Photo: J. Tracey.*

Figure 2.5: *Botrytis on grapes. Fungal infection is more likely on bird-damaged fruit. Photo: N. Reid.*

Damage to foliage, particularly by cockatoos and rosellas, occurs where the birds clip branches, stems and whole fruits, damage buds and growing tips, or pull up seedlings. Bird damage to foliage can directly affect fruit or nut production in the season it occurs, but can also influence plant growth in subsequent seasons. This is particularly serious when damage occurs at, or below, the lower internodes of growing plants. This can prevent adequate flow of nutrients to the developing foliage, flowers and fruit and can reduce leaf area and photosynthesis (Rawnsley and Collins 2003). In a study in the Eden Valley of South Australia, 57% of buds (n = 600) of grapevines were damaged by birds (Rawnsley and Collins 2003). Compensation occurred in some cases, with a 'double-burst' of buds after the loss of the first plant shoot. However, the second shoot that arises from the secondary bud is often less productive.

Bird damage in horticultural and other agricultural crops is not evenly distributed across regions, industries, varieties or seasons (Dyer 1967; DeHaven 1974b; Halse 1986; Sinclair and Bird 1987; Halse 1990; Subramanya 1994; Komdeur et al. 2005). Typically, flocks of pest birds concentrate their feeding and habitually visit particular areas and ignore others (Bray et al. 1975). For example, it has been reported that 5% of the fields in a region may bear 95% of the overall damage (Dyer 1967; Wiens and Dyer 1977; Whitehead et al. 1995). As a result, while particular growers suffer devastating losses, the impacts of bird damage measured over large areas may be small in relation to the overall loss to production. Unequal distribution of damage is important when interpreting economic losses over large areas. If damage is widespread but the majority of growers experience insignificant losses, broad-scale damage control may not be economically justified. However, management will be of great importance for individual growers experiencing severe damage.

Few published estimates are available of total horticultural losses caused by birds in Australia. However a recent national survey of horticulturists indicates that they perceive their losses to be significant. Over 1700 survey forms were returned, representing all major horticultural industries and regions. While damage varied widely between crop types and regions, horticulturalists' estimates of damage averaged: 7% for wine and table grapes; 13% for apples and pears; 16% for stone fruits; and 22% in the nut industry (J. Tracey, NSW Department of Primary Industries, Orange, unpub. 2007). Although verification with direct measures is still being conducted, these losses translate into significant costs to industry. Using Australian Bureau of Statistics 2005-06 values for agricultural commodities, horticulturalists' perceived annual production losses by birds for these industries alone are in excess of $290 million consisting of:

- $102.2 million to the wine and table grape industry;
- $83.7 million to apples and pears;
- $55.1 million to stone fruits; and
- $48.9 million to the nut industry.

Birds cause significant damage to grapes in all Australian States (Bomford 1992). Bird damage to grape crops in Victoria has been estimated to average 12% (range 1%–63%) (Bomford 1992). In vineyards in the Orange Region of New South Wales, grape losses of up to 95% were recorded and losses averaged 14% across 167 vineyard blocks (Tracey and Saunders 2003). If damage is greater than 60% the horticulture crops are often not worth harvesting. Vignerons in some regions have rated birds as their main pest, above a range of insect, nematode and fungal pests (Figure 2.6). Damage to cherries and stone fruits can also be severe, with birds destroying over 50% of fruit in some cases (Ron Sinclair, Animal and Plant Control Group, South Australia, pers. obs. 2005).

Figure 2.6: *Lorikeet damage to grapes in Adelaide. Photo: R. Sinclair.*

During three seasons in south-west Western Australia, Long (1985) found that damage to apples, pears, plums and nectarines caused by parrots (*Platycercus* spp. and *Polytelis* spp.) was minor overall (1.4%), although up to 12% damage was evident in individual varieties. More severe damage can occur in some seasons, particularly during perioed of poor marri (*Corymbia calophylla*) flowering (Rooke 1983; Halse 1986; Long 1987; Halse 1990). Other estimates of fruit damage to apple, pear and cherry trees suggest that damage levels range from less than 5% to 50% (Graham 1996; Graham et al. 1999).

Damage to buds and blossom of cherries can also be severe, with up to 90% of buds being removed by rosellas (Sinclair and Bird 1987; Fisher 1991, 1993). In a survey of 20 cherry orchards in South Australia, one-quarter suffered bud damage of over 60% (Sinclair and Bird 1987).

In one orchard, individual trees had over 95% of their buds taken by rosellas. In the same orchard an estimated three million buds were removed from 44 trees (Sinclair and Bird 1987). In Fisher's 1993 study, bud damage was most severe to 'Williams Favourite' (73.6%) and 'Black Douglas' (79%) cherry cultivars, with 'Lustre' (11.3%) and 'Makings' (13.5%) suffering less damage.

Bird damage to nut crops includes pruning of foliage and buds, ringbarking of trees, and cracking and eating the fruits of walnuts, hazelnuts, almonds, chestnuts, macadamias and pistachios (Figure 2.7). Sulphur-crested cockatoos (*Cacatua galerita*), galahs (*Elophus* [*Cacatua*] *roseicapilla*), little corellas (*Cacatua sanguinea*) and long-billed corellas (*Cacatua tenuirostris*) are the main bird pests in the nut industry. These species have been observed knocking more nuts to the ground than are actually consumed (Environment and Natural Resources Committee 1995). Submissions by the Australian Nut Industry Council and nut growers to a parliamentary inquiry into cockatoo damage in Victoria indicated that economic losses to the nut industry can be severe (Environment and Natural Resources Committee 1995). Damage to walnuts was particularly serious, with 42% damage being reported to Victoria's overall production. Hazelnuts (10%), chestnuts (5%) and pistachios (5%) also suffered high levels of damage, costing between $8 800 and $277 000 in lost production alone (Environment and Natural Resources Committee 1995). Further management expenditure and opportunity costs, where growers were reluctant to grow nuts because of cockatoo damage, were unquantified. In another submission, galahs were implicated in killing several hundred mature almond trees at a cumulative replacement cost of $516 per tree (Environment and Natural Resources Committee 1995). Crows and ravens can also be serious pests in almonds and, like the cockatoos, they often knock down many more nuts than they eat, reducing yield and quality.

A survey of horticulturists in the Northern Territory indicated that losses from birds and flying-foxes was moderate (20%–40%, severity damage index greater than 35%) for a range of crops, including passionfruit, longan, lychee, peach, nectarine, *Bactris* (peiibaye palm), rambutan, date, carambola, custard apple, pawpaw, sapodilla, guava, star apple, water apple, hogs

Figure 2.7: *Cockatoo damage to chestnuts. Photo: B. Mitchell.*

plum, abiu, grape, banana, melon, pulasan and mango, and vegetables such as beans (Lim et al. 1993). The main species, in order of importance, were the black flying fox (*Pteropus alecto*), rainbow lorikeet (*Trichoglossus haematodus*), little red flying fox (*Pteropus scapulatus*), sulphur-crested cockatoo, blue-faced honeyeater (*Entomyzon cyanotis*) and great bowerbird (*Chlamydera nuchalis*) (Lim et al. 1993). Although unquantified, damage to strawberries, currants, raspberries, loganberries, blackberries and blueberries occurs from a range of species, particularly mynas, silvereyes, starlings, rosellas, European blackbirds and sparrows (Bomford and Sinclair 2002).

'In one cherry orchard, rosellas removed an estimated three million flower buds, resulting in significant losses to production.'

Damage to the flower industry can be caused by parrots, cockatoos, corellas and rosellas chewing foliage, buds and flowers. Honeyeaters damage flowers when probing for nectar. The levels of damage to floriculture can be considerable in some regions, particularly by parrots, cockatoos and rosellas. Surveys of protea and banksia growers and direct measurements in Western Australia indicate that parrots can damage up to 50% of flowers (Hector 1989b; Massam 1990). In Massam's (1990) survey of 46 protea growers, 51% reported damage by birds.

Medium to large honeyeaters such as New Holland honeyeaters (*Phylidonyris novae-hollandiae*), red wattlebirds (*Anthochaera carunculata*) and noisy friarbirds (*Philemon corniculatus*) can affect the presentation and hence commercial value of flowers by grasping the petals and flowers with their feet, or by damaging the delicate stamens within the flower whilst feeding. Although there are no studies that have quantified the damage to flowers by honeyeaters, these species are known to concentrate their feeding on particular trees or shrubs and can carry large amounts of pollen. For example, Ford and Paton (1982) found that individual New Holland honeyeaters can carry up to 100 grains of pollen at a time from *Banksia* spp. and other native flowers.

2.4 Factors influencing damage

The number of pest birds is an obvious factor affecting the extent and severity of damage. However, a reduction in the numbers of birds may not lead to proportional reductions in damage (Section 3.3). A range of factors influences pest bird populations and the damage they cause. Predicting when damage is likely to occur allows for more efficient allocation of management effort. Similarly, knowledge of the factors influencing small-scale damage patterns on individual orchards can help in targeting control to locations where the damage is most severe.

2.4.1 Food availability

The availability of food has a major influence on the numbers of pest birds. Most birds are highly mobile and can travel long distances for food or breeding sites. Reducing access to food is essential for reducing populations of pest birds (Smith 1991; Feare 2004). Aside from the fruit or nut crop there may be many other foods available to birds, some of which may be consumed in preference to commercial crops. Monitoring of other food sources can provide useful information for managing damage.

2.4.2 Crop or orchard characteristics

At an orchard level, the characteristics of the property or crop and the surrounding area are perhaps the most important factors affecting levels of bird damage. Crops with adjacent suitable roosting habitat or perching sites, such as native vegetation, windbreaks of exotic trees or nearby powerlines (Figure 2.8), are more likely to suffer greater damage. This is widely accepted as an important factor for a range of crops, including grapes (Stevenson and Virgo 1971; Boudreau 1972; Burton 1990; Graham 1996; Somers and Morris 2002), sunflowers (de la Motte 1977; de la Motte 1990) and corn (Cardinell and Hayne 1945; Mitchell and Linehan 1967; Martin 1977; Bollinger and Caslick 1985a).

Land-use around a crop will also be important, as it will influence the availability of alternative foods. For example, there is quite a strong association between livestock and starlings (Figure 2.9),

Figure 2.8: *Starlings perching on powerlines. Photo: B. Lukins.*

as these birds preferentially feed on ground-dwelling insects (Wood 1973) and grazing makes the insects more accessible to birds. A study around Bathurst in New South Wales found that starlings preferred cleared agricultural habitats (Fisher and NSW Field Ornithologists Club 2000). In New Zealand, starlings increase their attacks on vineyards in wet weather and when pasture is too wet or high for them to feed on invertebrates (Richard Porter, Havelock North, New Zealand, pers. comm. 2005)

'Crops with adjacent suitable roosting habitat or perching sites, such as windbreaks or nearby powerlines, are more likely to suffer greater damage.'

The availability of pasture close to starling breeding colonies is also positively related to nestling survival and to the number of young produced per nest (Smith and Bruun 2002). It is not known whether orchards located near grazed pasture are more likely to be damaged by starlings or whether pastures actually divert starlings away from adjacent orchards. Mynas are closely associated with urban areas, particularly in the south-east of Australia (see factsheets in Part B). Therefore, orchards close to towns and

Figure 2.9: *Starlings in a sheep paddock. Photo: T. Bentz.*

cities in south-eastern regions of Australia are more vulnerable to damage from this species.

The size and shape of the cropping area also influence bird damage, with smaller fields often being more susceptible than large fields (Johnson et al. 1989). If the number of birds is similar, and equivalent amounts of fruit are damaged by birds in small and large orchards, smaller orchards will have higher percentage losses. This may also be exacerbated by birds' preference for the outer edges of the block (Johnson et al. 1989; Somers and Morris 2002;

Komdeur et al. 2005) and the high edge-to-area ratio of smaller fields. More isolated orchards and fields also tend to attract greater damage, as has been shown for brussels sprouts and spring cabbage (Jones 1974a; Jones 1974b), elderberries (Denslow 1987) and grapefruit (Johnson et al. 1989).

2.4.3 Fruit or variety characteristics

Time of ripening and other characteristics of the variety grown may also contribute to the level of bird damage within an orchard or vineyard. These characteristics include fruit age, maturity and sugar content; berry size, pulpiness and colour; fruit height; and plant vigour and foliage thickness.

Earlier-ripening varieties in some areas are known to suffer significantly greater bird damage than later-maturing varieties. This has been shown for blueberries (Nelms et al. 1990), cherries (Sinclair and Bird 1987; Tobin and Dolbeer 1987; Tobin et al. 1989a; Tobin et al. 1991), apples (Mitterling 1965; Baker 1980a; Baker 1980b; Tobin et al. 1989b), and other agricultural crops (Cummings et al. 1989).

Birds may start damaging fruit over a month before harvest Tracey and Saunders 2003; (Komdeur et al. 2005). For grapes, this occurs at veraison when the fruit begins to colour, corresponding to a sugar content of around 11–13 Brix° (Tobin 1984). After this level of maturity is reached, bird damage does not necessarily increase with increasing maturity (Stevenson and Virgo 1971; Tobin 1984; Komdeur et al. 2005). Some monitoring has shown that bird damage gradually increases after initial ripening, but more commonly considerable damage occurs late in the season, just before harvest (Komdeur et al. 2005).

Bird preferences have been linked to sugar concentration (Schuler 1983; Levey 1987) and type of sugar (Schuler 1983; Martinez del Rio et al. 1988) for a variety of fruits, but not grapes (Stevenson and Virgo 1971; Tobin 1984). Fat content (Borowicz 1988), other nutrients (Johnson et al. 1989; Piper 1986; Brugger et al. 1993) and aroma (Avery and Nelms 1990; Wager-Page and Mason 1996; Saxton et al. 2004) also may play a minor role in a bird's selection of fruit and seeds. Oil concentrations may also affect preferences. For example, rooks (*Corvus frugilegus*) in New Zealand show a strong preference for walnuts (Purchas 1980), and wild-caught greenfinches (*Carduelis chloris*) in New Zealand show a strong preference for oilseeds compared with similar-sized grass seeds or grains (Bomford 1976).

Size can be important in a bird's selection of fruits (McPherson 1988; Mladovan 1998; Sallabanks 1993; Avery et al. 1995; Jordano 1995). A related but independent factor, fruit pulpiness (the amount of pulp per fruit) may also influence choice (Piper 1986; Sallabanks 1993). Piper (1986) found the amount of pulp per fruit to be more important than other factors, including diameter, pulp to seed ratio, size of seeds, percentage lipid, protein or minerals.

Colour may be a cue for birds to identify ripe and nutritious fruit (Turcek 1963; Snow 1971; Willson and Thompson 1982; Willson et al. 1990). Puckey et al. (1996) found captive silvereyes (*Zosterops lateralis*) exhibited a strong preference for red fruit compared to white or yellow fruit. A study in New Zealand found that European blackbirds preferred red grapes and song thrushes (*Turdus philomelos*) preferred white grapes (Watkins 1999). Dark varieties of grapes (DeHaven 1974b; Burton 1990), cherries (Stevens and DeBont 1980) and apples (Long 1985; Long 1987) are found to suffer greater starling damage than lighter-coloured varieties. However, this does not occur in every situation (Tobin et al. 1991; Tracey et al. 2001) and varies depending on the bird species and their movements. Particular varieties can be targeted by certain species (Tracey et al. 2001). This may be due to the arrival of non-sedentary birds (Tracey et al. 2001), or a result of individual species' preferences for different varieties.

'Colour may be a cue for birds to identify ripe and nutritious fruit.'

Bunches at different heights on the vine or tree will attract variable levels of damage. Upper branches with sparse foliage often attract the heaviest damage (Boudreau 1972; DeHaven 1974b; Fisher 1991; Somers and Morris 2002). However, different bird species have different feeding strategies (see bird factsheets in Part B). For example, silvereyes may feed evenly throughout a vine or tree, whereas rosellas may preferentially feed in the upper branches (Fisher 1991).

2.4.4 Temporal or climatic factors

Many bird species usually feed in the early morning and late afternoon, when the birds are most active (Noske 1980). However, some bird species do not feed until later in the morning, as the earlier parts of their morning can be spent on other activities. The abundance of insects (Woronecki and Dolbeer 1980) and the weather (Morton 1967; Tobin 1984; Elkins 2004) are other factors that influence the number of birds or feeding behaviour and subsequently bird damage levels. For example, in Tobin's (1984) study, during and immediately after rainfall the number of birds feeding in a vineyard was found to be significantly higher. Timing of irrigation can also influence the number of birds frequenting crops. In hot weather, starlings have been observed moving with irrigation as the water stops in one block and comes on in another (Ron Sinclair, Animal and Plant Control Group, South Australia, pers. obs. 2005). It is not known whether they were drinking the water or whether the water-moistened soil gave them access to soil invertebrates.

2.5 Benefits of birds

Birds can also provide many economic and environmental benefits to growers including the control of insects, competition with, or predation of, pest birds and enhancement of environmental health and aesthetics.

Many birds found in horticultural crops are insectivorous, including honeyeaters. These species may play important roles in controlling insect pests. For example, the most important factor influencing the mortality of the codling moth (*Cydia pomonella*) is predation of the caterpillars by birds in autumn (Chapman et al. 1992). Birds are known to consume soil insects such as cockchafers and underground grass caterpillars (Subfamilies: Melolonthinae and Scarabaeidae), as well as codling moth pupae and the light brown apple moth (*Epiphyas postvittana*). Results show that bird predation can reduce grasshopper densities by 30%–50% (Joern 1986; Fowler et al. 1991; Bock et al. 1992). An integrated approach to managing birds and insects is likely to provide ongoing benefits in terms of reduced insect damage and reduced pesticide use. In some cases, insecticide spraying has been shown to increase the number of insect pests by inadvertently removing natural predatory insects (Prischmann et al. 2005). Birds also regulate harmful insects (Strong et al. 2000; Sanz 2001; Tremblay et al. 2001; Mols and Visser 2002). In a study in Spain, caterpillar damage to oak leaves was significantly less at sites where breeding birds were encouraged, compared with control sites (Sanz 2001). In another study, bird predation reduced pest insects by 50% and resulted in a 30% increase in the growth of oak trees in the Missouri Ozark deciduous forest (Marquis and Whelan 1994). In Canada and Europe, birds have been shown to benefit orchards by controlling overwintering Lepidoptera (Solomon and Glen 1979; MacLellan 1971). In a study in northern Sweden (Atlegrim 1989) the total density of insect larvae was 63% lower where birds had access to larvae than where exclosures were used; this resulted in significantly less insect damage to the annual shoots of bilberry.

'Birds can also provide many economic and environmental benefits to growers.'

However, the ability of birds to regulate insect populations and reduce insect damage depends on a number of variables, including bird population density (East and Pottinger 1975), insect life cycle (East and Pottinger 1975), habitat (Belovsky et al. 1990) and insect population dynamics. Despite feeding on harmful insects, birds in some situations may have a negligible effect on insect populations or the damage they

Figure 2.10: *Raptors such as this peregrine falcon prey on pest birds. Photo: B. Lukins.*

cause (East and Pottinger 1975; McLennan and MacMillan 1983).

Birds of prey and species that compete or exclude pest birds are desirable in horticultural settings. For example, magpies (*Gymnorhina tibicen*) are territorial and occasionally display agonistic behaviour towards, and attack, pest birds including sparrows (Barr 1986; Morgan et al. 2006), starlings (Morgan et al. 2006) and sulphur-crested cockatoos (Cilento and Jones 1999). Raptors (Accipitriformes and Falconiformes), particularly sparrowhawks, goshawks, falcons (Figure 2.10) and hobbies, are known predators of a range of pest birds. Attracting these birds to crops might provide economic benefits by reducing the numbers of pest birds and the damage they cause (Section 4.1.6). However, providing habitat to attract desirable birds requires careful consideration and management (Section 4.3).

2.6 Other damage caused by pest birds

Birds are pests of other industries as well as horticulture, and sometimes they also pose a risk to humans. They can:

- damage cereal and oilseed crops (Figure 2.11);
- damage aquaculture, taking fish and crustaceans;
- take and contaminate animal feed at intensive livestock and production facilities (Figure 2.12);
- eat and foul pasture;
- prey on lambs (rarely;)
- damage seedlings in plantation forests;
- compete with native species for nest holes and food;
- pose a risk to aircraft in terms of air-strike both on runways and in the air, and nesting in engines;

- be a social nuisance, particularly when they roost or nest in urban areas or where they damage woodwork or steal golf balls;
- spread disease to people and animals;
- physically attack people (for example magpies, butcherbirds (*Cracticus* spp.), masked lapwings (*Vanellus miles*)); and
- cause nutrient enrichment of soils and waterways by faecal contamination.

More comprehensive reviews of these impacts are available (Long 1981; Olsen 2000; Clarke et al. 2001; Bomford and Sinclair 2002).

Figure 2.11: *Galah damage to sunflower. Photo: P. Fleming.*

Figure 2.12: *Starlings feeding on supplementary feed for stock. Photo: B. Mitchell.*

3. Techniques for measuring and monitoring damage and abundance

Appropriate damage assessment is a critical step in the effective management of pest birds. Assessment allows for improved planning and evaluation (Section 1.4). The methods used for measuring bird damage in agriculture include:

- questionnaires: face-to-face interviews, phone interviews and mail surveys (Section 3.1);
- direct measures: counting, weighing and visual estimates (Section 3.2); and
- indirect measures: monitoring bird numbers and energy demands (Section 3.3).

3.1 Questionnaires

Questionnaires are useful in setting research and management priorities over large areas. Face-to-face interviews (Bennett 1984), phone interviews (O'Donnell and Vandruff 1983) and mail surveys (Atwood 1956; Dawson and Bull 1970; Crase and De Haven 1973; Stickley et al. 1979; Wakeley and Mitchell 1981; Bomford 1992; Johnston and Marks 1997; Graham et al. 1999) can all be used to gather damage information. There is a trade-off between obtaining specific information and the time and cost involved (Table 3.1). Face-to-face interviews are more useful when more complex information from specific groups is required (Orlich 1979), but they are more time-consuming and costly than mail or phone surveys. Mail surveys can be used over larger areas and have the lowest cost per response.

All questionnaires have potential biases. For example, biases can occur when a proportion of the targeted sample does not respond (Dawson and Bull 1970), or when the survey is conducted after too much time has lapsed (Sen 1972), or when respondents overestimate or underestimate damage (MacDonald and Dillman 1968). Other errors can be reduced by carefully wording

Table 3.1: *Comparison between face-to-face interviews, telephone surveys and mail questionnaires (based on rankings from Miller 1983; Crabb et al. 1988).*

Factor	Face-to-face interview	Telephone survey	Mail questionnaire
Large sample size	-	0	+
Large geographical area	-	0	+
Question complexity	+	0	-
Highest percent return	+	0	-
Lowest per unit cost	-	0	+
Ease of gathering information	-	0	+
Time required	-	+	0
Completeness of answers	+	0	-

Ranking: + most favourable; 0 intermediate; - least favourable (Miller 1983).

questions to avoid leading particular responses. Correct and objective phrasing of questions has been reviewed by a number of authors (Kahn and Cannell 1967; Orlich 1979; Filion 1981; Chadwick et al. 1984; Crabb et al. 1988).

In some cases, biases associated with questionnaires can be corrected (MacDonald and Dillman 1968; Sen 1972). For example, fruit growers with significant bird damage may be more likely to respond to a questionnaire about birds (Dawson and Bull 1970). By re-sampling a proportion of the candidates that did not reply, this 'non-response' bias can be estimated.

Estimates or rankings of damage should be correlated with actual damage. This can be determined by using direct measures. However, if growers' perceptions of damage are inconsistent, no adjustments to the type or design of a survey can standardise results. Surveys should be supported by other measures so that results can be verified or corrected for measured bias. It is important to ensure that the survey asks only questions for which data can be analysed.

3.2 Direct measures

Without counting and evaluating all crops on a property, estimation of bird damage requires the taking of a representative sample from which total damage is predicted. Standard random and systematic sampling procedures (Granett et al. 1974; Caughley and Sinclair 1994) (Appendix B) are used to achieve accurate and precise measures. The desired degree of accuracy or precision will dictate how much time and cost are required for measurement. For example, most producers can make general visual assessments without spending much time or money.

Direct measures of damage include weighing, counting and visual estimates. Counting and weighing are time consuming but can be used to calibrate visual methods. These techniques have been used for cereal crops (Dawson 1970; Khan and Ahmad 1990) and for apples, pears and stone fruits in orchards (Long 1985). Weighing and counting often fail to account for losses due to secondary spoilage (Section 2.3).

The decision to use weighing, counting or visual estimates will depend on the type of crop as well as the available resources. For example, when measuring damage to grapes it is often not practical to count all the individual berries on each bunch, so a visual estimate may be preferred. However, for larger horticultural crops such as vegetables and stone and pome fruits (such as apples and pears), counting may be just as efficient — and more accurate. The maturity of the crop may also be relevant to the measurement method used. Counting may be suitable at harvest as part of quality control. Earlier in the season visual assessments are more appropriate.

'Bird damage is often higher around the edges of a crop.'

Where damage is patchy within a block, stratification (Figure 3.1) will increase precision and decrease sampling effort. For example, concentrating the sampling around the edges of a crop, where bird damage is often higher, will usually improve efficiency and accuracy. If sampling is being conducted over larger areas, stratification according to the age of the crop, geographic area, variety, and early or late maturing date can also increase sampling efficiency and accuracy (DeHaven 1974b).

3.2.1 Weighing

Calculating bird damage by weighing involves cutting off and weighing a representative sample (plot) of individual fruits. This method has been used for measuring damage to grain crops (Khan and Ahmad 1990). The undamaged weight of a fruit or bunch is calculated from the mean weight of the undamaged samples in the plot. An estimate of the damage in each plot is then calculated from the difference between this weight and the actual weight of the whole sample from the plot. However, in most horticultural situations weighing is impractical because of the variable weights of fruits and failure to take into account pecked and partly eaten fruit. For example, if a piece of fruit is pecked it may not be suitable for sale, even though only a small fragment of the fruit may have been removed.

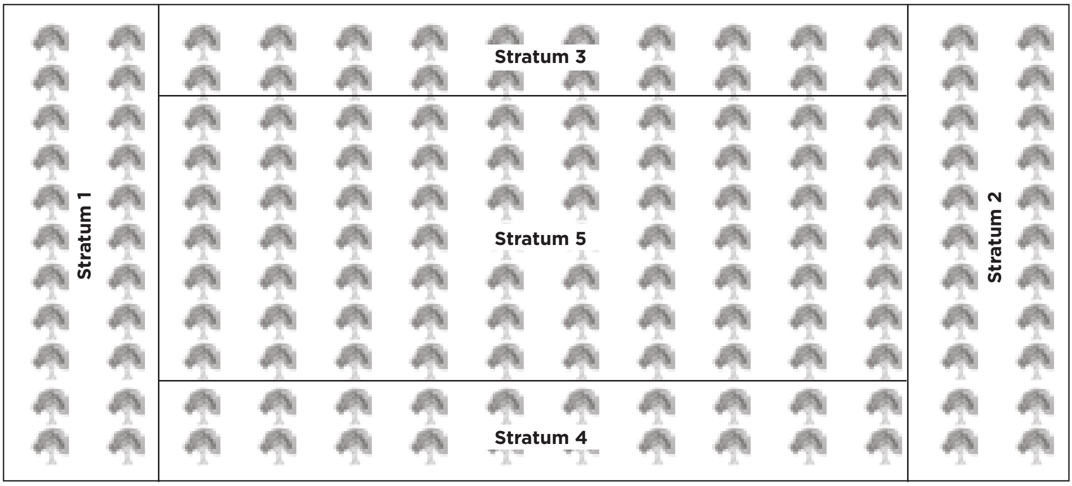


Figure 3.1: *A crop or orchard plan divided into strata for stratified sampling. Each stratum is assessed separately, so that where damage is severe in one stratum, but not in another, this information is collected. If the block was assessed as a whole, more samples would need to be taken to ensure estimates are accurate. Source: Corinne King.*

Hence, if a batch of damaged fruit has only 5% loss by weight, but 90% of the fruit has bird pecks and pecked fruit cannot be sold, the economic loss is 90%, not 5%.

An alternative weighing method can be used when distinct areas of the crop have been damaged exclusively and are therefore unharvestable. For example, consider several rows of wine grapes that are severely damaged by starlings to the extent that they have become uneconomic to pick. The weight of fruit or nuts lost from rows not harvested could be estimated from the average weight of harvested fruit or nuts from undamaged rows of an equivalent variety and age. Although this provides estimates quickly, it also assumes negligible damage has occurred in other areas.

3.2.2 Counting

Estimates can also be calculated by counting the number of damaged and undamaged samples within a crop. Although counting has been used to estimate total damage (Burton 1990), a common use of this method is to calibrate visual estimation methods (Stevenson and Virgo 1971; DeHaven and Hothem 1979; Somers and Morris 2002).

3.2.3 Visual assessment

Visual estimation is rapid and is the method most widely used to obtain measures of bird damage to agricultural crops (Stevenson and Virgo 1971; DeHaven 1974a; Dolbeer 1975; DeHaven and Hothem 1979). This is achieved by using experienced observers to estimate percentage loss (see case study 9.5), or by assigning a damage ranking to individual fruits or plants. To improve accuracy, estimates may be calibrated by counting or weighing samples that have been visually assessed. Sample cards or templates containing examples of damage levels can be useful guides for measuring losses visually (Fleming et al. 2002; Tracey and Saunders 2003).

3.3 Indirect measures

3.3.1 Monitoring bird numbers

Knowledge of the birds on a property is an important starting point for reviewing available options to reduce damage. Awareness of the species involved and an understanding of their behaviour, feeding habits, movements and interactions with other species (see bird factsheets in Part B) will aid decision-making.

For example:

- control should be targeted in areas of highest bird activity;
- non-sedentary species will require different management to sedentary species. Control outside the ripening period is more useful for resident species than for species arriving just before harvest;
- many species are beneficial and can consume large numbers of pest insects;
- native species are generally protected;
- more cryptic or solitary species may cause greater damage than more obvious species. Greater management effort should be placed on species causing the most damage; and
- some birds (for example magpies, red wattlebirds, pied currawongs (*Strepera graculina*) and birds of prey) exclude (Figure 3.2) or prey upon other crop-damaging birds. Control of these birds may be counterproductive.

A variety of techniques can be used to estimate the number of birds or bird species within a given area (Bibby et al. 2000). A method that simply identifies the species present is the 20-minute, two-hectare search (Middleton and McWaters 1996). This is used by many birdwatchers as part of the *Birds Australia Atlas* (Barrett et al. 2003).

Figure 3.2: *A hawk dispersing a flock of starlings. Some birds of prey exclude pest birds. Photo: R. Shirley.*

For horticultural and many other situations, to estimate population density or an index of abundance is much more useful, (recording counts of each bird species).

'Monitoring pest birds is an important starting point for reviewing options to reduce damage.'

Point counts, where the numbers of birds of each species are recorded for five- or ten-minute intervals, is one method used to estimate relative abundance. These counts are usually recorded after first light, when birds are most active. Caution must be taken to count birds that are more active in orchards at different times of the day, and to take into account differences in detectability between species. There is also a variety of ways to correct for bias associated with detection, such as using sighting distance to estimate the probability of detecting a bird by an observer (Buckland et al. 2001). Some assumptions of this method are that the probability of detecting a bird declines with distance from the observer and that all birds at the observation point are observed with certainty.

Counting numbers of birds can be used to help evaluate management techniques. This can be achieved by measuring the success of a management campaign in terms of reduced numbers of pest birds. For example, the number of pest birds recorded in areas where birds were shot may be less than in areas where only scaring devices were used. This type of information can be used in a cost-effectiveness analysis (Section 5.4). If changes in bird numbers are being used to evaluate management, the same measurement methods should be used before and after implementation to ensure an accurate comparison.

3.3.2 Relationship between bird population density and damage

Bird population density can be used to predict bird damage without directly measuring the damage. This can be achieved by using the relationship between density and damage

(Figure 3.3). Unfortunately this relationship is rarely known and is difficult to obtain.

'Direct measures of bird damage can be simpler, less time consuming and more accurate than estimating bird density and inferring the impact.'

Any prediction of damage from the number of birds relies on assumptions about density-damage relationships. Does bird damage increase at the same rate as pest density increases? There is little published information about these relationships in horticulture. Pest density-damage relationships are rarely simple proportional equations whereby halving the pest density halves damage (Figure 3.3). Measurements of density and damage taken over time need to be assessed to determine this relationship.

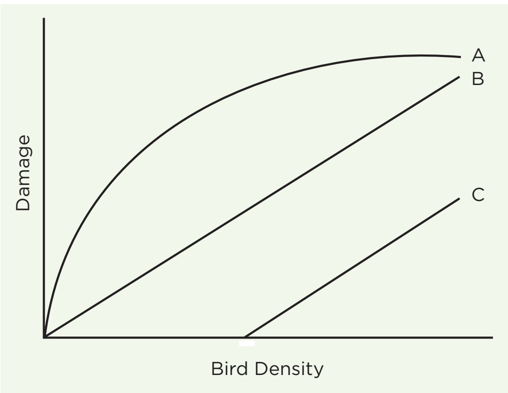


Figure 3.3: *Some possible relationships between bird density and damage.*

In Figure 3.3:

- **A** represents a situation where low numbers of birds still cause high levels of damage. European blackbirds may damage fruit in this way, where a few resident birds can inflict continuous levels of damage over the season.
- **B** represents a situation where damage is proportionally higher when there are higher numbers of birds. This has been shown to occur with bird damage to pistachios, where damage increases directly with increasing numbers of crows per unit area (Crabb et al. 1986).
- **C** represents a situation when damage does not occur until birds reach a certain threshold density. This could occur, for example, when native honeyeaters exhaust a preferred native food source before damaging fruit. This relationship could also occur if cherry trees compensate for a certain level of bud damage by rosellas before production yields are reduced (Sinclair and Bird 1987).

Even if these relationships are determined, they may be applicable only to a specific situation and often cannot be generalised. Unlike urban and environmental impacts of birds, direct measures of bird damage in agriculture can be simpler, less time-consuming and more accurate than estimating bird density and inferring the impact.

3.3.3 Estimating bird damage from energy requirements

Information on feeding and energy requirements of target species can also be used to estimate potential impacts. These methods predict damage by translating bird population abundance and daily energy requirements of individual birds (Kendeigh 1970) into the amount of the resource removed. Bird damage can be estimated as:

Daily amount of crop consumed = [number of birds] x [daily energy requirements of individual birds] x [proportion of energy obtained from the crop relative to all items consumed] x [energy available per weight of crop].

For example if we have 10 birds, each requiring 70 kilojoules of energy per day, and half the energy comes from grapes, which have 2.15 kilojoules of energy per gram, then the total weight of grape consumed by the ten birds is:

10 birds x [70 kilojoules/(day bird)] x [1/2] x [2.15 kilojoules/gram] = 163 grams/day

If these 10 birds were of species that remove whole grapes, then the 163 grams/day is approximately equivalent to 163 grapes (wine grapes average approximately 1 gram each) and this is an estimate of the loss. However, if the 10 birds were of species that only peck grapes, the 163 grams may come from many more than 163 grapes and is thus an under-estimate damage.

More complex approaches using other determinants of energy (such as age class, annual and daily change in abundance and behaviour, temperature and body weight) have been used to predict damage to corn and grain crops by starlings and American blackbirds (Icteridae) (Wiens and Innis 1974; Wiens and Dyer 1975; Weatherhead et al. 1982; White et al. 1985).

Considerable ecological information is required for energy and density measurement methods. This requires long-term research and in most cases is not available (Otis 1989). These methods also do not take into account the natural variation in damage (Otis 1989; Hone 1994); nor do they take into account losses due to secondary spoilage. Despite these difficulties, an enclosure study of American blackbirds and grain found that estimates of damage using energy requirements and bird density were equivalent to direct measures (Weatherhead et al. 1982).

Estimates of damage using energy are more useful when estimating damage over broad agricultural areas: for example, when density and feeding habits are already known, easily obtained, or being determined for other reasons. When applying these methods to the estimation of damage, consider factors such as uneven distribution of damage, opportunistic feeding habits and diets, and damage caused by different age classes. These factors are particularly important in horticulture, where fruit is often only a small proportion of a pest bird's diet (e.g. Adelaide rosellas *(Platycercus elegans adelaidae*) and cherries (Reynolds 2003)).

In the case of bird damage to horticulture, a number of factors make it difficult to estimate potential damage on the basis of observed bird numbers — required for any of the above -mentioned techniques. These include:

- unpredictability of bird movements, particularly for species that may not maintain feeding pressure on a particular crop throughout ripening;
- difficulty in assessing bird numbers, particularly for small, mobile species;
- patchiness of bird feeding and resultant damage within a crop;
- the fact that some damage is indirect (for example, mould developing on pecked grape bunches); and
- compensatory production, so that the crop partly or wholly recovers from damage that occurs during development.

Another problem with monitoring that is focused on pest numbers is that it often promotes a focus on lethal control techniques. In the case of pest birds, these techniques are rarely the best solution (Chapter 4).

3.4 Measuring secondary damage and compensation

In addition to the direct loss caused by birds eating fruit, crops may suffer secondary losses through spoilage to previously undamaged fruit from moulds, yeasts, bacteria and insects attracted to damaged fruit (Figure 2.4 and 2.5). This secondary damage is not easily measured in terms of cost, as it is associated with downgrading of fruit by purchasers, extra staff costs to remove bird-damaged fruit and increased costs for fungicide application. Timing and type of bird damage may also be a factor. For example, if wine grapes are damaged by birds that peck grapes (such as silvereyes and honeyeaters, Figure 3.4), rather than remove them, and this damage occurs immediately before harvest, disease is unlikely to establish and wine quality may not be compromised. There is a need to record the timing and type of secondary damage, as well as the costs incurred.

In some crops, a certain level of bird activity can be tolerated without any significant impact on final yield. This is because plants compensate for fruit loss, as measured by comparing yields of damaged and undamaged plants rather than by calculating the percentage of damaged fruit. In many horticultural crops, remaining buds can compensate for damaged buds. For example, in

Figure 3.4: *Honeyeater pecking damage to grapes. Photo: J. Tracey.*

cherries, removal of some buds results in larger fruit, which attract a premium price for quality. That is, fewer large fruits are worth a lot more than an equivalent weight of smaller fruits. Therefore some bud damage may, in effect, be similar to the normal horticultural practice of thinning and may result in economic benefits (Sinclair and Bird 1987).

However, when the damage occurs to the growing shoots the secondary shoots are often less productive and are likely to yield more numerous, but smaller, fruit. Damage to growing shoots can cause reduced productivity from the tree or vine in subsequent seasons (Section 2.3) (Rawnsley and Collins 2003). Peas can have their emerging shoots nipped off, mainly by sparrows. The missing shoot is often replaced by two new ones from the seed, but this causes the crop to ripen unevenly and be downgraded by the processing factory (Porter et al. 1994).

'Damaged crops may suffer secondary losses through spoilage by moulds, yeasts, bacteria and insect damage.'

An isolated assessment of bird numbers or damage needs to be considered in the context of the effects of damage on the critical stages of crop development and on final production. For example, Tobin et al. (1993) found that macadamia nut trees compensated for rat damage by producing more nuts, and overall yields were unaffected. In this example there are no economic benefits of pest control.

Woronecki et al. (1979, 1980) found that estimates of primary bird damage to corn were affected by the state of development of the kernels at the time of damage, the amount of compensatory growth, and the environmental factors that influenced secondary loss. For cherries, a reasonably accurate estimate of bud damage could be achieved by a single estimate just before flowering, as new buds are not initiated after flowering.

'Damage to growing shoots can cause reduced productivity from the vine or tree in subsequent seasons.'

In many cases, estimates of direct percentage loss will be sufficient as a basis for management decisions. However, these estimates are likely to be conservative when there is a high percentage of pecked or partly damaged fruit; or overestimated where damage takes place early in the season and compensation is likely to occur.

3.5 When to measure

The most appropriate time to measure damage will vary for different crops and situations. For example, measure as close as practicable before harvest when the majority of damage occurs late in the season and all damage is easily identified at this time. The situation is more complex when damage is occurring at different stages of growth before ripening, and when damage early in the season is no longer detectable before harvest. In these circumstances, measure damage in separate stages and collate the results to obtain overall damage estimates.

3.6 Early forecasting of damage

The techniques discussed so far have focused on estimating damage after it has occurred. However, this often prevents adequate management preparation for the same ripening season. Although bird damage can be variable, early predictions are useful for management planning. When damage is forecast, the following factors need to be considered:

- What was the damage to the crop in previous years? Assessing damage this season helps in management decisions for next season.
- What was the severity of damage other growers experienced in the area? Discussing bird damage with local industry associations, horticultural advisers and other growers in the district is helpful. Government and industry contact details are listed in Appendix A.
- Which bird species are likely to cause greatest damage in the area? See the bird distribution maps of the major pest species in the factsheets in Part B. Note that some species, particularly honeyeaters are non-sedentary and may be more of a problem when natural food sources are limited.
- Were weather conditions during late winter through to early summer conducive to a long and productive breeding season for pest birds? Damage is likely to be worse in years when large numbers of young birds enter the population. Local bird watchers and ornithologists will be useful sources of breeding season information.

4. Assessment of control techniques

Most horticulturists attempt to manage bird damage using either:

- strategic one-off control (netting); or
- strategic targeted control (usually some type of bird-scaring programme using visual and/or acoustic devices, with or without some shooting) - see Section 1.2.

This chapter describes research on control techniques that may support the above management options. The scientific principles underlying the effective selection and use of pest bird control techniques are outlined. This information is provided to help growers select the pest bird control techniques most appropriate for their individual circumstances (Section 1.2).

4.1 Bird scaring

Scaring and shooting are the most common approaches to pest bird control in Australia. Birds are scared by unusual, sudden, unexpected, unfamiliar or dangerous events (scare stimulus), or by something that mimics a predator or the response to a predator (such as bird alarm calls).

A bird's first reaction to being scared is flight. This is often followed by a period of curiosity, during which the bird tries to gather information about the scaring stimulus. Each time it encounters the stimulus, it gains more information. Eventually, it accumulates enough information to know that unless the stimulus presents a real threat, it can be ignored — that is, the bird has become habituated to the stimulus. The time taken for habituation will vary, depending on a suite of factors, including species, surrounding habitat and the regularity and type of noise. Habituation is the single factor that most limits the effectiveness of scaring, and maximum efforts should be directed towards its prevention. Even the simplest scarer may have some effect for a short period. It is also possible that once birds habituate to a stimulus, it could then work as a cue indicating the presence of available food (Conover and Perito 1981). Under these circumstances it would attract birds to a crop and have the opposite effect to that desired.

'Unless a concerted effort is maintained over the entire period for which a crop is vulnerable, scaring is unlikely to significantly reduce fruit loss.'

Ineffective scaring may increase damage levels. For example, if a grower uses a scaring device that results in the birds flying out of an orchard or vineyard every time a device fires, only to return and continue feeding, then damage can actually be increased. The birds may drop the fruit they are eating when the device fires, and pick another when they return, thereby increasing the amount of damage (Beeton 1977; Fleming 1990; Ford 1990).

With bird species that peck or bite fruit or berries (for example silvereyes, red wattlebirds and crimson rosellas (*Platycercus elegans elegans*)) rather than pluck them (for example, starlings (Figure 4.1), European blackbirds and corvids), scaring may spread damage and increase losses. According to Sinclair (2000a, 200b) each time a scaring device activates, it may simply disturb birds so that they move to another area. With grapes, for example, the result can be that many bunches will have only a few pecked berries, but these can promote insect damage or fungal infection over the whole bunch, severely reducing quality (Section 2.3). By not disturbing feeding birds, the loss might be restricted to severe damage on fewer bunches, which is better from a grape quality perspective (Sinclair 2000a; Sinclair 2000b). Unless birds are successfully scared to another feeding site, they will inevitably return to the crop where the scaring is being undertaken. In addition, each time birds fly away and then fly back again they use extra energy and need more food to satisfy their energy needs.

'Most successful scaring of pest birds is achieved by using a variety of scaring devices.'

Scaring devices may help to reduce damage if they are used when a crop is at the early stages of ripening, and before birds have established a habit of visiting the site. Scaring is also likely to be more effective when alternative attractive feeding sites are available (Jarman 1990; Crossfield 2000). Most successful scaring of pest birds is achieved by using a variety of different scaring devices (Bishop et al. 2003), starting them as soon as birds show an interest

Figure 4.1: *Characteristic starling plucking damage to grapes. In the foreground, the fruit stubs remain where whole grapes have been removed by the birds. Photo: J. Tracey.*

in a crop and before the birds get into the habit of feeding there. Changing devices and moving them around frequently will also help to avoid habituation (Marsh et al. 1991; Fisher 1992).

4.1.1 Bird species and behaviour in relation to scaring

It is important that growers do not treat all pest birds as if they were a single species. Birds differ in their biology and behaviour (Section 2.2 and factsheets Part B), and this is likely to influence how they respond to different methods of control (Fisher 1992). Growers do not categorise all pest insects as a single species: different insect species require specific control strategies. Not all pest plants are simply regarded as weeds and treated with the one herbicide. Similarly, not all pest bird species should be treated the same. Some birds may not take any notice of any scaring devices, including shooting (Richard Porter, Havelock North, New Zealand, pers. comm. 2005).

Some bird species are sedentary and live within a small area; others actively move around within a region or seasonally migrate into a region (Table 2.3). Individuals of some species live singly or in small groups, whereas others form large flocks. Seasonally migratory species such as silvereyes, or mobile species such as starlings and cockatoos, are not strongly attached to a territory when fruit is vulnerable to attack. Hence mobile and non-sedentary species should be easier to scare away than sedentary species. In contrast, sparrows, being a sedentary territorial species, are likely to be difficult to scare. They are strongly attached to their territory and will often have nowhere else to go if all neighbouring territories are occupied. These examples demonstrate the need to consider the behaviour of each bird species in formulating a management strategy.

'It is important that growers do not treat all pest birds as a single species.'

It is clear that the methods most suitable for reducing fruit loss by sparrows may differ from the methods suitable for starlings. For non-sedentary species, such as honeyeaters (Table 2.3), scaring should start at the first sign that birds are investigating a crop as a food source. The scaring programme may be more effective if started well before any sign of crop damage. With sedentary species, such as European blackbirds, sparrows, noisy miners (*Manorina melanocephala*) and rosellas, some scaring in the crop throughout the year may help in maintaining the message that the area is not a safe feeding site. However there is a trade-off between scaring to prevent birds from establishing a feeding pattern and starting to scare too early, which may increase habituation. Starting a scaring programme just before the most costly damage is likely to occur may ensure maximum benefit.

Alternative control methods, such as population reduction (wherever practical and legal), should also be considered for sedentary species.

Timing of scaring can be important. For example, feeding activity for some species is concentrated during the early morning and late afternoon and can also vary according to a range of environmental factors (Section 2.4).

4.1.2 Visual scaring methods

A wide variety of visual scarers are used. They include plastic shopping bags; car-yard bunting; spinning metal strips; reflective mirrors or tape; balloons displaying big eyes; and predator models such as scarecrows (human effigies), plastic silhouettes of birds of prey, or kites in the shape of predatory birds.

Balls or balloons with large eyespots are inexpensive scaring devices. Helium- or air-filled balloons with eyespots can be tied to vegetation or to long poles (Figure 4.2). They can be used successfully only in still conditions or in light winds; otherwise they will be blown flat and damaged. Tests of the effectiveness of eyespot balloons are mainly inconclusive (Marsh et al. 1991). McLennan et al. (1995) found that a commercial ball with a reflective eye that appeared to move as the ball rotated was significantly ($P < 0.01$) more effective at repelling sparrows from a feeding table than a beach ball with an eye painted on it, although the deterrent effect was minimal at 40 metres and ceased after nine days.

Figure 4.2: *Balloon bird scarer in a vineyard. Photo: N. Reid.*

Kites shaped like birds of prey (often falcons or hawks) are another type of inexpensive visual scaring device. These are usually tethered to the ground, or may be suspended from helium-filled balloons that are tethered to a stake by a long monofilament line 30–60 metres above the ground. Ground-tethered kites require constant, low-velocity wind to keep them aloft, but often in the early morning and late afternoon there is little wind and these are the times when some birds tend to feed. Winds of over eight kilometres per hour can blow down kites and balloons (Hothem and DeHaven 1982), which may also be damaged when they become entangled in trellises or vegetation.

Predatory bird kites suspended from helium-filled balloons have successfully reduced bird damage to blueberries (damage reduced by 35%), vineyards (by 48%; range 32%–88%) and cornfields (by 83%) in North America (Conover 1982; Hothem and DeHaven 1982; Conover 1984).

To be effective, the predator kites were used at a density of about one per hectare. The main cost when using the predator kites was maintaining the helium balloons, as most lasted only a few days. The kites were more effective against some pest bird species than others. The effectiveness of predator kites may be improved by selecting a model that closely resembles a predator species that occurs in the local area (Marsh et al. 1991). Some predatory bird silhouettes imported from North America and sold on the Australian market are not similar to Australian species and may not be recognised as a threat by pest birds here.

Another inexpensive scaring device used is a predatory bird model mounted on a pole or building (Figure 4.3). For example, Conover (1985) used animated owl models to protect vegetable plots from damage caused by American crows (*Corvus brachyrhynchos*). The owl model, grasping a crow model in its talons, was mounted on a weather vane so that it moved in the wind. The wings of the model also moved, either by the wind or by a battery-operated motor. This animated predator model reduced crop damage by 81% compared with an unprotected control plot and was relatively cheap to build.

'In general, visual scarers offer only short-term protection, as birds soon learn to ignore them.'

In general, visual scarers offer only short-term protection, as birds quickly realise that they pose no real threat and then become habituated (Long et al. 1990; Marsh et al. 1991; McLennan et al. 1995). For example, some birds habituate to predator kites after only five hours' exposure (Conover 1982). Visual scarers are simply something new and unusual in the birds' environment, and they soon learn to ignore them. This is particularly true for devices that are not kept in motion by wind or motor. Effectiveness also declines with distance from the scarer. For example, McLennan et al. (1995) found the effectiveness of eyespot balloons in keeping sparrows away from a feeding table was greatest at the closest distance measured (ten metres) and negligible at 40 metres.

Marsh et al. (1991, 1992) made some generalis-ations about scaring with scarecrow and predatory bird models on the basis of their review of the world literature on this topic. For best results, scarecrow and predatory bird models should:

- appear lifelike (Figure 4.4 and 4.5);
- have motion (for example, pop-up scarecrows and windblown predator models);
- be highly visible;
- be moved frequently to new locations in and around the crop to help prevent habituation;
- be supported by additional control methods, such as shooting to scare, or other acoustic scaring devices; and
- be started before birds develop a feeding habit in a crop.

Despite some old and resilient myths, birds do not seem to be scared by bird carcasses (Naef-Daenzer 1983) unless they are life-like or in a

Figure 4.3: *Visual bird scaring device shaped like a predatory bird. Photo: B. Mitchell.*

threatening pose, and even then habituation develops rapidly (Bishop et al. 2003). Snake and cat models are equally ineffective (Marsh et al. 1991).

The major limitation of attempting to scare birds using reflectors, bright spinning or flapping objects, or similar devices is rapid habituation (Marsh et al. 1991). Wind conditions are important, because wind creates motion and sometimes sound, which increases the effectiveness of visual scaring devices (Tobin et al. 1988; Marsh et al. 1991). For example, CDs (compact discs) hanging on string in fruit trees cause random light flashes in the wind (Figure 4.6). However, high winds can break, or even blow away, scaring devices.

Once birds habituate they will fly between scaring devices or even perch on them before entering a crop to feed. Different pest bird species may have different responses to scaring devices. For example, in Ohio, red-winged blackbirds (*Agelaius phoeniceus*) and sparrows were effectively scared from grain and sunflower crops by reflecting tape, but American goldfinches (*Carduelis tristis*) and mourning doves (*Zenaida macroura*) were not (Dolbeer et al. 1986). Reflecting tape was also found to be ineffective for repelling starlings, American robins (*Turdus migratorius*), house finches (*Carpodacus mexi-*

Figure 4.5: *Lifelike scarecrows, holding gun-like sticks, combined with gas gun operation, are more likely to be effective for controlling pest bird damage than either device on its own. Photo: R. Sinclair.*

Figure 4.4: *Examples of poor scarecrows, as they are not lifelike. Photos: R. Sinclair.*

canus), mockingbirds (*Mimus polyglottos*) and grey catbirds (*Dumetella carolinensis*) feeding in blueberry plots (Tobin et al. 1988). Dolbeer et al. (1986) speculated that reflecting tape might be more effective against flock-feeding birds than those that feed solitarily or in small groups.

4.1.3 Acoustic scaring methods

Scaring with acoustic (sound-producing) devices, including ultrasonic devices, is often promoted as effective, scientific, humane, cheap and simple to operate (Bomford and O'Brien 1990). Many types are marketed in Australia, ranging from cheap crackers and wind-operated devices to expensive, sophisticated electronic devices. The most commonly used acoustic devices rely on startling or fear for their scaring effects. Most are non-biological sounds generated by mechanical, electronic or explosive means and may include wind or mechanically powered noise generators, a range of electronically amplified sounds, propane gas cannons, crackers and firearms. Some devices produce bioacoustic sounds and others produce ultrasound (sound beyond human reception).

Figure 4.6: *Compact discs tethered in a crop can make good visual scaring devices, as they reflect light and move. Photo: B. Mitchell.*

Sound travels through air in waves, and the loudness of sound, usually measured in decibels, declines with the square of the distance from the source. This means that the loudness of a signal drops away rapidly with distance. Sound shadows also form behind objects, such as trees or bushes, which further decrease sound signal strength (Bomford and O'Brien 1990; Marsh et al. 1991).

'Birds ignore sounds after a short time if they are repetitive, emanate from the same point source, and pose no physical threat.'

Most acoustic devices are set to go off automatically at either regular or random intervals; others are triggered by the movement of birds. As with visual methods of control, birds become habituated to, and then ignore, sounds after a time if they are repetitive, emanate from the same point source, or pose no physical threat. An extreme example is the lack of response shown by birds adjacent to airport runways as jet aircraft take off or land, often only metres away, with noise levels well over 100 decibels. A scaring and chemical repellent system that operates only when birds fly through a radio beam was shown to be more resistant to habituation than alternative systems that operated at regular or random intervals for keeping waterfowl away from contaminated ponds (Stevens et al. 2000). There is at least one commercial device available in Australia that is triggered by radar detection of the birds and bioacoustic deterrent calls are activated by radio transmission (Muehlebach and Bracher 1998).

The most common form of scaring with sound relies on shooting to scare or harass, or devices such as gas guns (Figure 4.7) that produce loud bangs. Shooting should always be initiated before other scarers so that birds make a connection between a loud bang and real danger. Many native birds are protected, and a permit from a State fauna authority is required before they can be shot or harassed (Section 6.1). All introduced birds can be shot without a permit, provided that other firearm and animal welfare regulations are observed. Shooters should move around rather than stay in one location. Similarly, devices producing bangs should also be moved around to reduce the rate of habituation.

Bioacoustic or biosonic sounds are broadcasts of recorded calls used in animal communication: usually alarm, distress or predator calls, or electronic mimics of such calls, are used in a variety of acoustic devices available on the market. The calls are recorded, sometimes digitised and modified, amplified, and then broadcast through speakers (Aubin 1990; Marsh et al. 1991) (Figure 4.8).

Some birds give alarm calls when they see a predator or something they perceive as a threat. Alarm calls alert nearby birds to the presence of danger, and the usual response is immediate flight. Alarm calls are often species-specific, although some species will respond to other species' alarm calls (Baxter et al. 1999). When taped alarm calls, or electronic imitations of alarm calls, are broadcast, they may have a similar effect to a real alarm call. The effectiveness of broadcast alarm calls for scaring birds away is likely determined mainly by the quality of the sound and by how often it is repeated.

Distress calls are usually loud 'squawks' given by birds held captive, either in a net or by a predator. The common response to a distress call is for surrounding birds to be attracted to the site, where they often fly around making a lot of noise in what is called mobbing behaviour (Conover and Perito 1981; Conover 1994). Generally, distress calls are likely to be less effective for scaring birds than alarm calls, but distress calls are sometimes used because they are easier to record, and they have been shown to be effective for dispersing herons (Ardeidae), gulls (*Larus* spp.) and crows (Naef-Daenzer 1983; Gorenzel and Salmon 1993; Bishop et al. 2003).

Birds habituate rapidly and start to ignore a broadcast alarm or distress calls if the same call or call sequence is frequently repeated (Martin 1986; Aubin 1990; Yokoyama and Nakamura 1993; Harris and Davis 1998). They may take flight, but rapidly return to continue feeding. The quality of the broadcast sound is determined by

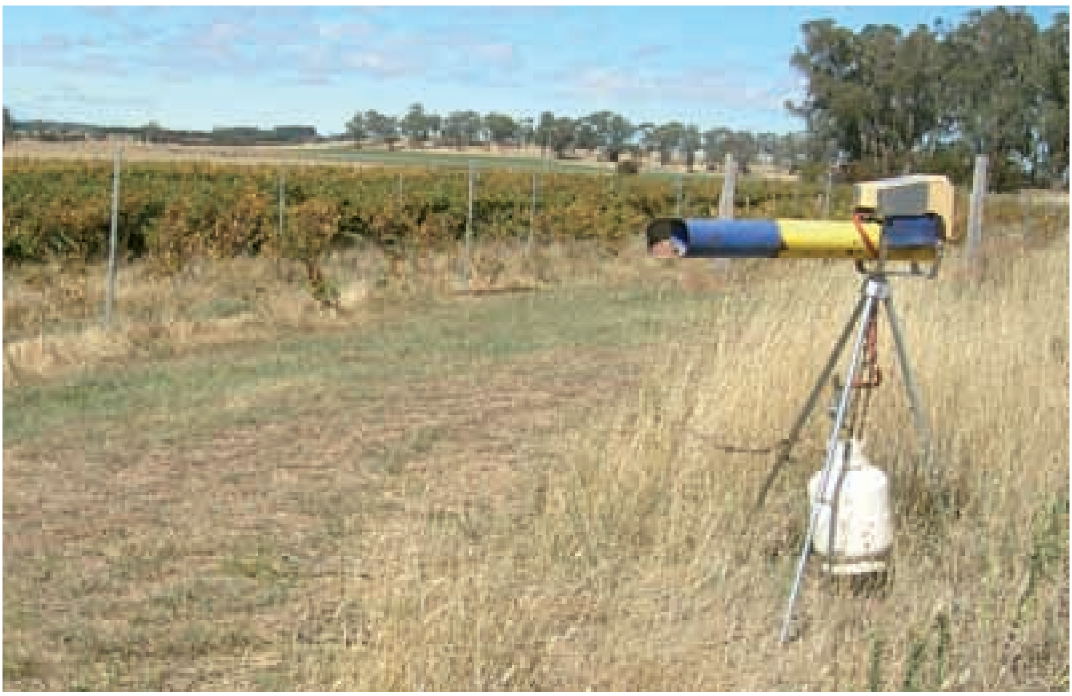


Figure 4.7: *Gas gun. These devices produce loud bangs at intervals to deter birds from a crop. Note that the placement of such devices near dry grass or other flammable material poses a fire hazard. Photo: N. Reid.*

Figure 4.8: *Electronic speakers used to broadcast sounds to scare birds away from crops. Photo: R. Sinclair. Inset photos left: T. Bentz, right: R. Sinclair.*

the quality of the recording and the quality of the amplifier and speakers used to broadcast the call. The broadcast calls generally need to be those of the bird species present, or at least calls from species the local birds usually respond to. Another factor that can influence the effect is whether the broadcast calls were recorded locally. Birds have dialects, and the alarm call of a bird from an area with a different dialect may be less effective than a locally recorded call (Marsh et al. 1991).

The calls of birds of prey or imitations are sometimes used to try to scare birds, and some of the devices on the market include bird of prey calls. There is little evidence in peer-reviewed literature that such sounds are effective. In fact, many predators do not call when they hunt, as it would make little sense for them to call out and warn potential prey that they are nearby and hungry. So it would seem unlikely that their calls would be effective for scaring birds.

Growers need to be wary of unsubstantiated claims about the long-term effectiveness of bioacoustic calls or simulated calls to scare birds. For example, in cage tests, Yokoyama and Nakamura (1993) found that for young tree sparrows (*Passer montanus*), the sound produced by a paper flag was significantly ($P < 0.05$) more aversive than a broadcast distress call of their own species. The distress calls were also subject to more rapid habituation.

Bird vocalisations, including alarm and distress calls, are extremely intricate. Birds are more likely to accurately interpret pre-recorded amplified sounds when high-quality recording, amplifying and broadcasting equipment is used (Aubin 1990; Marsh et al. 1991). In addition, if calls are recorded, digitised, stored on a computer chip and then amplified through speakers, there may be a marked reduction in the aversive stimuli contained in the calls. It is possible that such bioacoustic sounds represent little more than something new and unusual in the birds' environment, and different devices simply present different sounds.

It is possible that 'communication jamming' occurs when sounds with a similar frequency range to birds' communication calls are broadcast (Rooke 1983; Bomford and O'Brien 1990). This supposedly inhibits some flock-feeding birds such as silvereyes from hearing each other so they become confused. Some devices are designed to produce sounds that irritate, rather than scare or distress, to limit habituation. However, this has not been investigated.

'Growers need to be wary of unsubstantiated claims about the effectiveness of simulated calls to scare birds.'

Ultrasound is very high frequency sound above the range of human hearing (greater than or equal to 20 kilohertz). Most bird species cannot hear ultrasound, or they can hear only the lower frequencies (Beuter and Weiss 1986; Marsh et al. 1991). Even for birds that can hear ultrasound, there is no reason for it to be more effective for scaring than audible sound. Despite anecdotal user testimonials and unsubstantiated claims from advertisers, manufacturers and distributors, no scientific field experiments have indicated that ultrasound is of value for reducing bird damage to crops. In fact, experiments have shown that ultrasonic devices are ineffective (Bomford and O'Brien 1990; Bomford 1990a; Erickson et al. 1992; Haag-Wackernagel 2000).

Few reliable scientific experiments have been conducted on the value of acoustic devices for reducing bird damage to crops. However, on the basis of reviews of the world literature on this topic, Bomford and O'Brien (1990) and Bishop et al. (2003) drew some generalisations about scaring with sound.

They suggest that the best effect is obtained when:

- the sound is presented at random intervals;
- a range of different sounds is used;
- sounds are broadcast for the minimum time needed to get a response;
- the sound source is moved frequently;
- the sound is supported by other control methods; and
- the sound is reinforced by real danger, for example, shooting.

They also suggest that:

- loud sounds are more aversive than quiet sounds (if the frequencies are within the birds' hearing range);
- sounds with a wide frequency range are more aversive than pure tones;
- loud sounds produced by simple, inexpensive methods can be as effective as sounds produced by expensive devices;
- adult birds are more easily scared than juveniles;
- hunted species take longer to habituate to bangs;
- broadcast alarm and distress calls can be effective but are subject to habituation and are often species-specific; and
- all species eventually habituate to nearly all sounds tested.

4.1.4 Combining visual and acoustic scaring methods

The best results are likely to be obtained if different control methods are combined to prevent habituation (Bishop et al. 2003). For example, when a bird hears a distress call it usually approaches the sound, expecting to see a bird being grasped by a predator (Conover 1994). If such an image is not associated with the sound, rapid habituation occurs. If distress call broadcasts are paired with a predator model that appears to be grasping a struggling bird, observing birds are likely to have their fears reinforced, which in turn will delay habituation. Support for this hypothesis comes from the findings that starlings and American crows habituated less to plastic owl models when they appeared to be grasping a struggling bird (Conover and Perito 1981; Conover 1985). Nakamura (1997) found that playbacks of taped calls of jungle crows (*Corvus macrorhynchos*) were largely ineffective for scaring rufous turtle doves (*Streptopelia orientalis*), as was the presentation of a stuffed jungle crow. However, the combined stimuli of a stuffed crow with a crow call were highly effective and were resilient to habituation in the three successive trials conducted.

Combining treatments may be more effective for bird damage control but adds to the cost, and this needs to be taken into account when a grower makes decisions about implementing a pest control programme (Section 1.3). For example, Cummings et al. (1986) evaluated a mechanical, gas-operated, pop-up, life-size, human scarecrow model coupled with a propane exploder for reducing red-winged blackbird damage to sunflower crops. The device was set so that the exploder went off 15 to 30 seconds after the scarecrow popped up (Cummings et al. 1986). In three fields, damage was reduced by an average of 84% in the first five-day treatment period and by 59% in a subsequent five-day treatment period. In two other fields near roost sites where red-winged blackbirds were well established, damage was reduced by only 8% and 31%. Cummings et al. (1986) concluded that the scarecrow-exploder device would be economically worthwhile for crops in which damage levels exceeded 18%, which was about 1.2% of crops.

'To prevent habituation, the best results are likely to be obtained if different control methods are combined.'

Using scarecrows holding gun-like sticks (visual) (Figure 4.5), combined with gas guns (Figure 4.7) or another bang-producing device (acoustic) to scare birds, can be effective if this is randomly reinforced by real danger in the form of a person actually shooting at birds (Section 4.2.1). This technique involves farm workers acting as 'substitute shooters' (Porter and McLennan 1988; Sinclair 1998). This theory is that shooters should always wear distinctive clothing (visual) (for example, a shirt of the same bright colour), and that other people working around the crop should wear the same distinctive clothes (visual) and carry a gun-like stick (visual) and perhaps fire a starter pistol occasionally (acoustic). Birds may then learn to associate the clothing, gun-sticks and bangs with danger and be scared by farm workers.

In some situations it will be appropriate to place acoustic scaring devices in, and conduct shooting from, the middle of the crop facing out, rather than on the edges of crops, which may scare birds further into the crop. Where feasible, a shooter on a motorcycle (Figure 4.9) can cover a crop much better than a stationary shooter or scare gun, because they are able to drive into the centre and all parts of the crop. By driving up and down the rows, a motorcyclist can prevent birds from settling and encourage them to look for more peaceful places to feed in. However, these approaches to scaring have not been validated.

4.1.5 Scaring with aircraft

The use of model aircraft, ultralights or full-sized aircraft to chase birds from crops is an example of combining visual and auditory stimuli. These may be of most value in broadacre, high-value crops, as they are expensive in terms of labour and materials. In addition, if birds are continually harassed and made to fly considerable distances before they return, then they will need to eat more fruit to make up the energy loss than if they had been left undisturbed (Section 4.1).

Garrity and Pearce (1973) found that model airplanes controlled by skilled operators reduced the numbers of robins in blueberry fields, but they also achieved only partial coverage of the crop at risk. The robins resumed feeding during refuelling and soon after flights ceased. Similarly, trials of model aircraft in wheat revealed that sparrows quickly resumed feeding whenever the aircraft was not in use (Richard Porter, Havelock North, New Zealand, pers. comm. 2005).

4.1.6 Birds of prey

Falconry or ways of attracting true predatory species to remain close to a crop is often the subject of inquiry. Trained falcons and hawks are sometimes used to keep birds away from overseas airports (Erickson et al. 1990; Marsh et al. 1991). However, the efficacy of this has rarely been

Figure 4.9: *A shooter equipped to undertake bird control. It is important to take precautions such as informing neighbours that shooting is taking place. Photo: R. Sinclair.*

evaluated. In one study, trained falcons used at O'Hare International Airport to keep birds away from the runways were not as cost effective as two men with shotguns (Dolbeer 2003). Falconry is not permitted in most Australian States and Territories and is too labour intensive to be an economic option for protecting horticulture. High levels of training are needed for both birds and handlers, and suitable raptor species are often rare and protected. Previous attempts to use falconry to protect agricultural crops have mostly been unsuccessful (Kenward 1978).

In North America, artificial perches and nest boxes were provided in orchards in an unsuccessful attempt to attract birds of prey to reduce vole populations (Askham 1990). To attract birds of prey to vineyards, Howard et al. (1985) hung live decoy prey birds in cages from artificial perches. Hawks attacked the caged birds, but nearby feeding birds simply moved a short distance to other sections of the vineyards and grape damage was not reduced. In Australia, perches placed around the perimeter of irrigated soybean crops to enhance house mouse predation significantly ($P < 0.001$) increased the number of diurnal raptors visiting and hunting over these crops, compared with untreated crops (Kay et al. 1994).

Encouraging raptors to specific areas is problematic, as different species occupy different ecological niches. For example, sparrowhawks and goshawks (*Accipiter* spp.) prefer hunting amongst trees and tall shrubs to surprise prey. Conversely, most falcons prefer open country, and Australian hobbies prefer lightly timbered country along watercourses (Marchant and Higgins 1993). The most effective predators of adult pest birds are also unlikely to be attracted by carrion or other food sources. Species most likely to be attracted to carrion (such as wedge-tailed eagles (*Aquila audax*), little eagles (*Hieraaetus morphnoides*) and whistling kites (*Milvus sphenurus*)) do not normally hunt birds in flight. Some studies have shown that providing perches increases the numbers of birds of prey (Kay et al. 1994). However, this has not yet been demonstrated to reduce the number of pest birds or the damage they cause. The presence of predatory birds could also inadvertently increase damage levels if birds were repeatedly disturbed and returned to damage new fruit after each disturbance.

4.2 Population reduction

Some approaches to pest bird control are based on a belief that every dead bird is one less to damage crops and any attempt to kill pest birds is therefore worthwhile. In practice, killing birds is usually legally restricted, very labour intensive, and in most situations is unlikely to be cost-effective for reducing bird damage (Dyer and Ward 1977; Feare et al. 1988; Feare 1991). There are many physical, economic, legal, social and environmental limitations (Section 1.2.3) to using lethal control for birds. In horticulture there are native species involved (Section 2.2), and many of which may provide economic benefits.

To attempt long-term population control for any species, a good understanding of their population dynamics (Dolbeer 1998; Murton 1968) and the subsequent effects on the environment is essential. In many circumstances it is not uncommon for up to 65% of young birds born each year to die before they are one year old (Feare 1984). Therefore, killing when there are large numbers of juveniles may simply be removing birds that were soon going to die anyway.

'Killing birds is usually legally restricted, is very labour intensive and in most cases is unlikely to be cost-effective for reducing bird damage.'

Lethal control is often ineffective for species with high reproductive capacity and high rates of annual mortality. For example in Belgium, seven years of substantial effort using explosives resulted in almost 750 000 starlings being killed at their roosts in an attempt to reduce damage to cherry orchards (Tahon 1980). However, because of high immigration and recruitment rates this had little medium- or long-term influence on starling populations or crop damage.

For pest birds with high reproductive rates, control during breeding may be more effective than control during the ripening season (Paton et al. 2005). This is likely to be the case for starlings, because large numbers of juveniles congregate after breeding, which coincides with the grape-ripening season. However, for birds with low reproductive potential, lethal control can be up to six times more efficient than reproductive control (Dolbeer 1998). Hence population dynamics and targeting of the timing of control are important considerations.

Feare (1991) suggests that there are two fundamental reasons why attempts to reduce pest bird populations over broad areas have failed. First, most pests have a wide geographical range and much of the population is inaccessible to control operations. Second, control attempts can be counteracted by compensatory increases in breeding and survival. There are many examples where population control has not been successful for these reasons. Some examples are the aerial application of organophosphate for controlling quelea (*Quelea quelea*) in Africa (Ward 1979); shooting wood-pigeons (*Columba palumbus*) to reduce damage to grain and clover in Cambridgeshire, United Kingdom (Murton et al. 1974); application of the surfactant PA-14 to large roosts of common grackles (*Quiscalus quiscula*), red-winged blackbirds and starlings to reduce agricultural damage in Tennessee, North America (White et al. 1985); and the use of explosives to control starlings at roosts to reduce damage to cherries in Belgium (Tahon 1980). However, when dealing with a small, isolated population where immigration is preventable, a substantial reduction in numbers may be achievable (Feare 1991; Dolbeer 1998).

Short-term population reduction, such as concentrated efforts in small areas during critical ripening periods just before crop damage occurs, may be effective. Ward (1979) proposed that an 'immediate crop protection' strategy for quelea around cereal crops would be preferable than the previous 'total reduction strategy'. This was proposed after an estimated one billion quelea were killed annually by aerial spraying with avicides, with no indication of long-term reductions in population levels or damage. No published evidence could be found showing either short-term or long-term population reduction leading to reduced crop damage in horticulture.

4.2.1 Shooting

Shooting is the bird control technique most commonly used by horticulturalists in Australia (Fleming 1990, Tracey and Saunders 2005). Although few studies have evaluated its efficacy, shooting is unlikely to be cost-effective as a stand-alone control measure in reducing populations of pests or damage. For example, studies 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). Further studies showed that shooting did not increase the winter mortality of wood pigeons above the level experienced in the absence of shooting (Murton et al. 1974). Unless shooting is carried out effectively over an area much larger than the orchard, new birds will quickly move in to replace those that have been shot.

Shooting can be an effective way of enhancing a scaring programme (Section 4.1) (Figure 4.9). It can be regarded as a training technique to educate birds to associate a loud bang with a real threat, but the technique needs to be used intelligently. Indiscriminate shooting is not cost-effective, and attempts at culling large numbers of birds may be counterproductive. If too many birds that have been taught to be frightened of a shooter are killed, naive individuals that have not been 'educated' may rapidly replace them.

'Shooting is the most commonly used bird damage control technique but its cost-effectiveness in Australia is yet to be evaluated.'

Shooting may have most value if it is reinforced by other scaring techniques and if it is started before other scarers to establish the association between the loud bang and real danger (Section 4.1.3). A common problem is the failed use of a gas gun followed immediately by a shooting programme. By this time, many of the birds will have become habituated to the loud bang and may not be afraid of the sound.

4.2.2 Trapping and netting

In general, trapping birds is unlikely to be a useful stand-alone option for most horticulturists. In many situations, and for most bird species, trapping may not reduce pest populations to below the economic damage threshold. Its use is generally limited to small areas where few birds need to be removed, or when dealing with resident populations where large numbers can be captured. Trapping and netting are usually time-consuming and therefore costly, and growers soon become tired of these procedures. The legal status, care and humane euthanasia of trapped birds also need to be considered (Sharp and Saunders 2004b). One advantage of trapping is that it allows protected species of birds to be released unharmed.

'Trapping birds is unlikely to be a useful stand-alone option for most horticulturists.'

On the basis of a nationwide questionnaire conducted in the USA, Gorenzel et al. (2000) reviewed trapping for pest bird control. Most respondents (57%) considered that trapping was not important overall for bird control in crops. However, in California, some respondents thought trapping was important for control of starlings and house finches in grapes. Gorenzel et al. (2000) found no rigorous evaluations of the effectiveness of trapping or the factors influencing results. Most evaluations of trapping put an emphasis on the numbers of birds caught rather than on damage levels in relation to the cost of control. The most common trapping mistakes listed by respondents were failure to conduct adequate free-feeding and poor trap placement (Gorenzel et al. 2000). Free-feeding (also called pre-baiting or pre-feeding) is where bait is placed out for several days before traps are activated. Poor trap placement was probably due to inadequate observations of flight paths and roosting and feeding areas. Failure to use decoy or call birds in traps can also influence their effectiveness (Williams and Schwab 1974).

The success of trapping and netting depends largely on the skill of the operator. Several Australian State governments issue permits to a few select people to commercially use nets to trap and remove pest birds from areas such as orchards. Trapping is used successfully as part of an integrated programme to limit the spread of starlings into Western Australia (Case Study 9.2), and for managing cockatoo and corella populations in Victoria (Case Study 9.3). Some trappers can catch reasonably large numbers of birds. Free-feeding and knowledge of bird movements and behaviour in the target area are essential. Different trap designs that have been used successfully to capture pest birds are described below. The ability of these methods to reduce pest bird damage to horticulture has not been investigated.

Mist nets

Mist nets (Figure 4.10) are commonly used to capture birds for research but are restricted to licensed bird banders and controlled by the Australian Bird and Bat Banding Scheme (Lowe 1989). Mist nets are not recommended for managing pest birds, because of the likelihood of catching non-target species and the training required.

Figure 4.10: *Mist nets are comprised of very fine netting and are for restricted use only.*
Photo: J. Tracey.

Cannon nets

The use of cannon nets is more restricted than any other capture technique and requires considerable training, experience and many volunteers. In addition to licences from the Australian Bird and Bat Banding Scheme, a licence for the use of explosives is also required from State or Territory authorities. Explosives are used to propel nets over large areas. Although these nets have been used for ducks, parrots, eagles and starlings, they are most commonly used for catching shorebirds. This method has the potential to capture large numbers of birds that congregate in open areas, although appropriate sites can be difficult to locate. Cannon nets are unlikely to be useful for controlling pest birds in horticulture.

Pull nets

Pull nets (Figure 4.11) of various designs (Bub 1995), also known also as single clap nets or book traps, have been used since ancient Egyptian times (MacPherson 1897). One such design has been refined by officers of the Department of Sustainability and Environment in Victoria and has been used for over ten years to capture long-billed corellas and sulphur-crested cockatoos. This design includes a large net, two steel arms with a locking trip mechanism and two stretchable rubber leads. These nets can be activated by remote control or by hand with a long wire cable attached to the trip mechanism.

Figure 4.11: *Setting up a pull net.*
Photo: B. Lukins.

To improve capture efficiency and avoid non-target captures, observations of flock size and feeding behaviour and at least five days of free-feeding (Figure 4.12) are recommended.

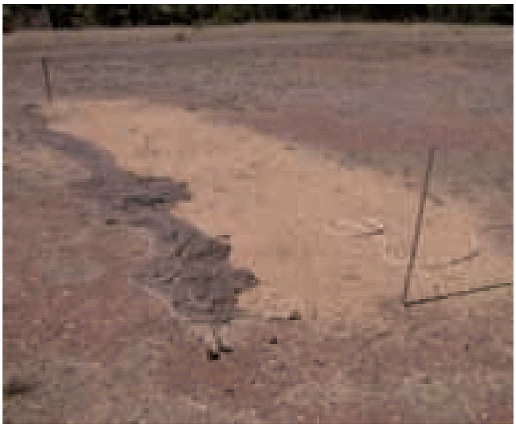


Figure 4.12: *Free-feeding grain for cockatoos and corellas before setting a pull net. Photo: J. Tracey.*

Modified Australian crow trap

A trap that has been used with some success in vineyards and orchards on a variety of bird species is the modified Australian crow (MAC) trap (Figure 4.13). This design was first developed to capture crows (Woodbury 1961) and is probably the trap most commonly used by horticulturists in Australia. Crows and starlings are the main species targeted. This design is also used in conjunction with other techniques to prevent the establishment of starlings in Western Australia (Case Study 9.2). The trap can capture

Figure 4.13: *Modified Australian crow trap with captured starlings. Photo: J. Tracey.*

and hold a large number of birds, provided that there is adequate shade, food and water (Sharp and Saunders 2004b). The V-shaped entrances of this trap can be adjusted for different species (Gadd 1996).

Walk-in cage trap

Walk-in cage traps (Figure 4.14) operate by attracting birds into a cage with a lure of food or other birds. Various mechanisms of capture can be used. For example, a drop-down door can be activated by a bird walking on a treadle plate, closing the bird inside the cage. A variety of funnel entrances can also be used, either at ground level or elevated with a perch beneath. The use of lure-birds is applicable for flocking birds such as starlings and territorial birds such as the introduced myna. Simple designs can capture a single bird at a time; more elaborate designs can capture multiple birds and include holding cages for lure birds.

Figure 4.14: *Two-stage cage trap with a starling passing through the one-way entrance. Photo: B. Lukins.*

Capture at nest sites

Catching by hand or with hand-held nets at nest sites is an opportunistic method that is legally restricted (Chapter 6). This trapping method is unlikely to result in large numbers of birds being captured. Removal of breeding adults also has animal welfare implications for dependent eggs and young (Sharp and Saunders 2004b).

A variety of single-catch nest box traps (Figure 4.15) have been used to capture hole-nesting species (DeHaven and Guarino 1969; Stewart 1971; Blums et al. 2000). Dehaven and Guarino (1969) used a spring-loaded trap door that closed over the entrance of the nest box when triggered by a treadle inside the box. More sophisticated designs use electronics for monitoring captures (Stewart 1971). Stewart (1973) operated a single nest box trap during a 124-day period and captured 56 starlings. Knittle and Guarino (1976) used 26 nest box traps in approximately 80 hectares (200 acres) and captured 294 starlings in 57 days. On the basis of the reproductive capacity for the area (Dehaven and Guarino 1970), they concluded that this achieved an overall reduction of about 959 birds from the post-breeding population (Knittle and Guarino 1976). They also suggested that a multi-catch design would greatly improve the efficiency of catching starlings and may be of benefit for small fruit orchards.

Figure 4.15: *Nest box trap.*
Photo: J. Tracey.

Euthanasia

Once captured, any non-target species should be released on site. Pest birds should be euthanased in the most humane way practicable. The preferred techniques are the use of carbon dioxide from a regulated cylinder, or neck dislocation. Safe and humane procedures for these methods are described in codes of practice and standard operating procedures available from http://www.deh.gov.au/biodiversity/invasive/publications/humane-control/ (Sharp and Saunders 2004c). To avoid the stress of additional handling and transportation, a practical method of euthanasia at the capture location is recommended.

4.2.3 Poisoning

Poisons specifically used for bird species are known as avicides. The use of poisons for pest birds is strictly controlled by legislation (Chapter 6), although there have been some problems in Australia with illegal poisoning (Du Guesclin et al. 1983; Alexander 1990; Environment and Natural Resources Committee 1995). The main dilemmas with poisons are: community resistance to their use; their impacts on non-target species; animal welfare concerns; and (depending on the poison used) their residual or secondary effects in the food chain. The availability of poisons in Australia is regulated by the Australian Pesticides and Veterinary Medicines Authority (Section 6.2). The use of lethal poisons for birds is restricted to licensed pest control operators, requires site permits from wildlife agencies, and may be permitted only for use in, or around, buildings. These requirements vary with the type of chemical and between States, and permits, restrictions and conditions of use are regularly reviewed and updated (Section 6.2).

Free-feeding (where unpoisoned bait is placed out for several days before the poison is added) is essential for a successful poisoning campaign. This is to attract birds to the site, allows the operator to determine how much bait is needed per day, and conditions the birds to take the bait at the site. Free-feeding should continue until the amount taken per day is roughly the same. On the day before poisoning, the amount of free-feed provided can be reduced (often halved) so that all of it is eaten and the birds are left a little hungry. The amount of poisoned bait provided can be less than the amount of the last free-feed (halved again) to minimise over-use of poison bait, reduce non-target impacts and lessen the potential for bait-shyness to develop.

'The use of lethal poisons for birds is usually restricted to licensed pest control operators.'

Bait-shyness occurs when birds receive a sub-lethal dose of poison but enough to make them ill and cause them to avoid the poison bait in the future. Bait-shyness can also develop if a poison acts too quickly and the birds that have not eaten the poisoned bait see those that have eaten it being affected (Richard Porter, Havelock North, New Zealand, pers. comm. 2005). Ensuring adequate free-feeding is the most effective way to reduce bait-shyness (Nelson 1994).

A range of poisons has been used to kill birds. They include organophosphates (Ridpath et al. 1961), endrin (Stickel et al. 1979), 1080 (Balcomb et al. 1983), nicotine (Ridpath et al. 1961), strychnine (Long and Vagg 1960; Ochs 1976; Redig et al. 1982), PA-14 (Heisterberg et al. 1987) and brodifacoum (Godfrey 1986; Porter 1996). Poisons currently registered for pest bird control overseas (DRC-1339) or in Australia (4-aminopyridine, alpha-chloralose and fenthion) are discussed in more detail below.

Most of the avicides discussed in this section have not been demonstrated to effectively reduce damage caused by Australian pest birds, and considerably more field research would be needed to establish their potential value. There are also animal welfare and target specificity concerns associated with many avicides, and there has been little assessment of their potential non-target effects on Australian species.

DRC-1339

DRC-1339 (3-chloro-4-methylaniline hydro chloride, Flockoff® or Starlicide®) is a poison that affects renal function in birds. It is currently not registered for use in Australia. This poison was identified by the Denver Research Centre (DRC) after evaluating more than 2000 chemicals for pest bird control between the 1940s and the 1980s (Spurr 2002). In North America and New Zealand it has been used for over 30 years (Bull 1965; Besser et al. 1967), and it is currently applied to cereals, cereal pellets (Figures 4.16 and 4.17), bread and dripping, sultanas and potato chips for controlling starlings, red-winged blackbirds, crows, ravens and gulls.

In New Zealand it has been used for many years to control rooks. Initially, ground baiting of rooks was conducted using bread and dripping at carefully selected times of the year when their preferred foods were lacking. These control operations were very successful in terms of numbers of birds killed (over 86 000 were killed in the first 15 years) (Porter 1987). More recently, a jellied form of DRC-1339 has been applied to the edges of nests by an operator hanging from a helicopter (Richard Porter, Havelock North, New Zealand, pers. comm. 2005).

DRC-1339 is unique among avicides, as it has selective toxicity for different bird species. Many species that are regarded as pests, including starlings, pigeons, gulls, crows and ravens, are highly sensitive (United States Department of Agriculture 2001; Eisemann et al. 2003). Conversely, DRC-1339 has been shown to have low toxicity to most mammals (except cats) and many bird species native to North America (Eisemann et al. 2003). Of the 55 bird species tested, two are native to Australia: the budgerigar (*Melopsittacus undulatus*) and the barn owl (*Tyto alba*). As this toxin is metabolised rapidly there is minimal risk of secondary exposure. The mode of action is irreversible kidney and heart damage, which causes death three to 50 hours after ingestion (United States Environmental Protection Agency 1995). There are potential animal welfare concerns for birds that receive a

Figure 4.16: *Preparing free-feed bait prior to trials of DRC-1339. Photo: J. Tracey.*

sub-lethal dose and suffer the effects of kidney and/or heart damage beyond one or two days (Sharelle Hart, RSPCA, pers. comm. 2006). However to avoid this, each bait is loaded with at least a lethal dose for the target species. A recent review (J. Dawes, Pestat, Canberra, unpub. 2006) suggests that although birds may become thirsty after ingesting starlicide they do not display other signs of distress, and birds that survive ingestion of the toxin show no signs of pathology at either the gross or microscopic level. However, it should be pointed out that humaneness of toxins is difficult to assess, and the absence of obvious distress signals does not mean an animal is not feeling unwell or even experiencing pain. The review by Dawes (Pestat, Canberra, unpub. 2006) suggested that non-target impacts can be minimised by appropriate design and application of baits.

Aminopyridine

Aminopyridine (also called 4-aminopyridine or Scatterbird®) has effects similar to those of central nervous system stimulants and is currently registered for application to grain baits in New South Wales, Tasmania and Victoria (Section 6.2), where its users are restricted to Pest Control Officers and government workers. When birds eat treated grain, it causes them to behave erratically and to give off distress calls before death (Goodhue and Baumgartner 1965; Gadd 1992). This may frighten away nearby birds or cause them to mob the affected bird. Hence this chemical is also considered a secondary chemical repellent (Section 4.5.2).

There are animal welfare, social perception, target specificity and human safety concerns about the use of this chemical, and it is unlikely to gain registration in other States and Territories.

Alpha-chloralose

Alpha-chloralose (or α-chloralose) is a chloral derivative of glucose that acts as a soporific or narcotic by depressing the cortical centres of the brain. As a soporific it is the most humane of the avicides. Alpha-chloralose can be mixed with grain bait at a concentration of around 2% and offered to birds after a period of free-feeding (Nelson 1994). Alternatively it can be added to drinking water. Care needs to be exercised with the use of alpha-chloralose to avoid bait shyness. An advantage of alpha-chloralose, particularly where non-target species may be

Figure 4.17: *Avicide ground bait.*
Photo: N. Reid.

at risk, is that the dose can be reduced so that birds are immobilised and not killed. Non-target species can be revived and released and target birds can be killed humanely. The dose rate that causes mortality varies with the species, the size of the bird, and the ambient temperature. Higher mortality is evident in smaller birds and at low (< 12 °C) or high (> 30 °C) air temperatures.

The main use of alpha-chloralose is for controlling feral pigeons around buildings. It has also been useful for removing small or establishing populations of sparrows, starlings, mynas (Case Study 9.1) and crows. When used for bird control, alpha-chloralose usually kills few individuals but causes the bulk of the population to disperse, and this may last long enough for a crop to ripen. Hence, it may be considered to act more as a chemical repellent (Section 4.5) than as a poison. However, non-target species may be at risk (Section 7.2.2). Sinclair and Cerchez (1992) trialled alpha-chloralose on sparrows in apricot and grape crops and on starlings in a cattle feedlot. With sparrows, they found that 0.5% weight/weight alpha-chloralose on mixed canary seed resulted in variable mortality rates between trials. However, the baiting caused dispersal of local flocks away from the crops. The dispersal lasted up to 90 days, which was long enough for the crops to be harvested (Sinclair and Cerchez 1992). At the cattle feedlot, starlings were successfully dispersed using 1.5% weight/volume alpha-chloralose in water or 1.5% weight/weight alpha-chloralose in cattle feed placed outside but adjacent to the feedlot troughs where the birds were foraging on split food.

Fenthion methyl

Fenthion methyl (commercial names include Control-a-Bird®, Rid-a-Bird®, Avigel® and Avigrease®) is an organophosphate that acts as a cholinesterase inhibitor and neurotoxin. It is registered in Victoria, Tasmania and the Northern Territory. Use of this product is limited to pest control officers and requires a licence in Tasmania (Section 6.2). It is used only against introduced species of birds. The chemical is usually mixed in a special grease or gel for surface application inside buildings and on structures such as bridges and steel girders. Birds get the grease on their feet and the poison is absorbed through the skin. The chemical is rapidly metabolised in birds, thus reducing the risk of secondary poisoning. Non-target species may succumb to primary poisoning if they consume the feet or beaks of birds poisoned by the grease (Hunt et al. 1991, 1992). This chemical is not available as an oral toxin, and its use has non-target (Bruggers et al. 1989), welfare (Spurr 2002) and human health (Jeremiah and Parker 1985) concerns. Because of these issues, it is unsuitable for protecting horticultural crops.

4.2.4 Chemical fertility control

A number of chemical products cause infertility in birds when added to their food. Reproduction is also prevented when chemicals or oils are sprayed on their eggs. Although birds are considered North America's most significant vertebrate pests and pest bird research has been well funded there, fertility control agents have not been considered sufficiently promising to attract research funding in recent decades. No products are currently registered for this use in

Australia. No published evidence could be found demonstrating that fertility control chemicals can reduce pest bird damage to crops in Australia or overseas.

A drawback of many fertility control agents is that they require several doses. There is little information about the effects of these products on offspring that do hatch but may have received a partial dose. Oestrogen-based products are likely to affect the fertility and sexual development of any non-target species taking bait.

'No published evidence could be found demonstrating that fertility control chemicals can reduce pest bird damage to crops in Australia or overseas.'

Bomford (1990b) reviewed chemical fertility control techniques and assessed the potential value of several chemicals that reduce fertility in birds, including the following:

Mestranol

Mestranol (17-ethynyl-3-methyl ether) is an orally active oestrogen. In a cage trial, spraying the eggs of Japanese quail (*Coturnix coturnix*) with mestranol increased embryo and chick mortality, and made all quail that hatched irreversibly sterile (Wentworth et al. 1968). Force-feeding mestranol-impregnated grit to adult quail reduced their fertility, but this was not developed as a technique suitable for use on wild birds (Wentworth 1968).

BDH 10131

BDH 10131 (the 3-cyclopentyl ether of 17α-hexa-1′,3′diynyloestra-1,3,5(10)-trien-17β-ol) is a synthetic oestrogen that was investigated as an alternative to mestranol or quinoestrol because it was shown to be active for a longer period in laboratory rats (Kendle et al. 1973). In laboratory trials on birds, Kendle et al. (1973) fed BDH 10131 to caged pigeons (*Columba livia*) for two days and found that fertile egg production dropped to less than 20% of that in untreated birds.

Ornitrol®

Ornitrol® (20,25-diazocholesterol hydrochloride) is a steroid that is a long-acting inhibitor of ovulation in many bird species and also inhibits testicular growth. When added to food at 0.1% it has been shown to delay or reduce egg production in caged and wild pigeons for up to six months (Elder 1964; Wofford and Elder 1967; Woulfe 1968). At this concentration it took seven days for birds to ingest an adequate dose, but at a 1% concentration the birds refused to eat enough grain to be effective. Higher doses can also be toxic to birds (Lofts et al. 1968), and the signs described could have welfare implications. Wofford and Elder (1967) concluded that two treatments a year at 0.1% would control fertility if both treatments were timed to coincide with the breeding season.

Ornitrol® at 0.1% or 0.05% on grain fed to field populations of red-winged blackbirds had variable success, reducing hatch success by between 7% and 61% in various trials (Fringer and Granett 1970). Timing of baiting, variable uptake of bait and promiscuity were proposed as factors reducing success rates. Canary seed impregnated with Ornitrol® at 0.1% and fed to captive sparrows resulted in 0% hatch success compared with 64% in a control group (Mitchell et al. 1979). This effect is not permanent, as a fertile egg was produced about a week after treatment ceased. Within a month hatch success was similar to that in the control group.

Triethylenemelamine

Triethylenemelamine (TEM) (2,4,6-tris(ethylenimino)-s-triazine) arrests spermatogenesis through inhibition of meiosis. Vandenbergh and Davis (1962) field-tested TEM on a breeding population of red-winged blackbirds in a marsh for two years. In both years the hatch rate was significantly reduced relative to that at a control site. In contrast, Fringer and Granett (1970) and Guarino and Schafer (1974) field-tested TEM on territorial male red-winged blackbirds and found that it did not reduce breeding success. Davis (1961) found that caged starlings orally dosed with TEM in winter, when the testes were fully regressed, did not recover their fertility for several months. A small field trial of TEM on male starlings, which were captured, dosed with TEM and released, showed that their breeding success was reduced. However, the production of some fertile eggs in the territories of sterilised males indicated that their female partners were occasionally mating with other males.

ThioTEPA

ThioTEPA is the abbreviation for triethyleneth iophosphoramide (tris (1-aziridinyl) phosphine sulfide). Potvin et al. (1982) sterilised wild male red-winged blackbirds by feeding them thioTEPA-treated corn for ten days. The hatch rate was 46%, which was significantly lower than the average hatch rate of 85% in the control area. The fertility of some female partners of treated male red-winged blackbirds was suggested to have been a result of females copulating with males from other territories.

Nicarbazin

Nicarbazin ($C_{19}H_{18}N_6O_6$), is a complex of two compounds, 4,4'-dinitrocarbanilide (DNC) and 4,6-dimethyl-2-pyrimidinol (HDP). Nicarbazin is an oral contraceptive for birds and is registered by the United States Environmental Protection Agency (US EPA 2005) for use against pest geese and pigeons. DNC is the active component but it is very poorly absorbed and requires HDP for absorption and to achieve a contraceptive blood level. Once absorbed, nicarbazin interferes with the formation of the vitelline membrane, separating the egg yolk and egg white. The effect on hatchability is a function of time and dose and is reversible (US EPA 2005). Nicarbazin must be consumed daily, consistently and in adequate quantity to achieve a contraceptive effect and a single or intermittent dose will not affect egg hatchability.

Smaller birds, including passerines, have the most inefficient absorption of nicarbazin, requiring a higher bait concentration and dose (M. Avery in prep.). A pigeon requires a dose rate of 83 mg/kg bodyweight/day. Assuming similar values for passerines, a 150 gram passerine would need to consume 5 g of 0.25% nicarbazin bait/day to obtain the recommended dose for effective contraception. Many passerines might require even higher doses. Delivering such high, consistent daily doses throughout the breeding season would be difficult for most birds that damage horticulture.

Egg oils

Vegetable and mineral oils can be used to prevent hatching when the oils are applied directly to eggs in the nest. An advantage of applying oils, rather than destroying eggs or nests, is that birds may continue incubating, in some cases beyond the normal time for hatching (Christens and Blokpoel 1991; Cummings et al. 1997). For many bird species re-nesting is common after nests and eggs are destroyed. Vegetable and mineral oils prevent the hatching of 96% to 100% of the eggs of chickens (*Gallus gallus*), ring-billed gulls (*Larus delawarensis*), herring gulls (*Larus argentatus*) and Canada geese (*Branta canadensis*) (Blokpoel and Hamilton 1989; Christens and Blokpoel 1991; Baker et al. 1993; Christens et al. 1995; Cummings et al. 1997; Pochop et al. 1998b).

A study comparing mineral oil with commercially available oils (including castor, corn, linseed, safflower and soybean) found that they were equally effective (Pochop et al. 1998a). Preventing the hatching of eggs by using oils is effective, but may have a high labour cost due to the inaccessibility of many bird nests. Therefore this technique may only be useful for small or isolated pest populations (Miller 2002). There may be an application for reducing small urban populations of pest birds with extended breeding seasons, such as ibis (Threskiornithidae) (Martin and Dawes 2005).

4.3 Habitat management and decoy feeding

With increasing regulatory and social restrictions on killing birds or using noisy scaring devices, there is greater interest in manipulating habitat quality as an alternative means of reducing bird damage (Van Vuren 1998). A number of approaches (reviewed by Bishop et al. 2003) can be applied. Habitat quality can be reduced so that fewer resources are available for a pest species and their numbers decline, or the crop can be made less attractive to pests. Alternatively, pest birds can be lured away from an area by providing more attractive habitats or food elsewhere.

4.3.1 Reducing habitat quality

For environmental and economic reasons, the removal of roosting vegetation is not practicable for reducing populations of pest birds over large areas. Furthermore, there are State and local government controls over vegetation modification, and even pruning of some trees is not allowed without permission in some jurisdictions (Section 6.4). It may be possible, however, to modify or remove isolated trees or shrubs that are used for roosting, although inquiries must be made to determine whether this action will be in contravention of State native vegetation retention legislation (Section 6.4).

St John (1991) found that modifying access to food and water reduced the number of little corellas roosting in river red gums (*Eucalyptus camaldulensis*), and alleviated damage. Experimental trimming of roost trees in Houston, Texas to reduce the urban impacts of brown-headed cowbirds (*Molothrus ater*), starlings, grackles (*Quiscalus quiscula* and *Cassidix mexicanus*), red-winged blackbirds and American robins was effective in preventing roosting (Good and Johnson 1976, 1978). In this study, trimming consisted of removing one-third of the canopy; this is considered a 'heavy' trim by professional tree surgeons. Stands of pruned trees were not occupied, whereas trees that were not pruned were occupied to the same level as in previous seasons (Good and Johnson 1976, 1978).

Removing nearby food sources may also reduce damage on a local scale (Section 4.3.3). For example, removing blackberry bushes that are exploited by starlings, rosellas and silvereyes may help reduce damage to nearby fruit.

4.3.2 Orchard management decisions

Some horticultural bird problems can be reduced by decreasing the attractiveness of orchards. The varieties of fruit grown can be important with respect to both time of maturity, sugar content and type, fruit size, colour and texture (Section 2.4). Depending on the main species of pest birds in an area, some varieties of fruit may be less prone to damage. For example, the fruit of some olive varieties may be too small or too large to suffer high levels of bird damage from particular species (Mladovan 1998; Spennemann and Allen 2000). Growers may be able to avoid growing varieties most prone to damage from information obtained from established growers in an area.

There is a range of factors that influence the severity of bird damage (Section 2.4). These factors may provide opportunities for reducing bird problems. For example, the only crop in an area (Section 2.4) (Figure 4.18) or the first (Baker 1980a) or last crop in a district to have fruit maturing are more likely to sustain bird damage. Therefore, in areas where bird problems are likely to be significant, choose varieties that mature at the same time as others in the area. This can help reduce damage by spreading the availability of food over a wider area.

'Isolated orchards tend to suffer more damage than those surrounded by other orchards that produce similar fruit.'

Orchard location can be important. For example, proximity of the orchard to either native vegetation, windbreaks consisting of exotic species (Figure 4.19), or powerlines may increase fruit losses caused by to some species (Stevenson and Virgo 1971; Graham 1996). Land use around an orchard will also be important, as it will influence the availability of alternative foods (Section 2.4). For example, there may be an association between livestock and starlings, as these birds regularly feed on ground-dwelling insects and grazing makes these insects more accessible to the birds. Isolated orchards tend to suffer more damage than those surrounded by other orchards producing similar fruit. Hence, before planting, consider the surrounding habitat and the bird species that may become a problem.

Figure 4.18: *An isolated vineyard. The only crop in an area may be more susceptible to bird damage. Photo: J. Tracey.*

Figure 4.19: *A vineyard surrounded by a windbreak of exotic and native species. Depending on the pest species present, a windbreak of purely exotic species may make a crop more susceptible to bird damage. Photo: J. Tracey.*

The pasture sward in an orchard and the surrounding area may influence damage levels. When planted in an adjacent field it may offer an alternative (decoy) food that helps to attract the birds away from the fruit (Section 4.3.3). Conversely, pasture within orchard rows may provide food that attracts birds, and when the crop ripens it becomes an additional item for the birds to eat. For example, in New Zealand, orchards that have a sward of grass that seeds in late winter or early spring attract birds such as sparrows and greenfinches, and these species will nip the fruiting buds of apples and pears, causing losses as high as 90% (Richard Porter, Havelock North, New Zealand, pers. comm. 2005) Regular management and maintenance of pasture swards between rows can reduce the alternative food for some pest species (Figures 4.20; 4.21).

Figure 4.20: *A healthy, well-maintained inter-row pasture sward. Management of pasture in an orchard and the surrounding area can influence bird damage in different ways. Photo: J. Tracey.*

Figure 4.21*: Unharvested fruit left to drop can provide a food source for pest birds. Photo: B. Lukins.*

Depending on the grass species and height, the pasture sward can either increase or decrease the abundance or availability of certain insects, and this in turn may influence bird damage in different ways. For example, starlings prefer short (Whitehead et al. 1995) and freshly mown (Tinbergen 1981) grass where insects are more accessible. Woronecki et al. (1981) and Woronecki and Dolbeer (1980) found a strong and consistent relationship between reduced insect populations and reduced corn damage by red-winged blackbirds in Ohio. Conversely, in New York, reduced damage by the same bird species in corn was found to be related to increases in insect populations (Bollinger and Caslick 1985b).

It is important to observe the birds responsible for crop damage and their behaviour patterns. Forde (1989) recommended planting rows of alternative food such as sudax grass to reduce damage to fruit by regent parrots (*Polytelis anthopeplus*) and yellow rosellas (*Platycercus elegans flaveolus*) because he observed that the birds preferred sudax seed to other native seeds, commercial seeds, fruit or nuts. Reynolds (2003) observed Adelaide rosellas foraging on soursob bulbs (*Oxalis pes-caprae*) in cherry orchards and showed that the birds could be attracted to feed at plots where the bulbs had been made available by light cultivation. He concluded that a number of weed or pasture species could be similarly manipulated to act as decoy foods but suggested that measures encouraging birds to feed elsewhere should be counter-balanced by an integrated approach, discouraging them from feeding in the susceptible crop.

4.3.3 Decoy food

Decoy feeding is a potentially viable method of reducing bird damage, but it requires further investigation for horticulture. Growing decoy crops has been successfully used to reduce bird damage to sunflower crops (Broome 1979; Allen 1982, 1984; Cummings et al. 1987). Providing alternative food sources for horticulture requires careful consideration of the pest species and their preferences and feeding behaviour.

A decoy crop needs to be at a stage of maturity where birds will feed on it just before the grower's commercial crop becomes vulnerable to attack, so that the birds' feeding patterns are established on the decoy food. Scaring can be used in conjunction with decoy feeding and should be concentrated around the orchard and kept well away from the decoy site. It may take more than one season to develop established feeding patterns on a particular decoy site. If decoy food (rather than a decoy crop) is supplied, it must be highly palatable and at least as nutritious as the commercial crop, otherwise there is little reason for birds to be attracted to it.

The strong attraction starlings have for soil insects may offer an opportunity to exploit a particular feature of a pest species' diet by using a 'decoy feeding' strategy. When fruit matures in late summer or autumn, soil insects are often largely inaccessible to starlings because the soil is dry and hard. Keeping an area of ground moist may improve access to soil insects, the preferred food source. However, this strategy has not yet been proven to reduce fruit losses, and omnivorous birds may still consume fruit preferentially when it is available.

4.3.4 Native vegetation

Native flowering plants can be planted to act as decoy food sources (Section 4.3.3) for native honeyeaters. Increasing plant diversity and the extent of native vegetation on farmland is known to increase the diversity of birds, particularly native species (Green 1986; MacDonald and Johnson 1995). This leads to the perception that damage to fruit crops will be amplified with increased plantings of native vegetation. However, many pest birds, including crows, ravens, starlings, cockatoos and corellas, prefer open agricultural areas. Other species, such as European blackbirds and mynas, thrive in urban environments. Pied currawongs and noisy miners thrive in fragmented habitats with little structural diversity. Increasing the extent of well-structured and diverse native vegetation may not increase the abundance of these species. The bird species, the plant species and their times of flowering, and the structure and extent of vegetation will determine whether plantings serve as decoy food sources or whether they attract more damaging species.

'Many birds will preferentially feed on nectar-producing trees and shrubs rather than on fruit crops.'

Many birds, including honeyeaters and silver-eyes, are attracted to nectar-producing trees and shrubs. They will preferentially feed on these plants rather than on fruit crops. When the surrounding vegetation produces good quality nectar, bird damage is often low. When investigating nectar flows in the Margaret River, Rooke (1983) found that higher average yield of honey per hive corresponded with lower damage by silvereyes to grapes. Bird damage was lowest during good nectar years, which coincided with warm springs and autumns and relatively cool periods during February and March. Further research suggested that silvereyes prefer alternatives to grapes, including sugar-water and plants such as marri, seaberry saltbush (*Rhagodia candolleana*), nightshade (*Solanum* spp.), berries and figs. Research has also found that birds damaging grapes were usually in poor physical condition, possibly because of a lack of natural food sources. Rooke (1983) also discovered that providing additional food did not increase the number of silvereyes.

Native flowering plants also attract insectivores, including many honeyeaters. These bird species may be beneficial in the vineyard throughout the year by controlling insect pests (Section 2.5). Providing well-structured native vegetation can serve to provide shelter for insectivores, support bird diversity, and supply an effective decoy food source. Selecting the most appropriate plant species is crucial to ensure that the nectar source is acting as a diversion from the orchard rather than attracting more pest birds. Habitats with exotic flowering plants can be preferred by introduced bird species such as starlings and European blackbirds (Green 1986; Williams and Karl 1996; Kinross 2000) and native frugivores (Recher and Lim 1990) that damage fruit. Many birds beneficial in vineyards are absent from introduced vegetation such as pines. The absent species include specialist predators, *Eucalyptus* canopy feeders, obligate cavity-nesters and insectivores (Suckling et al. 1976). These species can control harmful insects or compete with, or prey on, pest birds (Section 2.5).

A balance of native shrubs and trees of varying heights is recommended for conservation and may reduce the numbers of pest birds. To avoid colonisation by aggressive edge-specialist honeyeaters (for example, noisy miners), O'Neill (1999) suggests that revegetation should not include more than 20% of nectar-producing shrubs. Providing excess nectar in winter may also cause normally non-sedentary species, such as silvereyes or lorikeets, to overwinter in orchards. Plantings of marri, figs, banksia and seaberry saltbush are recommended to reduce silvereye damage to grapes in the south-west of Western Australia (Rooke 1983).

An awareness of the main bird species in an area is vital in deciding the most suitable plant species and where to plant them. Plantings should be located where they are most likely to attract birds and far enough away from the orchard to avoid damage. Ideal decoys for honeyeaters will be those plants that flower before a commercial crop becomes vulnerable to attack and that continue to produce nectar throughout the ripening period.

The flowering periods of decoy plantings and how this relates to the ripening times of the varieties present on the property need to be considered. Abundant nectar just before or after ripening can inadvertently result in increased damage. For example, large numbers of noisy friarbirds damaging vineyards in Orange, New South Wales, have been linked to heavy flowering of red stringybark (*Eucalyptus macrorhyncha*) in the same season (Tracey and Saunders 2003). In that season, harvesting was delayed by adverse weather. Noisy friarbirds attracted to flowering red stringybark in the area, then switched to feeding on mature wine grapes after nectar loads were exhausted. Hence it is important to select decoy trees and shrubs that are productive for the whole period that crops are vulnerable to bird damage. For honeyeaters, the preferred species for decoy plantings include *Eucalyptus* spp., *Melaleuca* spp., *Callistemon* spp., *Banksia* spp. and *Grevillea* spp. Appendix C provides a list of native shrubs and trees and their flowering periods. These plants may attract insectivores and serve as decoy food sources for native honeyeaters and silvereyes.

In summary, the most appropriate plants to act as a decoy food source will depend upon:

- the pest bird species;
- the time of ripening for the varieties grown;
- climate; and
- soil type.

Locally indigenous plant species are less likely to become weed problems and are more likely to be attractive to local bird species.

The use of decoy plantings can be risky because of seasonal variations in the timing of flowering. This control technique should be used with caution and in conjunction with other control methods.

4.4 Exclusion

4.4.1 Netting

Exclusion netting (Figure 4.22) has become a popular method of controlling bird damage in Australia. This is because of the advent of long-life, ultraviolet radiation-stabilised, strong plastic netting. It is now in use over a wide range of crop types and over areas of more than 50 hectares. There is no engineering reason why even larger areas cannot be covered.

Using nets to physically prevent birds from gaining access to crops is an effective way of reducing or preventing damage (Case studies 9.4 and 9.7). As bird damage is often variable and difficult for growers to predict (Section 2.3), one of the attractive features of exclusion netting is that it reduces uncertainty and the

Figure 4.22: *Exclusion netting. Photo: R. Sinclair.*

need to monitor the bird problem. Netting also overcomes increasing concerns about the use of chemicals, animal welfare issues, and restrictions on the use of acoustic devices under noise pollution control legislation.

'Netting overcomes concerns about the use of chemicals, animal welfare issues, and restrictions on the use of acoustic devices.'

Netting is not the best solution in all situations. It is an acceptable solution when the benefits from excluding birds and not having to carry out any other bird control exceed the costs of netting (Chapter 5). Permanent netting is unlikely to be an economic solution for low-value crops or for crops that usually sustain only a low level of bird damage (Hector 1989a; Sinclair 1990; Slack and Reilly 1994).

Drape-over or throw-over nets (Figure 4.23), although previously used mainly in home gardens and on small hobby farm tree crops, are now becoming increasingly common on commercial horticulture crops — particularly high-value grape and berry crops. They offer short-term protection over the ripening season. Drape-over nets are lightweight, relatively inexpensive, extruded or loosely knitted fabrics that are available in a variety of colours, mesh sizes and widths (Duffy 2000). Laying nets over a crop and removing them for re-use can be labour-intensive, but a number of labour saving methods have been developed (Fuller-Perrine and Tobin 1993; Taber and Martin 1998; Duffy

Figure 4.23: *Drape-over or throw-over nets. These are being used increasingly on commercial horticulture crops. Photo: J. Tracey.*

2000) and are now commonly used (Figure 4.24). Keeping the ground between grapevines clean of prunings and weeds will extend the life of drape-over nets. Because of the fixed cost of the equipment required to apply and remove nets efficiently, it is more economical to use drape-over nets on large or high-value crops where bird damage levels are generally high (Fuller-Perrine and Tobin 1993). On small or low-value crops the value gained from avoiding the damage may not outweigh the cost of netting (Chapter 5).

Figure 4.24: *One of the net machines available that growers use to save on labour costs of netting. Photo: A. Carter.*

Alternative drape-over netting options include one- (Figure 4.25), two- (Figure 4.26), four- (Figure 4.27) or six-row netting or a 'lockout' system (Figure 4.28), whereby nets are draped over orchard trees or vines and then joined together to create a complete cover. The 'lockout' method requires more labour but less material, as the netting does not drape to the ground on the inside rows of the block. When spraying for botrytis and other diseases or to reduce fruit splitting, some growers use small tractors to enable them to spray underneath the netting, particularly for 'lock-out' and multiple-row netting systems. Less netting is also required when covering multiple rows, rather than a single row, and this improves cost-effectiveness.

Some growers construct lightweight total-exclusion netting systems, using second-hand water pipe for poles, star-droppers for anchors, and soft wire or baling twine to hold up low-cost, short-lived nets, such as fish gill nets. These systems have a high maintenance component and usually require replacing every one to three years. For crops that need only short-term protection, these lightweight systems may be appropriate if a low-cost source of labour is available for maintenance.

Figure 4.25: *Single-row drape-over netting. Photo: J. Tracey.*

Figure 4.26: *Two-row drape-over netting. Photo: J. Tracey.*

Figure 4.27: *Four-row drape-over netting. Photo: N. Reid.*

Figure 4.28: *Lockout netting, where a net is pinned to the ground on the outside of the block only. Photo: A Carter.*

In Australia, permanent total exclusion systems are a popular form of bird exclusion for some tree crops. The basic design is simple, involving a pole and wire or cable structure supporting roof and side netting (Figure 4.29). Most structures now consist of panels of net that are individually erected, with each panel stretched tightly between wires joined at the selvedged edges. The perimeter poles are usually wood, although steel can be used. The structures are designed so that loads that develop on the structure from wind, rain, hail or snow are transferred back to the ground anchors guying back the perimeter poles.

Figure 4.29: *Permanent total exclusion system in a nectarine orchard. Photos: P. Fleming.*

According to netting manufacturers, some black nets have life expectancies of over ten years, and white nets last five to eight years. The supporting structure should outlast several nets with minimal maintenance if it is well designed and erected. In New Zealand, some wire netting has lasted even longer (45 years) and is resistant to chewing and breaching by birds.

Permanent netting may not be feasible for older established orchards or for crops planted on steeply sloping ground. Even where netting is technically feasible, it is a significant expense to purchase and erect. The most economical option is to incorporate the costs of design and erection of full netting into farm plans at the early establishment stage. The costs and benefits of netting are considered in Chapter 5. There are considerable economies of scale as the area netted increases. An awareness of the main species responsible or potentially responsible for damage is necessary to determine the appropriate mesh size. When only larger parrot and cockatoo species cause damage, increasing mesh size can reduce costs.

'There are considerable economies of scale as the area netted increases.'

If nets are erected over an existing orchard with a history of bird damage, it may be desirable to temporarily conduct a scaring programme to break the birds' habit of feeding on the crop. Otherwise birds may chew on the netting to try to get inside.

Where bird damage is worst around the edges of a vineyard, Taber and Martin (1998) suggest it may be worthwhile netting just the edges of a large crop (Figure 4.30). Scaring devices can then be used to keep birds away from the crop centre. If birds are forced to feed in the centre of a crop, well away from shelter, they may feel less comfortable and scaring may be more effective. Another advantage of netting the edges of vineyards is that low-flying birds such as European blackbirds are forced up into the sky, allowing time for them to be shot. Alternatively, it may be more beneficial to leave a couple of outside rows uncovered and net rows further into the crop. This way, those outside rows operate as a sacrificial decoy and help to prevent birds over-flying the netted of rows and entering the crop.

Figure 4.30: *Netting on the edges of a crop only. This may be feasible where the damage is worse at the edges. Photo: R. Sinclair.*

Effects of netting on production and management

Netting can benefit fruit quality by reducing the prevalence of blemishes, sunburn and wind rub. Netting can, however, also increase the vigour of foliage and affect the size and colour of fruit by altering the microclimate. For example, hail netting, which has a much finer mesh (two millimetres) than that required for birds, reduces light levels by 20%–25% if black, 18% if grey and 12%–15% if white (Middleton and McWaters 1996). Under hail netting, wind speed can also be reduced by up to 50% and humidity can increase by more than 50%. Despite a perceived change in temperature under nets, netting has little or no effect on temperature and does not offer frost protection (Middleton and McWaters 1996).

Altered conditions under netting are likely to necessitate changes to management practices to ensure maximum productivity. Changes in the choice of rootstock and in pruning and irrigation practices may need to be considered, especially in the case of vigorously growing varieties. Disease management may also require

Figure 4.31: *An electrified wire shock system. Photos: J. Tracey.*

further consideration in cooler climates, for slow-ripening varieties, and in disease-prone regions.

In Middleton and McWalter's (1996) study of the effects of hail netting in apple orchards in Stanthorpe (Queensland), Orange (New South Wales), and Drouin (Victoria), less fruit was produced under netting. Reductions in fruit set were not large and were beneficial in this study, as less thinning was required. Reduced fruit size and increased shoot growth occurred on vigorous trees under netting. The effects on fruit colour depend on the variety and fruit position. Pollination may also be affected by netting; fewer bees are observed on trees under black netting than on uncovered trees (Middleton and McWaters 1996). Exclusion of insects has also been considered a benefit in orchards, for example, for fruit-flies in stone fruit (Lloyd et al. 2005). Placing beehives in the netted areas may overcome poor pollination.

For low-chill stone fruits, exclusion netting (hail net of two millimetres hole diameter) was found to enhance fruit development by seven to ten days and to improve fruit quality by increasing sugar concentration by 20%–30% and increasing colour intensity by 20% (Lloyd et al. 2005).

4.4.2 Other methods of exclusion

Some systems have been developed to incorporate electrified wires over crops (Figure 4.31). The principle is that birds standing on the electric wires will receive a small electric shock, sufficient to scare them away but not to harm them. Although no scientific investigation of the effect of these electrified systems on crop damage has been reported, field observations of bird behaviour (Emma Crossfield, University of Adelaide, South Australia, pers. comm. 2005) in a vineyard have revealed that birds learn not to stand on the electrified wires and perch elsewhere in the crop. These observations suggest that this form of control is unlikely to reduce damage.

Attempts have been made to protect horticultural crops by using monofilament lines strung over crops. Optimum filament size and spacing are still being developed. Knight (2000) found that birds were repelled about 25 centimetres from filament erected like a tepee over fruit trees. However, a field experiment to test monofilament lines placed at 30-centimetre intervals over a grape crop showed that they were ineffective in preventing damage by starlings and other species (Steinegger et al. 1991). There are also welfare concerns with monofilament lines, as injuries to birds can occur.

In a field experiment, Chambers (1993) demonstrated that covering individual table grape bunches with polyester sleeves significantly ($P < 0.05$) reduced the damage caused by Cape sparrows (*Passer melanurus*). The polyester sleeves did not reduce grape quality or yield. The obvious disadvantage of this approach is that it is labour-intensive and hence costly. Although damage was reduced to almost negligible levels in this experiment, not all bunches were covered, so the birds had access to uncovered grapes. It is possible that if all bunches were covered the birds would have pecked through the sleeves, as occurred in one instance.

4.5 Chemical repellents

Chemical repellents (or deterrents) are aversive substances that are usually sprayed onto crops because their taste, smell, colour or physiological effect makes the treated fruit unattractive to birds (Mason and Clark 1997). Many chemicals used or tested as bird repellents were originally registered as agricultural products such as insecticides or fungicides (Clark 1998). Currently there are few available chemical repellents in Australia that growers can use to prevent loss of fruit caused by birds (Section 6.2). One limitation is that chemical repellents can leave residues in fruit that make them unsuitable for human consumption (Porter et al. 1996). In addition, some chemical repellents are phytotoxic and damage sprayed plants. A further problem is the small size of the Australian market for such chemicals. The cost of obtaining and keeping registration of agricultural chemicals has meant that neither industry nor government is prepared to meet the costs of minor-use chemicals such as bird repellents.

4.5.1 Primary repellents

Primary bird repellents are agents that produce an immediate avoidance response by birds because of their unpleasant smell or taste, or because they cause irritation or pain (Clark 1998). Considerable work has been conducted in the United States in the last 20 years on primary chemical repellents to protect agricultural crops from birds (Avery 1992; Cummings et al. 1994; Curtis et al. 1994; Cummings et al. 1995; Avery et al. 1996b; Watkins 1996; Watkins et al. 1996; Cummings et al. 1998a,b; Dolbeer et al. 1998; Gill et al. 1999; Askham 2000). Much of this work has focused on methyl anthranilate, a human food-flavouring additive that occurs naturally in many plants. This work showed that some formulations of methyl anthranilate are effective in reducing bird damage to some horticultural crops, but that their effectiveness is variable.

In Australia, Sinclair and Campbell (1995) conducted cage trials testing the repellency of methyl anthranilate on four species of pest bird: the Adelaide rosella, silvereye, little corella and starling. They found that when alternative food was provided methyl anthranilate was highly repellent to all four species. However, field trials with the chemical on apricots, grapes, cherries, and apples did not demonstrate effective repellency at application rates that were not phytotoxic (Sinclair and Campbell, unpublished). Staples et al. (1998) found that the chemical was phytotoxic to rice seeds and seedlings and also warned of its potential toxicity to marine animals if the chemical was applied in marine environments.

The size of the fruit can affect a repellent's effectiveness. For example, apples and pears may not be protected because the treated surface area of the fruit is small in relation to the volume of edible flesh. Birds need only to make a small hole in the skin to access large amounts of untreated flesh (Richard Porter, Havelock North, New Zealand, pers. comm. 2005).

There are, unfortunately, a number of dubious bird repellent formulations being promoted that contain chilli or compounds that taste bitter to humans. Because birds have very different taste receptors to humans and are insensitive to many compounds that humans find distasteful, these repellents are likely to be ineffective. For example, a chilli extract with a heat strength claimed to be over 80 times that of the strongest chillies used by humans was tested on sparrows, and they ate it without being repelled (Richard Porter, Havelock North, New Zealand, pers. comm. 2005). Naphthalene and capsaicin, although marketed in the United States as bird repellents, have not been shown to be effective in deterring birds (Dolbeer et al. 1988; Mason et al. 1991; Clark 1997).

'Some repellent formulations contain compounds that taste bitter to humans — birds have very different taste receptors to humans and are insensitive to many compounds that humans find distasteful.'

Mint derivatives (Avery et al. 1996a) and caffeine (Avery et al. 2005) are other repellents that have undergone preliminary testing. However, further field investigation is required before these can be recommended for application to horticultural crops.

4.5.2 Secondary repellents

Secondary repellents work by making birds feel ill, so that they subsequently develop a conditioned aversion to the food to which the repellents have been applied (Clark 1998). Methiocarb (Mesurol-75®) is a carbamate insecticide that is also used as a snail and slug poison. It acts by inhibiting the activity of acetylcholinesterase, an enzyme that catalyses the breakdown of the neurotransmitter acetylcholine. In the 1970s methiocarb was trialled in Australia as a bird repellent. It provided good protection against European blackbird and silvereye damage over two seasons in trials in the Riverland region of South Australia, with the yield harvested from treated areas being almost double that of untreated areas (Bailey and Smith 1979).

Porter (1982) compared the effectiveness of methiocarb and netting individual trees to protect sweet cherries from exotic bird species in New Zealand. The pest species present were mynas, starlings, European blackbirds and song thrushes. Spraying with methiocarb significantly ($P < 0.001$) reduced damage: sprayed trees lost 10% of their fruit to birds, whereas unsprayed trees lost 80%. Sprayed and netted trees lost only 2% of their fruit to birds. Over a 12-year repayment period, spraying alone, without the high cost of netting trees, gave better financial returns. Methiocarb residues on the fruit were reduced by 50% (to within the New Zealand Agricultural Chemical Board limit of seven parts per million) after the fruit had been washed in water. Residues were reduced by 66% after washing in dilute detergent (Porter 1982).

Tobin et al. (1989a) tested the effectiveness of methiocarb spray in protecting cherries from pest birds (mainly starlings, American robins, and house and common grackles). Although they found that sprayed blocks had significantly ($P = 0.03$) less damage (6.5%) than unsprayed blocks (8.8%), the level of reduction in damage was not sufficient to justify the cost of spraying. In a later field trial, Tobin et al. (1991) found that spraying cherries with methiocarb did not significantly ($P > 0.5$) affect the average percentage of cherries damaged by starlings and 14 other species of birds.

In aviary trials, Cummings et al. (1998b) found that spraying with methiocarb significantly ($P < 0.01$) reduced the consumption of lettuce seedlings by horned larks (*Eremophila alpestris*). Topical application of methiocarb to sprouting tomato seedlings reduced skylark (*Alauda arvensis*) damage to minimal levels (Anonymous 1970).

Hardy et al. (1993) conducted field trials to assess the safety of spray applications of methiocarb. They concluded that even heavy repeated spraying did not pose a hazard to wildlife, despite the fact that mammals and birds were exposed to the compound.

The use of methiocarb as a bird repellent applied to fruit has been discontinued in Australia because the manufacturer failed to provide long-term toxicological data to support continued registration. For re-registration of methiocarb for this purpose, information would be needed on its potential impacts on non-target species and its residues in fruit and wine. This research would be expensive, and the market for the product is considered too small to justify the cost. Methiocarb residues, however low they may be, are not acceptable in wines in most wine-importing countries.

Methiocarb as a seed-dressing has had mixed results and is not generally recommended. Holding (1995) applied methiocarb to canola seed and recorded good deterrence against skylarks with a doubling of the yield in treated versus untreated plots. However, delayed germination may cause insufficient chemical to be absorbed by the sprouting seedlings, which may lead to increased bird damage. This has been found in the case of treated tomato seed (Bergman 1970).

Porter and McLennan (1995) tested the effectiveness of cinnamamide (a secondary plant compound) and netting for protecting grapes from pest birds. The pest species present were mainly sparrows, silvereyes, greenfinches, European blackbirds and song thrushes. Both treatments significantly ($P < 0.01$) reduced the numbers of pecked and missing grapes. Cinnamamide reduced damage by 40% and netting by 84%; however, neither treatment significantly increased mean bunch weight or mean yield. This was possibly because the vines compensated for missing grapes by increasing the size of the surviving fruit. Porter and McLennan (1995) found residues of cinnamamide in wine made from treated grapes, and this chemical also left a 'plastic-like' flavour on grapes, making them unacceptable for making wine.

Other secondary bird repellents that have been used in North America are lindane (an insecticide that stimulates the central nervous system) and captan and thiram (originally fungicides), which depress the central nervous system (Clark 1998). There is also Kocide®, which is a copper-based fungicide (Avery et al. 1994); and fipronil, an insecticide developed for use on rice seed and other crops (Avery et al. 1998). Brugger et al. (1993) and Martinez del Rio et al. (1997) suggested that sucrose (household sugar) in high concentrations on fruit might act as an effective secondary repellent for starlings and other pest birds because they lack the enzymes necessary for its digestion. Avery et al. (1995) found that caged starlings and cedar waxwings (*Bombycilla cedrorum*) ate significantly ($P < 0.1$) more artificial fruit containing hexose (a mixture of glucose and fructose) than artificial fruit containing sucrose, and this preference overrode pre-existing preferences for fruit colour. However, tests conducted by Askham (1996) on starlings do not support the theory that birds are intolerant to sucrose.

Anthraquinone, commercially known as Flight Control®, is a polycyclic aromatic hydrocarbon that occurs naturally in insects, plants and fungi. Although commonly used in the manufacture of dyes and as a catalyst in the paper industry, this chemical has also been used as a grazing repellent to deter birds (particularly Canada geese) from golf courses, airports, urban and industrial areas and landfills, and as a seed coating and repellent to protect crops. Anthraquinone and related compounds have been shown to reduce consumption of rice, millet, sorghum and maize by red-winged blackbirds, brown-headed cowbirds and dickcissels (*Spiza americana*) (Wright 1962; Avery et al. 1997; Dolbeer et al. 1998; Avery et al. 2001; Cummings et al. 2002). Cage trials with horned larks indicated that high levels of damage (60%) still occurred to treated lettuce (York et al. 2000). However, York et al. (2000) suggested that bird damage was artificially high because of the nature of the enclosure situation and indicated that field trials were required.

4.5.3 Delivery of primary and secondary repellents

Repellents that are eaten target oral receptors if they are primary repellents, or gastrointestinal receptors if they are secondary repellents (Clark 1998). Chemical repellents are rarely delivered in raw form, but are combined with other substances and applied in accordance with label instructions (Clark 1998). Carriers, spreaders, stickers and wetting agents improve the deposition of the repellent. These products ensure even coverage and improve retention by slowing environmental degradation and weathering losses. The stability of the repellent can be affected by carriers, stabilisers, solvents, binders, biocides and antioxidants (Clark 1998). The concentrations of the repellent agent and additives are important, as these will influence efficacy and cost. For some agents, concentrated applications can leave unacceptable residues. If toxic repellents are used, concentrated applications can cause blemishes on the crop, damage the foliage, or kill non-target species (Staples et al. 1998).

4.5.4 Tactile repellents

Clark (1998) investigated the use of contact tactile repellents applied to perches to irritate birds' feet. Starlings avoided perches painted with tactile repellents containing plant extracts or methiocarb. None of the substances tested caused illness in birds. Clark (1998) concluded that further work was needed to see whether such non-lethal repellents are useful for pest bird control.

A number of non-toxic, sticky or oily substances are used for bird control (Clark 1998). Polybutene is one product that is registered in some Australian States (Section 6.2), but its use is illegal in South Australia under the *Prevention of Cruelty to Animals Act 1985*. When applied to surfaces where birds perch, these substances feel unpleasant and the birds avoid them. Some problems may occur with short-legged species (for example, welcome swallows (*Hirundo neoxena*)), whose wing-tips sometimes become glued to the surfaces to which the gel has been applied.

4.5.5 Seed coating

Coating seeds with substances such as clay, cement, plaster (Dolbeer and Ickes 1994), diatomaceous earth (containing sharp particles), or starch can make it more difficult or unpleasant for birds to crack them open, thus reducing damage. Handling time increases, making the seeds less attractive to the birds. In cage tests, Cummings et al. (1998b) found that coating lettuce seeds with clay significantly ($P < 0.01$) reduced seed consumption by horned larks. These treatments have the potential to reduce damage to newly sown crops.

4.6 Biological control

Biological control or biocontrol is the control of pests using other living organisms. Usually infectious disease agents are used that kill the pests, or cause them to become infertile. Currently there are no biocontrol agents that can be used against pest birds, and no research is being conducted in Australia to discover a bird biocontrol agent. Falconry or attracting predatory birds to crops for pest bird control may be considered a biological control (Section 4.1.6).

5. Economic decision-making

After the bird damage problem has been defined and before management is initiated, alternative strategies will need to be reviewed (Section 1.2). Different types of economic analysis are available to help in directing this process. These analyses can contribute in a descriptive or prescriptive way to decision-making (Mumford and Norton 1984). The use of descriptive models helps to develop an understanding of economic relationships. For example, they may be useful for estimating the level of bird control that has the maximum economic benefit. Descriptive models require accurate measurements of a range of factors, including damage and management costs, benefits of applying control, and the relationships between bird density and the damage birds cause. In comparison, prescriptive models incorporate value judgements and compare different management strategies using specific, subjective criteria. Both economic models can be useful in selecting the most appropriate strategy.

Five types of analysis are reviewed here, with an emphasis on birds in horticulture: direct cost–benefit, economic threshold model, marginal analysis, cost-effectiveness and decision theory. To promote practical application, a simple stepwise procedure is then described to help horticulturists in selecting optimal bird management strategies. This includes a description and an example of a simplified cost–benefit analysis, which explains the procedure of estimating the benefits and costs of particular activities. Where information is available this can incorporate some aspects of different analyses and will provide a reasonable prediction of the most cost-effective management regime.

5.1 Direct cost–benefit analysis

Cost–benefit analysis is a commonly used method that compares benefits and costs at a particular level of activity. If benefit exceeds cost the proposal is economically profitable. There are three main criteria calculated in a cost–benefit analysis: benefit to cost ratio (BCR), net present value (NPV) and internal rate of return (IRR). The BCR is the ratio of discounted benefits to discounted costs and indicates the potential return per $1 invested over the period. NPV is the present-day value of the discounted benefits less the discounted costs. The IRR is the discount rate that equates discounted benefits and costs over time, that is, the discount rate at which NPV = 0. Profitable control options will have a BCR greater than one, a positive NPV and an IRR greater than the discount rate. Wherever possible, benefits and costs should be valued at current market prices, as these values are known and allow direct comparison over time.

‘Wherever possible, benefits and costs should be valued at current market prices, to allow direct comparison over time.’

Comparison of many benefit-to-cost ratios will enable a prediction of the most suitable management strategy and desired level of management activity. Incorporating risk into cost–benefit calculations will improve their relevance. This normally involves discounting, which takes into account declining monetary values over the management period. Discount rates include the effects of inflation and also include the perceived risk of a management strategy. Riskier management decisions are reflected in higher discount rates. Time and risk are important considerations when planning control, because initial decisions will usually have economic effects in subsequent periods.

5.1.1 Cost–benefit analysis for bird netting in vineyards, Orange (New South Wales)

(John Tracey and David Vere, NSW Department of Primary Industries)

A cost–benefit analysis was conducted to evaluate four bird-netting options in vineyards that sustained damage levels of 15%–30% of annual yield. No damage was assumed to occur under the netting options. Average annual damage levels in the Orange district are about 15% (Tracey and Saunders 2003). District yield averages of 13 tonnes per hectare and an average price of $1300 per tonne were also used. The period of the analysis was ten years, with a real discount rate of 5%.

'Netting options generated positive economic returns.'

The results are given in Table 5.1. The base no-netting option generated positive cost–benefit criteria and has a unitary (1:1) BCR at an annual damage level of about 40%, above which a vineyard operation without netting would be an uneconomic proposition. No netting was profitable at the district average damage level (15%), but long-term returns were significantly reduced as damage increased. Each of the netting options generated positive economic returns. Permanent netting was the most expensive control option, but it had sound cost–benefit criteria over a 10-year period. Direct comparison with the no-netting option suggests that permanent netting is an economic investment only if bird damage averages about 25% over time. The drape-over netting options (Figure 5.1) are more profitable. The BCRs for the drape-netting options are of a similar magnitude but favour the four-row option. Although no bird damage is assumed to occur when nets are installed, the unitary BCR estimates indicate that damage levels up to 19% for permanent netting and 30–33% for the drape netting options could be absorbed by investment in netting.

Figure 5.1: *Netting is generally the most economically viable option for pest bird control where damage is greater than 15%. Photo: B. Mitchell.*

Sensitivity analysis was undertaken to determine the break-even prices and yields for each of the options (Table 5.1). Price was sensitised against the base yield, as was yield against the base price. Permanent netting remained marginally profitable at a tonnage price of $1100 at the budgeted yield (13 tonnes) or a yield of 10.5 tonnes per hectare at the budgeted price of $1300 per tonne. This indicates that the price/ yield margins are narrow (a fall in price of 15% and a yield decrease of about 20%) for this option when compared with the base values. In comparison, the drape-over netting options have much higher tolerances for price or yield reductions. Comparative tolerances without netting are between $990 and $1160 per tonne and 9.4 and 11.4 tonnes per hectare for increasing levels of damage.

The overall result is that protection against birds with netting is a profitable investment for Orange district vineyards, where damage levels average 15% annually (Tracey and Saunders 2003). Below that level, there appears to be little economic benefit in installing permanent netting unless this option results in significant yield increases (this possibility has not been considered). Drape-over netting generates much higher NPVs than the no-net option that incurs 15% damage; it has similar BCRs and IRRs as for the one-row option, and all cost–benefit analysis criteria are higher for the two- and four-row options. This protection option is therefore a sound economic practice. Additional sensitivity analysis indicated that a no-net option would approximate the NPV to one-row drape netting at a 9% damage level. Experience in the Orange district suggests that bird damage exceeds this level in many vineyards.

This example deals only with direct loss by birds. For example, lost income for reduced quality due to bird damage can be severe, particularly in a climate of over-supply. In many cases bird damage can result in total rejection of a load of fruit. The value of the loss under these circumstances can be very much higher than the loss due to yield reduction from bird predation.

Table 5.1: *Cost–benefit and sensitivity analysis of bird netting options (ten years at 5% real discount).*

	COST-BENEFIT CRITERIA			SENSITIVITY ANALYSIS		
	NPV ($'000)	BCR	IRR (%)	Maximum damage level (%)[a]	Minimum price at base yield ($/tonne)	Base yield (tonne /hectare)
No netting				39.1		
15% damage	19.19	1.31	15.5		990	9.4
20% damage	15.14	1.25	13.5		1 045	10.0
25% damage	10.09	1.18	11.5		1 100	10.6
30% damage	7.03	1.12	9.3		1 160	11.4
Permanent netting	15.20	1.19	10.5	19.2	1 100	10.5
Drape netting – one-row	24.09	1.34	15.3	30.1	975	9.1
Drape netting – two-row	25.66	1.37	16.3	32.2	950	8.9
Drape netting – four-row	26.97	1.39	17.2	33.4	930	8.7

a Level of bird damage that generates a unitary (1:1) BCR.

5.2 Economic threshold model

The economic threshold model also uses direct costs and benefits but indicates the density of a pest population at which the benefit of management just exceeds its cost (Stern et al. 1959; Mumford and Norton 1984). This break-even point can be used to decide the pest density at which a particular management strategy should be initiated. To apply this model managers need knowledge of:

- bird density;
- levels of damage resulting from a range of bird population densities (density–damage relationships);
- the impact of different levels of management on bird density;
- value of output (for example, in dollars per tonne); and
- costs of different levels of management techniques.

As an example, consider a fully irrigated olive grove with 250 Manzanillo trees per hectare that incurs annual starling damage. The grove produces 10 000 kilograms per hectare and the manager receives $0.60 per kilogram (P). Measurement of starling feeding behaviour might suggest that each additional starling per hectare reduces yield by 10 kilograms (D) during the growing season. Lethal shooting might cost $100 per hectare (C) but is only 50% (K) effective in reducing damage. Applying the economic threshold concept in this case indicates that a density of 33 starlings per hectare could be endured before initiating control. Implementing control when starling densities were lower than this would cost more than the savings that would be achieved in reducing damage.

The calculations for the above example are as follows. To calculate the pest density at which benefit of management equals the cost:

Management benefit	=	Management cost
PDKθ	=	C
P	=	price of olives per kilogram ($)
D	=	loss in olive yield (kilograms) caused by one starling per hectare
K	=	the proportional reduction in damage achieved by shooting (with '1' representing 100% reduction)
θ	=	starling density
C	=	the cost of shooting per hectare ($)

To calculate starling density where benefits equals costs, this formula becomes:

$$\theta = \frac{C}{PDK}$$

$$\theta = \frac{100}{0.6 \times 10 \times 0.5}$$

$$\theta = 33.3 \text{ starlings per hectare}$$

5.3 Marginal analysis

Marginal analysis determines either: (1) the pest density at which maximum profit occurs; or (2) the level of control that is most profitable for a particular pest density. As distinct from the economic threshold model, marginal analysis investigates the optimal level of control rather than simply identifying whether control should start. It also differs from the previous two models by using incremental changes in costs and benefits rather direct costs and benefits. These incremental changes are measured as marginal cost, which is the change in total cost resulting from a unit change in output, and marginal benefit, which is the change in total benefit resulting from a one-unit change in the benefit of pest control (McTaggart et al. 1992). The desired level of activity is that at the point where the marginal cost of the extra unit of input equals the marginal benefit of that unit (Hone

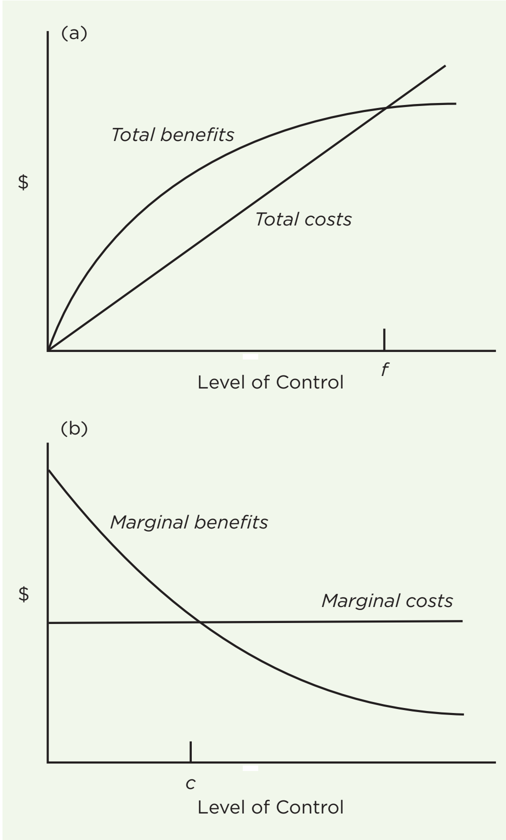


Figure 5.2: *Possible relationships between: (a) total costs and benefits and the level of control inputs; and, (b) marginal costs and benefits and the level of control inputs.*

1994). The difference between using total costs and benefits and marginal costs and benefits is outlined in Figure 5.2.

Total costs equal total benefits at *f*, which is also the break-even point (where the cost–benefit ratio equals one), and maximum profit occurs at *c*, the level of inputs at which the marginal cost equals the marginal benefit (after Hone 1994).

This model recognises different initial pest densities and optimum levels of control for each density. As initial pest density increases, so does the marginal value of pest control, which will justify more control inputs (Johnston 1991). This concept would encourage the use of appropriate levels of control. However, damage levels and how various levels of control will influence damage need to be known with reasonable certainty.

5.4 Cost-effectiveness analysis

This type of analysis is used to compare the cost-effectiveness of different management strategies (Hone 1994) and is used when benefit is difficult to measure. Instead of estimating monetary benefits, it compares cost per animal with pest density or the number of animals removed per unit area. It is therefore more often used when comparing strategies that rely on direct population manipulation for reducing damage.

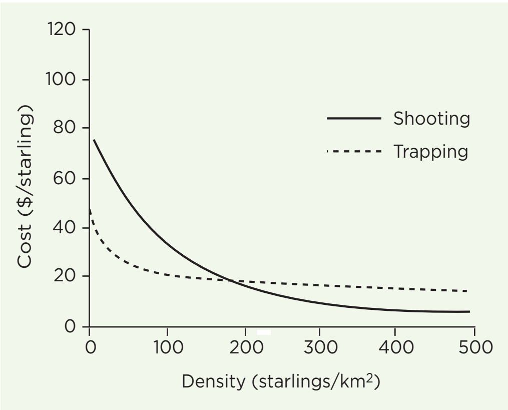


Figure 5.3: *Hypothetical relationships between the costs of trapping and shooting starlings ($/starling) and density (starlings/km^2).*

This analysis allows consideration of alternative techniques when removing different levels of pest populations. For example, it may be more cost-effective to trap starlings when they are at low density but more effective to shoot at higher densities (Figure 5.3).

The two techniques will achieve an equal cost per starling where the two lines cross — that is, at a density of about 165 starlings per square kilometre.

5.5 Decision theory (payoff matrix)

This form of analysis provides perhaps the most useful support to horticulturists. Most other economic models require accurate measures of costs and benefits or assumptions about density–damage relationships, which are often highly variable and difficult to estimate. This model can incorporate probabilities of different outcomes, which is a simple way of assessing risk. These can be estimated from past experiences in an area or from general or subjective information on individual techniques or expected damage. Chapter 4 (Assessment of control techniques) provides a useful guide to help determine the benefits of different strategies.

To illustrate with a simplified example, consider silvereye damage to vineyards in the Margaret River area of south-west Western Australia. A study between 1971 and 1983 (Rooke 1983) suggested that the highest levels of silvereye damage coincided with poor flows of marri nectar, the birds' preferred food. Marri produces low-quality nectar and/or low quantities one in every four years, on average. Thus, the probability of suffering high damage can be assumed to be 0.25, whereas the probability of negligible damage is 0.75. A hypothetical example to compare netting with no netting is presented in Table 5.2. In this example, we assume that:

- net returns are $10 600 per hectare in years with no bird damage;
- losses of 60% occur in poor marri flowering years; and
- bird netting costs $1120 per hectare per year (including labour) and is 90% effective in reducing damage (that is, reduces damage from 60% down to 6% in poor marri flowering seasons).

The desirable option is the one with the highest expected profits. In this example bird netting is more likely to produce slightly higher profits in the long term than no netting. It would also be more beneficial in terms of consistent cash flow between seasons.

Table 5.2: *Pay-off matrix of expected profits per hectare for two management options for silver-eyes in vineyards.*

Bird management strategy	Probability of damage		Expected profit
	No pest damage (0.75)	Pest damage (0.25)	
No netting	$10 600	$4240[2]	$9010[4]
Netting	$9480[1]	$8844[3]	$9321[5]

1 $10 600 – $1120 = $9480
2 $10 600 x 0.40 = $4240
3 ($10 600 x 0.94) – $1120 = $8844
4 ($10 600 x 0.75) + ($4240 x 0.25) = $9010
5 [($10 600 – $1120) x 0.75] + [($10 600 – $636 – $1120) x 0.25] = $9321

5.6 More complex analyses

The above analyses do not take into account many variables that influence the costs and benefits of management: for example, soil fertility, rainfall, climate, habitat and temperature may influence food availability and the preferences and movements of pest bird species. These factors may help to predict when and where damage is likely to be most severe, or the success of particular management options. Additional economic factors can also be incorporated, such as more detailed information on accountability of development and operation costs, externalities and discount rates (Perkins 1994). Where these variables demonstrate consistent relationships, linear programming can be used (Luenberger 1984). Dynamic programming goes a step further and allows the inclusion of factors that change in the way they influence or predict costs and benefits (Bauer and Mortensen 1992). Both models require expert programming knowledge, as well as an understanding of how and when the range of biological and economic factors will influence pest populations, damage and management. These could be used to improve property-based decision-making or to evaluate management options and aid decisions at a regional or national level.

5.7 Stepwise approach

The following section is a guide for deciding when, where and how to implement bird management and provides a reasonable prediction of the most cost-effective management regime. This step-wise approach incorporates some components of the above models, and could be applied to optimise management strategies for birds.

Step 1. Estimate the cost of bird damage

Estimating the cost of the damage will provide a basis for deciding how much should be spent to manage a problem. Methods for estimating damage are outlined in Chapter 3.

Step 2. List the cost of different management strategies

List all management strategies and how much they would cost to implement. Management strategies can include individual techniques or combinations, and different levels of application. Table 5.3 provides a starting point for considering the relative costs and benefits of different management techniques. However, the actual costs and benefits can vary considerably according to a range of factors, including bird species, crop variety, size of the orchard, terrain, climate, harvest strategy and control techniques. Hence costs and benefits should be calculated for each situation. Also consider carefully the labour involved for each strategy. Growers often underestimate the value of their own time and the money spent maintaining different techniques.

Table 5.3: *Relative costs and benefits of management techniques for pest birds in horticulture. Categories applied to costs correspond to approximate dollar values per hectare: Very High > $10,000; High $3000–$10,000; Medium $500–$3000; Low < $500; Nil $0 or incidental costs. Categories applied to benefits correspond to an increasing level of effectiveness: Low, Medium or High, as determined from the information reviewed in Chapter 4. '?' indicates insufficient information available.*

MANAGEMENT TECHNIQUE	COST		BENEFIT
	Upfront	Annual	
Grow another crop	Med?	Low?	Low?
Grow decoy crop	Med?	Low?	Low?
Harvest date	Nil	Nil	Low
Harvest technique	?	?	Low
Alternative foods	Low	Med	?
Shoot	Low	Low	Low
Permanent netting	Very High	Nil-very low	High
Drape-over netting	High	Med	High
Repellents	Low	Low?	?
Acoustic deterrents: electronic	Med	Low	Low ?
Acoustic deterrents: gas gun	Med	Low	Low
Acoustic deterrents: combined	Med	Med	Med
Acoustic deterrents: with shooting	Med	Med	Med
Visual deterrents	Low	Low	Low
Poisons	Low?	Low?	?
Replanting or transplanting	Med	Nil	Low?
Electric fencing	Low	Low	Low

Step 3. Consider the effectiveness and benefit of each strategy

Estimating the benefits of each management strategy is difficult, as horticulturists themselves seldom have the resources to trial different techniques. It is also unrealistic to provide prescriptive guidelines of when techniques will work for every situation, particularly when using a combination of techniques. Chapter 4 and Table 5.3 provide an objective guide as to the range of available techniques and their relative effectiveness. Consider how applicable and effective these are for the crop being assessed, and estimate the benefits of their implementation.

Step 4. Calculate cost–benefit ratios for management strategies

Using the information from steps 1–3, estimate the costs and predicted benefits of implementing each management strategy. If the benefits exceed the costs, then the ratio of benefits to costs is greater than one and the management strategy is economically profitable. The desirable management strategy is one that will provide the maximum benefit to cost ratio.

Step 5. (Optional) Construct a table listing the management strategies and their costs and benefits (pay-off matrix)

This allows different options to be compared after the current conditions are considered. For example, a grower may construct different matrices for different bird densities, seasonal conditions or commodity prices. Including probabilities of the likelihood of each state will aid decision-making. Examples of pay-off matrices for different pest densities and probabilities are presented in Table 5.2 and Table 5.4. A problem for many growers will be estimating probable costs of bird damage for different bird densities and management strategies. For example, in Case Study 9.9 growers estimated fruit losses were very high (40%–70%) on the basis of their perception of the proportion of fruit damaged, whereas estimates of monetary losses indicated much lower losses of fruit (< 10%) for these pome fruit orchards. One option is to estimate maximum and minimum values for losses and create two matrices, one using minimum estimated values and the other using maximum values. If the same management strategy gives the highest expected profit in both matrices then there is no need to collect better information on potential damage levels. If, however, different management strategies give maximum profits in the two matrices, then it is probably desirable to collect better information on damage before investing in expensive management strategies such as permanent netting.

Step 6. Decide when to implement

Some of the economic models discussed can be used to identify the level of control that is most profitable for a particular bird density. For example, these models can take into account the relationships between density and damage and differences between the costs of controlling different densities of pests. An optimal level of control could be estimated for fluctuating bird density and implemented when benefits exceed costs.

In practice, density–damage relationships of pest birds in horticulture are often not available and can be highly variable. Even when good information is available it is often not practicable for horticulturists to be immediately responsive to short-term fluctuations in density or damage. When damage becomes significant it is usually too late to implement effective control. For example, effective use of scaring often requires a 'start early' approach to prevent birds from establishing a feeding pattern. Similarly, investment in netting cannot easily be withdrawn for seasons in which damage is below the cost–

Table 5.4: *Pay-off matrix of four management options for three different probabilities of bird damage. Management strategies include: (0) do nothing; (1) low intensity control; (2) moderate intensity control; (3) high intensity control (after Norton 1988). Each cell contains the $ value of each combination of management strategy and probable bird damage. The 'Expected profit' column allows the grower to compare the benefits of the alternative strategies – see Section 5.5 and Table 5.2 for an example showing how to calculate these $ values.*

BIRD MANAGEMENT STRATEGY	PROBABILITY OF BIRD DAMAGE			EXPECTED PROFIT
	Low (L)	Medium (M)	High (H)	
(0) Do nothing	$ Outcome L,0	$ Outcome M,0	$ Outcome H,0	$A
(1) Low (e.g. visual deterrent)	$ Outcome L,1	$ Outcome M,1	$ Outcome H,1	$B
(2) Moderate (e.g. scaring with shooting)	$ Outcome L,2	$ Outcome M,2	$ Outcome H,2	$C
(3) High (e.g. netting)	$ Outcome L,3	$ Outcome M,3	$ Outcome H,3	$D

benefit threshold. Instead, horticulturists need to look at costs and benefits over a longer time frame and make decisions accordingly. Where damage in an area is likely to be high or there is a history of high damage, investing in continuing bird management is likely to be worthwhile, even if damage is highly variable between seasons.

5.8 Other factors to consider

With any management decision there are always components of risk. Different bird management strategies will have varying levels of risk. Managers who are risk-averse will select strategies that provide reasonable returns under the widest range of conditions, but a potential trade-off may be lower profits. If a manager's priority is to maximise profit in the long-term, the preferred strategy will be that which is likely to give the highest returns even though there may be increased risk of no returns or losses during bad seasons. Direct cost–benefit and decision theory methods allow managers to account for some of the risks of damage or management success.

Economic models attempt to draw simple conclusions from dynamic, complex systems. They are more applicable when dealing with single pests, where reductions in pest density result in corresponding reductions in damage, or when costs and benefits are easily measured. Birds in horticulture rarely conform to these ideals. Incorporating a range of other factors will improve the relevance of economic models but will also increase their complexity.

Culling pest birds using techniques such as shooting, poisoning or trapping has often been unsuccessful in achieving long-term reductions in population size or agricultural damage (Section 5.2). Although mostly unquantified in Australia, bird damage is highly variable among regions, growers and seasons. Management action would therefore be more efficiently targeted in industries and regions where damage is significant, instead of aiming for broad-scale reductions in bird density. There is a diversity of native bird species that cause damage, but it is often undesirable ecologically and politically to reduce the populations of these species. Birds are highly mobile, have high rates of recruitment, and can quickly recover to pre-control densities. These factors highlight the difficulties in applying economic models that rely on reducing density to reduce damage to horticultural enterprises.

Legal, social and environmental considerations are additional factors that should be considered in decision-making (Chapter 7). Some of these are:

- Neighbour relations — will an intensive scaring campaign inhibit future cooperation between neighbours?
- Off-site considerations — does a control strategy adversely influence adjacent land use?
- Environmental — is the management action environmentally acceptable?
- Animal welfare — is the technique humane?
- Occupational health and safety — are the management practices safe for operators?
- Legal — will bird control breach any legislative requirements?
- Indirect effects of control — will reduction in the numbers of birds in vineyards increase harmful insect loads?
- Debt servicing — are consistent profits needed to service debt?

5.8.1 Tax considerations

Currently there are no federal tax concessions available for bird control infrastructure for horticulture crops. However, netting and other infrastructure or equipment used for controlling birds can be depreciated through the tax system. For example, the Australian Taxation Office (ATO) has reviewed the effective life of permanent netting structures for primary producers. From 1 July 2006, the ATO has given a 'safe harbour' effective life of 20 years for permanent nets for birds, sun, hail and wind. However growers may still assume a shorter effective life based on their circumstances.

6. Legislation

Legislation relevant to pest birds can include Acts, Regulations and policies for: quarantine; exports and imports; nature conservation; agriculture; biological diversity; ecologically sustainable development; clearing of vegetation; animal welfare; and the management of stock routes, forestry and conservation reserves (Appendix D). Many of these are applicable in addressing national, State-wide or regional concerns about pest birds. However, the influence of legislation on a landholder's decisions is often unclear. Issues that are of most concern to horticulturists have a direct influence on the management of birds on their property. These include inquiries such as:

- Which bird species require destruction permits? How are these obtained? (Section 6.1; Appendix E)
- Which chemicals may be used for bird control? (Section 6.2; Appendix F)
- What are the restrictions on chemical use? (Section 6.2; Appendix F)
- Who supplies the chemicals? (Section 6.2; Appendix F)
- What are the restrictions for using scaring devices? (Section 6.3)
- Can pest bird roosting or nesting habitat be cleared? Is a permit required or available? (Section 6.4)
- Are there animal welfare implications to be considered including codes of practice, for example for the shooting of birds?

It is important that these questions be considered at the time the available management alternatives are reviewed. The questions are discussed below.

6.1 Destruction of birds

Permits are not required for the control of introduced species in Australia (Appendix G). However, the destruction of any bird must abide by other legislation. For example, in New South Wales the techniques used must be humane (*Prevention of Cruelty to Animals Act 1979*; Section 7.4); birds must not be owned by anyone or on another person's property (trespass; *Enclosed Lands Protection Act 1901*) and no birds may be culled within a National Park or reserve (*National Parks and Wildlife Act 1974*). Equivalent legislation applies in other States and Territories. Under Commonwealth legislation (*Environment Protection and Biodiversity Conservation Act 1999*) threatened species are protected. Birds may also be afforded protection as components of World Heritage properties, Ramsar wetlands and Commonwealth areas. In many cases, legislation will also apply to non-lethal disturbance of native birds and hence permits may be required for the use of some non-lethal methods of control.

'Native bird species are protected, and penalties apply if they are destroyed without a permit.'

In general, native bird species are protected, and heavy penalties apply if they are destroyed without a permit. However, there are various provisions in State legislation that allow the destruction of certain native species in designated regions without a permit. These species are termed 'unprotected' (Victoria, subject to certain conditions, and South Australia) or 'locally unprotected' fauna (New South Wales); or are species that are subject to year-round 'restricted open seasons' for specified areas (Western Australia) (Figure 6.1).

In most States and Territories permits may be obtained from National Parks and Wildlife agencies for controlling protected native birds, excluding endangered or threatened species.

Damage, or potential for damage, to agriculture or the environment must be demonstrated and permits are usually issued for a specific number of birds and for a designated period (Appendix E). However, in the Australian Capital Territory, wildlife may be killed only if it is considered a danger to people. Destruction permits are not issued in the Australian Capital Territory for any native bird species, even if they are considered to be causing damage to agriculture (Appendix E).

6.2 Chemicals registered for bird control

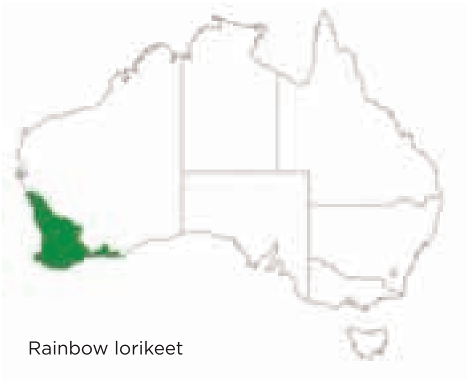
All legally available chemicals used in horticulture are registered with the Australian Pesticides and Veterinary Medicines Authority (APVMA). The APVMA is responsible for the assessment, registration and regulation of pesticides and veterinary medicines and administers the National Registration Scheme for these chemicals. Registration is constantly reviewed and updated, and permits for many chemicals are issued for only limited times. Horticulturists can contact the APVMA (02 6272 5852) or access the PUBCRIS registry database online at http://www.apvma.gov.au for up-to-date information. Chemicals currently registered in each State and suppliers and conditions of use are listed in Appendix F. Apparent conflicts in legislation may occur; for example, polybutene is currently registered in South Australia by the APVMA although its use is illegal under the *Prevention of Cruelty to Animals Act 1985* (Published in the South Australian Government Gazette 11 July 1996 p. 113; sub-regulation 2 b: 'gel for bird feet prohibited'). This emphasises the importance of consulting State governments for advice, as they hold the responsibility for controlling the use of chemicals in each jurisdiction.

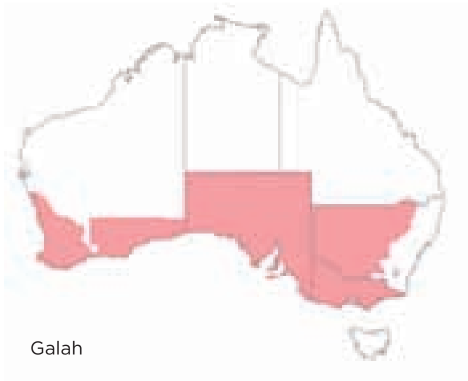
6.3 Legislation relating to noise

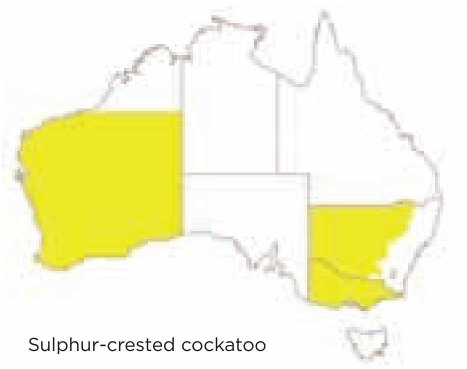
Encroaching urban development and changing land-use are major issues for horticulture in areas close to towns and cities. The use of acoustic scaring devices is one example where increasing conflict is occurring (Section 7.5). Environmental protection authorities in most Australian States and Territories have developed guidelines for the levels of noise that can be emitted beyond property boundaries. For example, in New South Wales this is regulated under the *Protection of the Environment Operations Act 1997* (Sections 136–140 and Sections 263–283). In some States, local councils have been given jurisdiction to resolve these conflicts and to establish guidelines and appropriate zoning laws. This often includes specifications for the frequency and intensity of noise and the time of day when acoustic devices may be used. There have been several cases where horticulturists have been prosecuted for repeated use of prohibited or restricted-use scaring devices (Section 7.5).

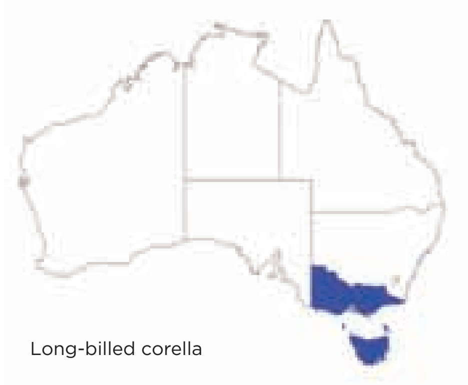
6.4 Clearing vegetation

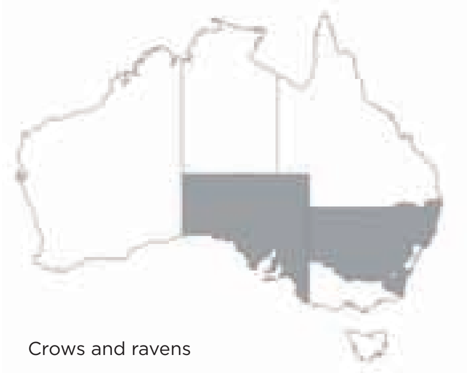
Habitat manipulation can be effective for reducing pest populations (Van Vuren 1998; Section 4.3). However, this may have severe environmental consequences and may inadvertently increase the numbers of other pest birds (Section 7.7). Clearing of native vegetation is legally restricted in all States and Territories, and permits are required from State planning and natural resources agencies (Appendix D). Even pruning of trees may not be allowed without a permit. Some States have restrictions on the removal of exotic trees if they are very old specimens or are heritage listed. Local government also has a role in establishing and enforcing tree preservation orders.

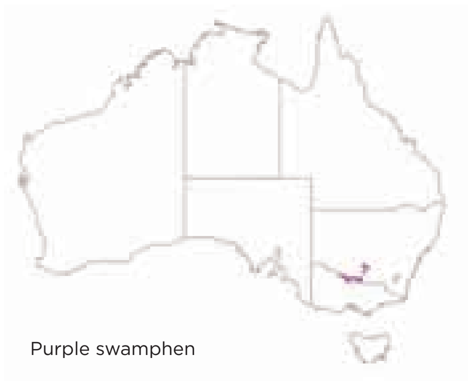












Budgerigar, zebra finch, little corella, red wattlebird and silvereye

Figure 6.1: *Regions of Australia where some native bird species are classified as locally unprotected. Note: More detailed maps showing the delineations within States are available from www.feral.org.au. National Parks or conservation agencies should be contacted for current information on protected species (Appendix E).*
Source: Peter Worsley Resource Information NSW Department of Primary Industries.

7. Social and environmental factors affecting bird management options

In addition to technical and economic considerations, there is also a range of social and legal issues to take into account when selecting bird management options, including:

- acceptability of culling target birds (particularly if native species);
- risk of killing of non-target animals;
- consequences of use of chemical repellents (phytotoxicity, residues and breakdown products);
- animal welfare issues associated with lethal, and some non-lethal, techniques;
- noise pollution associated with acoustic scaring devices and shooting;
- aesthetic acceptability of visual scaring devices and netting; and
- issues associated with habitat modification and decoy feeding.

Conflict is likely to be greatest in more densely populated areas. Horticulturists in many regions are under increasing pressure from urban expansion. Improvement in the compatibility of land uses is essential to ensure that productive agricultural land is retained and standard agricultural practices are not compromised. In Australia this responsibility falls primarily under the control of local governments. However, some State government departments have developed guidelines to encourage rural residents and commercial farmers to work together and to provide a supportive social and regulatory structure for agriculture. For example, in Victoria the State Planning Policy Framework includes a policy commitment to protect agricultural activities that fall within acceptable industry performance standards (Department of Primary Industries Victoria 2005).

However, even where there is no social pressure affecting choice of management strategy, landholders should select legal strategies that reduce damage but have minimal impact on non-target animals and the environment. Humane culling of pest birds should be used only as a last resort.

7.1 Culling of pest birds

Lethal control poses a number of real and perceived problems. The practice may attract adverse public attention, particularly in urban areas. Many people perceive birds, even introduced species, not as pests but as a delight to see and hear. A focus on culling is also rarely the most appropriate solution (Section 4.2) and may detract from accurately defining the problem (Section 1.1). Carefully identifying the species involved, assessing whether bird impact is economically significant, and reviewing the full range of damage reduction options are important considerations before implementing a culling programme. The stress some landholders experience from bird damage may lead them to focus on the birds themselves, which in turn may lead to an emphasis on lethal control techniques. Part of the problem is that bird damage is often more obvious than other impacts on fruit quality and volume, and bird management may be considered in isolation from other management considerations.

'Lethal control may attract adverse public attention, particularly in urban areas. Many people perceive birds, even introduced species, not as pests, but as a delight to see and hear.'

Permits may be obtained to cull some native pest birds in some States. Lethal control techniques for which permits may be obtained include shooting, trapping and poisoning (Chapter 6).

7.1.1 Shooting

Shooting can be target-specific and humane if conducted properly. However, the use of shotguns may pose a risk of non-target kills in mixed species flocks, as well as the likelihood of injuring birds. Consideration of appropriate firearms and ammunition size for target species will reduce the risks of unnecessary injury (Table 7.1) (South Australian National Parks and Wildlife Service 2001). There are also safety issues associated with firearms that necessitate their restricted use (Figure 7.1). Public attitudes towards shooting are often negative. This is reinforced by negative publicity towards duck and kangaroo shooting.

Figure 7.1: *Signage may be required where firearms are used. Photo: T. Bentz.*

Table 7.1: *Recommended firearms, ammunition and shooting ranges for the humane destruction of birds.*

Bird species	Firearm	Optimum range (m)	Effective range (m)	Shot size
Small birds to starling size silvereyes, sparrows	410 shotgun 12 gauge shotgun	15-30	25-30	10's 10's-12's
blackbirds, starlings	410 shotgun, 12g shotgun	15-30	25-30	7's-9's 7's-9's
red wattlebirds, rosellas, lorikeets	12 gauge shotgun	30	30	6's-8's
Birds up to teal size galahs, little corellas, silver gulls, feral pigeons, chestnut teal*, grey teal* pink eared duck*, white-eyed duck*	12 gauge shotgun	30	30	4's-6's
Birds up to shelduck size long billed corellas, sulfur-crested cockatoos, cormorants, magpies, crows, ravens, black duck*, wood duck*, Australian shelduck*	12 gauge shotgun	30	40	3's-5's
Cape barren geese	Centrefire rifle with telescopic sights	50	200	manuf. specs
Emu	Shotgun - only 12 gauge	30	40	1's & 2's (36g)
	Heart shot - centrefire rifle	50	100	manuf. specs
	Head shot - shotgun (injured birds only)	5	10	1's & 2's

* Non toxic shot must be used, adjusting shot size as necessary.

Source: South Australian National Parks and Wildlife Service 2001. Note: Western Australian authorities currently use 0.22-calibre rifles with silencers for starling control due to the particular requirements of eradicating localised populations.

7.1.2 Poisoning

Alpha-chloralose is the only chemical that is currently registered in some States for culling birds in agricultural situations (Section 4.2.3). If used at lethal concentrations it can be made target-specific to a certain extent through free-feeding in particular areas, and by using specific feed types that will attract the target birds. Alpha-chloralose should be added only if observation confirms that only target birds are feeding on the bait. If non-target species are likely to take the bait, a change of bait type or placement may help. Otherwise, a lower concentration of alpha-chloralose can be used so that birds are sedated rather than killed. Non-target species can then be revived and released and target birds humanely killed. However, there is likely to be a negative community perception about the use of poisons to control birds, regardless of whether they are defined as 'pests' or not.

'The use of illegal toxins is a concern on environmental and animal welfare grounds.'

The use of illegal toxins is a concern on environmental, occupational health and safety and animal welfare grounds. Illegal poisoning may kill non-target animals and contaminate crops and the environment. Landholders employing such techniques are liable to prosecution under various State laws, discussed in Chapter 6 and outlined in Appendices E and F.

7.1.3 Trapping

Trapping, and particularly the use of traps that catch many birds (Figure 7.2), presents a graphic image that will concern some people. Restricting the use of trapping to skilled operators, and justifying trapping (and indeed, any lethal control programme) in terms of a demonstrated reduction in damage, should improve the general acceptance of such techniques. Nonetheless, where native species are culled there will always be some controversy. An example is the case of the cockatoo-trapping programme coordinated by the Victorian Department of Sustainability and Environment (DSE) to reduce damage to grain and horticultural crops (Figure 7.3). Damage caused by cockatoos before or after control is not measured. However, DSE uses skilled operators, employs a humane method of euthanasia (CO_2, Sharp and Saunders 2004c), collates information on the number of birds culled, and runs an education programme aimed at reducing on-farm practices that attract cockatoos. The Department is therefore in a position to respond to criticism of the programme.

Figure 7.2: *Some traps catch many birds. Such traps may be of concern to people unaware of the damage pest birds can do. Photo: B. Lukins.*

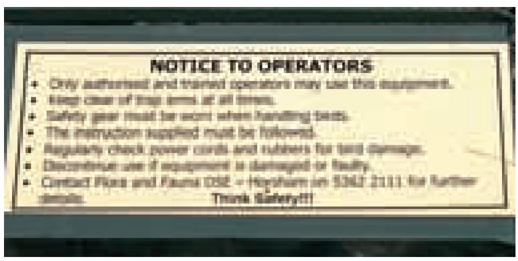


Figure 7.3: *Ample signage and using skilled operators are some of the precautions taken by The Victorian Government in its cockatoo trapping programme. Photo: B. Lukins.*

7.1.4 Social factors

The culling of any animal, regardless of its pest status, will concern a portion of the general community. If the animal is native, and particularly if it is appealing or iconic, more people are likely to be concerned. In a survey by the Victorian Institute of Animal Science (Johnston and Marks 1997), 23% of respondents (all of whom were from Victoria) considered corellas to be pests, compared with 59% for starlings and 38% for mynas. To put these figures into context, 95% and 87% of respondents regarded rabbits and foxes, respectively, to be pests. Corella damage to sown cereal crops is a reasonably high-profile pest issue in Victoria. Interestingly, there were no strong differences in attitude between farming- and non-farming-background respondents, although there was significant local variation in responses.

Another point of interest from the Victorian survey relevant to bird management is that a relatively high proportion of respondents were undecided as to whether starlings and mynas were pests, possibly reflecting a lack of awareness of the impacts caused. Another influence may be that 19% of respondents believed that introduced species that have been in Australia for more than 100 years should be regarded as 'native'. This figure is likely to increase in the future with increasing urbanisation of society, ignorance of species' native or introduced status (particularly with regard to birds), and the belief that the culling of any animals is unacceptable regardless of the species' origins or pest status. The survey included an open question allowing respondents to list other animal species that they classified as pests. Of the 822 survey responses, the numbers that were identified as pests are listed in Table 7.2.

Table 7.2: *Responses to a survey by the Victorian Institute of Animal Science asking Victorians to list 'other'* bird species that they classified as pests.*

Introduced species	No. of responses
Sparrow	44
European blackbird	20
Starling ***	12
Myna ***	6
Rock dove (feral pigeon)	3

Native species	No. of responses
Cockatoo**	33
Crow or raven	17
'Seagull'	11
Galah	8
Duck	6
Corella ***	4
Magpie	3
Budgerigar	1
Cormorant	1
Eagle	1
Emu ***	1
Ibis	1
Swan	1
Waterhen	1

* 'Other' referred to those species not already covered in the main survey.

** The common and/or colloquial term 'cockatoo' refers to a number of species that may include galahs and corellas.

*** These bird species were included in the main survey and would therefore not be listed by most respondents as 'other' pest animals—hence these values are underestimates.

These figures are based on a Victorian survey, and results would obviously vary by region and State depending on species distribution and density, land use and local community attitudes.

7.2 Killing of non-target animals

In the 1996 Victorian Institute Animal Science attitudinal survey (Johnston and Marks 1997), 39% of respondents thought it was acceptable for small numbers of non-target native wildlife to die during efforts to control a large number of pests. However, 49% of respondents found this scenario unacceptable. There was a similar breakdown (38% and 51% respectively) of attitudes towards the killing of non-target domestic animals. Although not surveyed, there is likely to be less concern about the killing of non-target, unowned, introduced species. There are a number of bird control techniques used by horticulturists and land managers that affect non-target species, including shooting, poisoning, trapping and netting.

7.2.1 Shooting

Shooting is a relatively target-specific form of pest animal control. However, there is the possibility of unintentional killing of non-target birds through misidentification or the use of shotguns on mixed groups of birds. Intentional killing of non-target or non-approved native birds is illegal and ad hoc shooting is likely to attract adverse public attention. This adverse attention leads to further restrictions on what may be a useful supplementary technique for scaring and targeted culling of pest birds.

7.2.2 Poisoning

Poisoning birds can put a large number of non-target species at risk. For example, during control work for tree sparrows in Port Hedland, Western Australia using alpha-chloralose, a large number of non-target peaceful doves (*Geopelia striata*) were accidentally killed through their high intake of poisoned grain (Marion Massam, Department of Agriculture and Food, Western Australia, pers. comm. 2005). However, alpha-chloralose can be used (where legal) in such a way as to make it target-specific, as sub-lethal doses have a temporarily disabling (soporific) effect (Section 4.2.3). It is difficult to develop target-specific lethal toxins that have sufficiently variable toxicity to different bird species. DRC-1339 (Section 4.2.3) is an avian-specific poison that does have some selective toxicity for different bird species: many pest species in North America (for example, starlings and crows) are highly sensitive. The target specificity of this toxin for Australian species is unknown. Nonetheless, lethal toxins (or lethal techniques in general) are unlikely to ever become a mainstay of best practice bird management. Careful selection of the bait type, monitoring of baiting areas, and a detailed understanding of the behaviour of target species are essential when reducing non-target deaths and before considering lethal toxins for reducing bird damage.

7.2.3 Trapping and netting

Some non-target bird species are likely to be captured when trapping, even though some trap designs can be made more species-specific by changing the size of the trap entrances (Section 4.2.2). Free-feeding and field observations can reduce this risk, and regular checking (Sharp and Saunders 2004b) can ensure that non-target species are released unharmed. Traps or nets used for flocking birds pose a risk of harming non-target birds in mixed groups.

Even though target and non-target species can be caught and occasionally injured or killed in exclusion (particularly in drape-over) netting (Figure 7.4), from a welfare perspective it is clearly preferable to any form of intentional lethal control. Problems with animals getting caught in the nets or trapped within them can be managed by the selection of appropriate net materials and construction and by regular inspections. Permanent netting enclosures generally pose lower risks of accidentally catching non-target species than other forms of netting, especially if one-way escape doors are included.

Figure 7.4: *A goshawk inside drape-over netting. Target and non-target species can become caught in netting. Photo: J. Tracey.*

7.3 Chemical repellents

Currently there are no registered chemical repellents to prevent bird damage to fruit in Australia, and there are a number of issues to be considered if such a product were to become available in the future. Some chemicals (such as methyl anthranilate) can be phytotoxic and therefore may damage sprayed plants to an unacceptable level (Staples et al. 1998). Chemical repellents may also leave residues on fruit, posing problems for human consumption and/or subsequent processing. There may also be animal welfare issues associated with some repellents, particularly 'secondary' repellents (Section 4.5).

7.4 Animal welfare

Community attitudes towards animal welfare depend very much on the species involved. There are likely to be greater concerns and media attention associated with native versus introduced birds, particularly if they are appealing, iconic or rare.

Unfortunately, assessment of the humaneness of pest control techniques is difficult because of the complexity of pain perception and physiology. The assessment of pain requires a multi-disciplinary approach that incorporates an understanding of physiology, pathology and animal behaviour. The difficulty with wild — and particularly prey — animals is that masking the signs of illness is an important survival mechanism. Subtle behavioural responses to pain can lead observers to conclude that some animals have a limited ability to experience pain (Gregory 2004).

'Community attitudes towards animal welfare differ dramatically according to the species involved.'

The Royal Society for the Prevention of Cruelty to Animals (RSPCA) acknowledges that in some circumstances it may be necessary to implement a control programme if there is an imbalance in wild populations of some native species or to reduce the impacts of introduced animals (see also Temby 2005). However, RSPCA's policy states that lethal control should be employed only where there is no humane non-lethal alternative, (RSPCA Australia 2004). Furthermore, the RSPCA states that lethal control programmes should be target-specific; be directly supervised by government authorities or be part of an approved management programme; and collect publicly available data to justify the culling in terms of subsequent reduction in damage.

The overarching philosophy of the RSPCA is that any pest animal control needs to be justified in terms of measured damage, and that management needs to focus on the most effective damage reduction strategies, which do not necessarily involve lethal control. If lethal control is employed, it should be carried out in a strategic way using the most humane and effective techniques available to reduce the need for recurrent culling. These general views are shared and promoted by State and Territory agencies responsible for pest animal management. Regardless, general pest bird population reduction is often illegal (particularly for native species) and often socially unacceptable and/or ineffective in reducing damage (Section 4.2), although small-scale culling through shooting may be useful to enhance the effect of scaring devices.

With regard to specific lethal control techniques, shooting can be humane, although the use of shotguns clearly poses the risk of injuring, but not killing, birds, which then need to be dispatched as quickly as possible. Trapping can be relatively humane, provided it is conducted by skilled operators and the caught birds are killed humanely (for example, with carbon dioxide or by neck dislocation). The humaneness of any chemical (such as alpha-chloralose) is always difficult to accurately assess, as obvious symptoms are not always a good indication of the pain and distress experienced by an animal (Barnett and Jongman 1996). Where alpha-chloralose is used as a low-dose soporific, there is potential for birds that leave the site under the effect of the chemical to be injured or preyed upon before they have a chance to recover.

RSPCA supports research into fertility control for pest animals, provided that the methods are humane, specific and likely to be effective in reducing target populations (RSPCA Australia 2004). There is no research currently being conducted into fertility control of introduced birds in Australia. Any form of fertility control for over-abundant native birds would have to be non-disseminating so that it could be targeted at a regional level.

In the 1996 Victorian Institute of Animal Science attitudinal survey (Johnston and Marks 1997), the only question that provided potential insight into general public attitudes towards pest birds and animal welfare was one seeking feedback on preferred lethal control techniques for different pest animals. The bird pests specifically mentioned in this question were starlings and mynas, and there was a relatively high level of 'undecided' responses (33% and 45% respectively) for preferred control methods compared with those for better-known pests such as rabbits. This probably reflects a greater ambivalence towards pest birds and a lack of understanding of their impacts and potential control techniques. A relatively high percentage of respondents (17% for starlings; 15% for mynas) thought there was no appropriate control technique for these pest birds. Interestingly, 21% (for starlings) and 18% (for mynas) of respondents thought that biological control was the best approach for these species. It is unknown what various respondents meant by 'biological control' in the case of pest birds. There were lower-level (6%–12%) preferences for other control techniques, such as shooting, poisoning and trapping.

7.4.1 Standard Operating Procedures

Animal welfare standard operating procedures have been developed for pest animals, including for the euthanasia, shooting and trapping of birds (Sharp and Saunders 2004a; Sharp and Saunders 2004b; Sharp and Saunders 2004c). These provide recommendations for reducing animal welfare impacts on target and non-target species; outline health and safety considerations; and describe operating procedures. The recommended methods of euthanasia for captured birds are inhalation of carbon dioxide gas, neck dislocation, and injection of barbiturates.

7.5 Noise pollution

Noise pollution associated with acoustic scaring devices and shooting is an issue near residential areas co-located with horticultural properties. The problems are exacerbated by the recommendation that these techniques be employed in the early morning and evenings when birds are most active.

Fortunately, some 'best practice' recommendations for the use of acoustic scaring devices (Section 4.1.3) and shooting comply with reduced noise pollution objectives — for example, scaring devices should be used sparingly and at random to avoid habituation. Similarly, shooting is likely to be most cost- and time-effective when used sparingly to reinforce scaring devices, rather than for general population control.

> ***'Noise pollution associated with acoustic scaring devices and shooting is likely to become an issue near residential areas.'***

Most Australian State and Territory environment protection agencies have general guidelines and legislation regarding noise pollution (Section 6.3). However, regulatory responsibility for environment protection legislation often resides with local councils. Horticulturists that repeatedly use acoustic devices may be held liable if any residence or occupier is 'affected by an offensive noise', and if a local court finds this to be offensive. In regions where conflicts between horticulture and urban residents occur, some councils have developed specific guidelines for the use of acoustic devices. For example, the Adelaide Hills Council, South Australia, restricts the use of gas guns to between 7am and 8pm, six detonations per hour, more than 200 metres from a neighbouring residence, hospital or school, and one device per 4.2 hectares.

7.6 Visual scaring devices and netting

The use of plastic shopping bags, car-yard bunting and reflective materials potentially poses aesthetic problems if placed in crops in public areas, and safety problems along roadways. The use of scarecrows and kites shaped like birds of prey is likely to be less of an aesthetic issue. Regardless, visual scaring devices that are left in one position for a prolonged period are generally ineffective (Section 4.1.2). Netting can be made more aesthetically acceptable by using darker colours. However, birds may be more likely to become tangled in darker-coloured netting: white netting poses more of a visual barrier that birds can avoid. Netting thickness and mesh diameter may also influence visibility by birds and therefore the likelihood that they may become tangled in the netting.

7.7 Habitat modification and decoy feeding

There may be some scope for acceptable habitat modification or management when establishing a new orchard or vineyard in a previously cleared area. This may include not planting crops near trees that may be used for roosting and food (particularly flowering natives). At the same time, reduction in the threat of bird damage needs to be balanced with other objectives such as windbreaks and vegetation corridors for conservation. Clearing of existing native vegetation, even where legal, may be socially and environmentally undesirable.

The use of decoy crops may be a non-controversial way of resolving bird damage in some situations (Section 4.3). However, even this method may cause conflict in a community under the following scenarios:

- where the decoy crop is a grass or pasture species and there are concerns about weed spread to surrounding properties;
- where the decoy food is meat (used, for example, for crows, with the aim of protecting nut crops or attracting birds of prey); and/or
- where there are concerns from other growers that decoy crops are maintaining, or even increasing, the numbers of pest birds in the area.

8. Extension

There are a number of potential impediments to the adoption of 'best practice' pest bird management. These include:

- lack of information about the damage birds cause and options for reducing damage;
- landholders lacking the time and/or money to conduct bird control;
- cost-effectiveness of pest bird control may be marginal on the basis of currently available techniques; and
- some landholders are not concerned about, or simply accept, the level of damage and/or have had little historical interest and involvement in pest bird management.

Specific impediments to adoption of 'best practice' pest bird management include:

- problems are sporadic and often unpredictable;
- impacts may not be obvious and/or are difficult to measure;
- cheaper control techniques are often labour-intensive and ineffective;
- proven techniques such as netting are expensive and may not be cost-effective for low levels of damage;
- a great many of the species involved are protected native species; and
- entrenched beliefs that nothing 'works'.

The above can be illustrated by comparing bird management with management practices undertaken for foxes. Foxes can be a threat to lamb production in certain situations (Saunders et al. 1995). The challenge is to determine whether there is a significant impact at the local or regional level. If the impact is significant then there is a conceptually simple and cheap resolution, with 1080 baiting being shown to be effective if conducted according to current 'best practice' principles. Therefore, the role of extension would be to encourage landholders to monitor fox activity and lamb losses and to coordinate best practice fox baiting with their neighbours if there is a problem.

In the case of pest bird management, the extension message is not as simple. Bird damage is unpredictable, and exclusion netting — the main damage prevention measure that has been demonstrated to be highly effective — is expensive. A range of less expensive techniques and strategies has either been shown to be ineffective (for example, many scaring devices), or has not yet been adequately evaluated. Others are not responsive enough to be used for occasional pest bird problems (for example, decoy crops) or may not be suitable for established properties (for example habitat modification).

Clearly, where the economics of exclusion netting are uncertain or negative, pest bird management is limited by the lack of available, inexpensive and proven control techniques that are not labour- intensive. In areas where pest bird problems are sporadic and unpredictable, there is a need for responsive techniques that can be used once a pest bird problem arises. For most pest animal problems, the objective is strategic management to prevent population build-up at a property (for example, mice), local (for example, rabbits) or regional (for example, foxes and wild dogs) level. In the case of flocking gregarious birds, there is a case for reactive, improvised control (for example, some scaring devices) to supplement longer-term approaches (such as habitat modification).

8.1 The purpose of extension

Extension may serve the following purposes:

- Inform landholders of new research that quantifies damage and evaluates damage reduction options and/or the cost–benefits of different approaches in the context of other property management obligations. The concept of 'best practice' is dynamic and should be constantly re-evaluated as new information becomes available. Landholders should be informed of their options for strategic and reactive control depending on whether pest birds are a constant or occasional problem.
- Inform landholders of new commercial products that have become available (for example, new types of exclusion net).
- Coordinate landholders where problems (such as flocking gregarious birds) need to be managed on a regional level.

8.2 Engaging with landholders

The most important thing for a specialist pest animal management researcher or extension advisor to understand is that bird damage is just one of many issues that producers have to deal with. Other issues, such as water and nutrient availability, have a much more direct and predictable link to horticultural production and will be uppermost in producers' minds. Similarly, other pest issues such as weeds, insect pests and disease may be more significant, predictable and solvable than bird damage. The motivation of most landholders relates to current, rather than potential, damage. Bird damage also occurs during the ripening and harvest season, when producers are preoccupied with a range of issues, including irrigation, disease and insect pest management, and machinery/labour requirements leading up to harvest.

The main problem with encouraging producers to develop strategic approaches to managing bird damage is unpredictability. This encourages a crisis management approach, as with mouse plagues. Having said that, past and current research and modelling are improving the predictability of mouse plagues with the aim of developing and encouraging preventive management. Pest bird research in Australia is less advanced, but hopefully current and future research will improve the predictability of bird impact and provide a greater range of cost-effective strategies to reduce impact.

'The unpredictability of bird damage encourages a crisis management approach.'

In the meantime, landholders need to be made aware of the cost–benefits of preventive options such as exclusion netting. An awareness of early intervention solutions is also important should a pest bird problem become apparent.

There are a number of 'hi-tech' commercial products that have the appeal of advertised instant results for moderate cost and are therefore selected over more expensive and/or long-term approaches. Unfortunately these products may fail to live up to manufacturers' claims. Extension has a role in helping landholders balance these claims with the most recently available scientific evidence. Advisors should also discuss the legalities and 'externalities' of various control options in helping landholders develop a damage reduction strategy. For example, many pest birds are native and protected, and this places restrictions on lethal control techniques.

If nothing else, landholders should be encouraged to:

- balance local folklore with new extension material and their own assessment;
- review current approaches;
- try new recommended approaches;
- work with neighbours; and
- assess results over several years and modify their approaches accordingly.

8.2.1 How landholders obtain their information

One-on-one contact is invariably more effective than written material. Landholders need to be approached when a problem is likely and the information is therefore directly relevant. At the same time, landholders should also be approached outside of busy periods, when they are more likely to be interested in strategic considerations.

Sustained direct communication is the most valued and effective form of conveying and receiving the landholder perspective (Andrew 1997). Meetings should have a clear, practical purpose and be held at times that suit landholders.

'Meetings should have a clear practical purpose and be held at times that suit landholders.'

Extension workers need to identify and work with key players in the community and industry. For example, large vineyards are likely to have the labour and financial resources to work with researchers and try new pest bird management approaches. This should bring profile to the issue and lead to wider adoption. However, it is important not to neglect smaller growers, who may best be targeted through cooperatives or grower associations.

Researching and implementing new approaches is a long-term endeavour. The best results will occur where the same person works with the community over a long period, builds trust and, as a result, becomes aware of the real issues and limitations on solutions.

Landholders (and people in general) often respond differently to questionnaires than they would in person (Andrew 1997). It is not uncommon for researchers to receive simplistic feedback on complex issues through surveys. Researchers may then become disillusioned once research has begun if there is little landholder commitment. Thus it is important for researchers and extension officers to have ongoing contact with landholders to determine what the real issues are and which solutions are likely to be practical. This initial 'reality check' will help ensure that research is focused on practical solutions.

The next step is to involve landholders in the research to ensure it remains practical and is re-focused as necessary. For example, if it becomes clear that landholders do not have time to implement certain management actions at certain times of the year, then alternative actions should be investigated. Towards the end of the research phase, preliminary research results should be provided to a wider group of landholders who have not been directly involved in the research process. This will allow further fine-tuning of recommendations before extension materials are produced. It is important to recognise that pest bird management attracts a range of views and hence to expect and respect diversity of opinion.

Local 'experiments' (for example, netting half a row to demonstrate what the level or quality of production would be without bird damage) can be particularly effective. Landholders are more likely to take note of these results than more rigorous research results derived from outside the local area.

'PESTPLAN' (Braysher and Saunders 2003) provides a process to help regions prioritise and plan pest animal management. In doing so, it also helps identify regional research and extension priorities.

9. Case studies

9.1 Indian myna incursion in Port Adelaide, South Australia

Ron Sinclair, Animal and Plant Control Group, South Australia.

9.1.1 Define the problem

Indian mynas are absent from South Australia but are listed as one of the world's worst invasive species (Invasive Species Specialist Group 2005). They have considerable potential to become established in other regions of Australia (Bomford 2003). Information on mynas suggests that potential environmental and agricultural impacts on South Australia could be significant (see factsheet in Part B; Perumal et al. 1971; Toor and Ramzan 1994; Clarke et al. 2001; Bomford and Hart 2002; Bomford 2003).

In December 2004, the Animal and Plant Commission of South Australia received information from a member of the public regarding the sighting of mynas on a road verge near Port Adelaide. The last confirmed report of this species in the State had been in 1988. This report was investigated and two mynas were observed foraging on the median strip of a busy suburban road. They were observed carrying food to a nest site in a hollow metal cross-arm of an adjacent power pole.

9.1.2 Develop a management plan

Define management objectives and performance criteria

Prevent the establishment of mynas in Port Adelaide (South Australia).

Select an appropriate management option

Eradication in this situation is feasible as the population is small (only an isolated breeding pair was observed) and not yet established, so further immigration may be preventable.

Formulate a management strategy

The application of a toxin is technically possible and practicable in this scenario. Alpha-chloralose is legally permitted under certain restrictions (Section 6.2). Mynas are an introduced species and are likely to consume bait material. As the baiting will occur in a specific isolated location, social and environmental impacts are limited. Direct observation and free-feeding will ensure minimal risks to non-target species.

9.1.3 Implement the management plan

Bread was scattered along the median strip where the birds were observed foraging, and three birds fed on it almost immediately. Alpha-chloralose (360 milligrams) was mixed with margarine and was spread very thinly on slices of soft white bread with the crusts removed. Each slice was cut into squares weighing approximately one gram, so that there was an average of 3.75 milligrams of alpha-chloralose per square. The squares were then put together (margarine sides inside) to make it easier to transport and handle the baits. At first light on the following morning, the alpha-chloralose 'sandwiches' were scattered in the same location and by 08:00am three mynas were captured: an adult male, a juvenile and a breeding female. None of the birds died as a result of consuming the bait, but the birds were sufficiently affected to enable them to be captured by hand.

9.1.4 Monitor and evaluate

Monitoring of this site by observation confirmed that all mynas were successfully eradicated from this location. Continued action on reported sightings of mynas is proposed to prevent the establishment of this species in South Australia.

9.2 Eradicating starlings at Manypeaks, Western Australia

Andrew Woolnough and Colin Parry, Department of Agriculture and Food, Western Australia (DAFWA).

9.2.1 Define the problem

Starlings are known to cause significant damage to fruit where they occur (see factsheets in Part B) and have a demonstrated capacity for rapidly colonising new areas (Long 1981). Starlings were introduced to Victoria (1856–1871), New South Wales (1880) and South Australia (1881) by acclimatisation societies (Long 1981) and rapidly colonised Australia's south-east. However, despite the suitable climate (Bomford 2003), starlings are not yet established in Western Australia. The Nullarbor Plain offers a natural barrier to their westward expansion, and the Agriculture Protection Board and DAFWA have continuously controlled emerging populations since 1971 to prevent their establishment. Populations have been eradicated from Esperance, Dalyup, Bremer Bay and Manypeaks, and persistent incursions are being continuously controlled at Condingup and Munglinup (Woolnough et al. 2005).

A strategic approach to managing starlings has been adopted by the Agriculture Protection Board and DAFWA. This approach has assessed potential impacts, implemented control of establishing populations using radio-tagging, trapping, netting and shooting, and evaluated cost-effectiveness of the management programme (Hector 1989c; Coyle 1992; McElwee 2000; Woolnough et al. 2005).

One example of a successful campaign of starling eradication was that at Manypeaks. The following account is from the records of the District Officer in charge of the incident, Colin Parry:

'In late November 1987, a landholder reported to the Agriculture Protection Board that a flock of birds on their property at Manypeaks could be starlings. Two visits were made to the property to investigate the report. The first visit failed to find the flock but the second visit found the flock and a specimen was recovered. By late December it had been confirmed that the specimen was an immature starling and therefore confirmed that there was a flock of starlings present at Manypeaks, east of Albany. Through appropriate surveillance, it was determined that 43 birds were present.'

9.2.2 Develop a management plan

Define management objectives and performance criteria

Prevent the establishment of starlings in Western Australia.

Select an appropriate management option

Eradicate emerging populations and conduct continuous control. Appropriate control options include trapping, mist and cannon netting, and shooting. At the same time, engage the community to participate in surveillance and increase awareness of starlings to determine the routine of the known flock and detection of other flocks/birds in the area.

Formulate a management strategy

The key to the eradication strategy was planning and surveillance. Planning included:

- obtaining appropriate permission for the use of silencers with .22 rifles;
- sourcing traps and other resources from other starling operations;
- having a number of control options available; and
- clearly planning when to use which option.

The incident response also required appropriate management endorsement for resource expenditure. The general strategy was to shoot birds during nesting (August) and, until that time, to desensitise the flock to hides and vehicle movements, maintain lure traps, and identify the movements, habits and nesting sites of the starlings.

9.2.3 Implement the management plan

In the first month of the incident the community had been fully informed through media campaigns (radio, television and newspaper) and public meetings. Simultaneously, the strategy was developed and implemented, with the key being a comprehensive surveillance programme. The surveillance programme identified flight paths that were suitable for mist-netting. Two attempts at mist-netting captured 19 of the 43 birds. Importantly, by having knowledge of the roost trees, the birds could be counted as they returned to the roost after each attempt to confirm remaining numbers. Surveillance identified that there were occasional opportunities to shoot individual birds with silenced .22s when the birds were separated from the main flock. Great care was taken to not disturb the main flock. Four birds were removed in this way. Surveillance also identified that there were opportunities to use cannon nets near where the starlings bathed and drank. In two sessions of cannon netting, nine birds were caught in the first firing and eight in the second. The remaining three birds were shot with shotguns in the week following the second cannon-net firing.

Five months after the first report all starlings had been removed from Manypeaks. In this example, netting (cannon and mist) and shooting (rifles and shotguns) were the optimum control techniques, underpinned by comprehensive surveillance.

9.2.4 Monitor and evaluate

Monitoring of the site confirmed that all starlings had been eradicated from Manypeaks. A media campaign was undertaken to inform the public of the success and for ongoing promotion of reporting. Inspections were carried out at weekly intervals until there was complete confidence that there were no longer starlings at Manypeaks.

9.3 Cockatoo mitigation project in Victoria

David Brennan, Department of Sustainability and Environment, Victoria.

9.3.1 Define the problem

Sulphur-crested cockatoos, long-billed corellas and galahs have a documented history of causing damage to a wide range of agricultural crops in Victoria. Damage is often sporadic and viewed as an individual farmer's problem rather than industry-wide. The cost to the individual experiencing this damage can equate to several thousands of dollars in a season. Damage is diverse, including: ringbarking of grape vines; snipping bunches of grapes before harvest; pulling out newly planted trees; eating fruit and nuts; feeding on sown and maturing grain and oilseeds; and structural damage to buildings and farm equipment. However, a significant aspect of 'the problem' is that these cockatoos and corellas are large and white, and thus highly conspicuous birds especially when they occur in flocks. For some growers, their mere presence is assumed to be associated with damage.

9.3.2 History of managing cockatoos in Victoria

Reports of cockatoo damage to Victorian farming enterprises increased dramatically from the late 1960s to the point where the problem consistently entered the political arena. In 1995, the Environment and Natural Resource Committee (ENRC) began an 'Inquiry into Problems in Victoria caused by Long-billed Corellas, Sulphur-crested Cockatoos and Galahs'. Several recommendations were made, including to support shooting not as a control method but as an important part of a scaring strategy, to support trapping and gassing and to double the penalty for the deliberate poisoning of wildlife. Several recommendations referred to the need to assess the frequency and extent of damage being caused by cockatoos, and to measure damage levels following management actions. The overall emphasis of the report was to support extension and education and to take the focus away from lethal controls as 'the answer'. In its response to Parliament, the Department of Sustainability and Environment Victoria stated that on the basis of the ENRC inquiry, its objective was to minimise the economic damage that the birds were causing farmers, as opposed to managing the species.

Consultants were engaged to assist with production of an education and extension package. Training sessions for extension officers were held and initial planning was undertaken to trial diversionary feeding as a damage reduction technique. This strategy, however, did not reduce farmers' claims of ongoing economic damage or reduce their appeals for assistance through political channels.

In 1999, despite the recommendations of the ENRC report, the government allowed the use of agricultural chemicals to poison cockatoos under regulatory conditions. Farmers who did not meet the conditions for the use of poison had the option of trapping and gassing. In 2000, trapping and gassing was expanded and poisoning was deemed illegal.

In 2000, a five-year strategic plan was developed for cockatoo damage management in Victoria to address key issues, including control (trapping, gassing and repellents), research, compliance and human resourcing. The first priority was to minimise the economic damage that the birds were causing to farmers by providing on-ground help in the form of trapping and gassing 'teams'.

Figure 9.1: *Construction of a pull net trap in Bendigo, Victoria. Photo: B. Lukins.*

This involved working directly with farmers and by demonstrating that birds could be caught. In this way, the debate about whether or not poisoning was the only effective management option, was quelled.

9.3.3 Current management strategy

In 2002, it was realised that the farming community required better information about cockatoo behaviour, and ecology. A review of the management strategy changed the emphasis of the project to a more educational and self-help approach by teaching farmers about bird behaviour and management techniques.

An extensive training programme is currently in place to teach farmers across Victoria how to effectively minimise economic damage whilst promoting non-lethal techniques. As farmers have different levels of experience and understanding of bird management, effective communication often means 'one-on-one' or small group on-site tuition. Training includes cockatoo identification, ecology and behaviour; legal responsibilities; and management techniques, including farm hygiene (minimising the food source that attracts the birds to the property), effective scaring, and effective implementation of trapping and gassing. For farmers to be able to trap and gas cockatoos in Victoria, they must be trained and accredited by the Department, demonstrate scaring techniques, improve hygiene practices, and most importantly, be experiencing serious damage.

The Department continues to work to promote non-lethal techniques by, developing best practice guidelines for chemical control of onion grass (an attractive and preferred food for cockatoos) in turf and high profile areas, providing advice on new technologies such as better grain bunker tarps and trialling engineered solutions to minimise spilt grain and reduce access to grain storage areas and feedlots.

To evaluate the education-based approach, demand for training was monitored. Every farmer trained was seen as a step closer to achieving the Department's goal of empowering farmers to reduce economic damage on their property. Over the past three years the Department has trained and accredited over 120 farmers and farming enterprises to gas and trap cockatoos. Since the inception of the five year project the Department has been able to achieve a reduction in ministerial correspondence (measuring communities' perceptions), a reported perception by farmers of reduced economic loss, and a reduction in the number of birds trapped annually. Over the past eight years a total of 80 000 cockatoos (with a peak of 22 600 in the year 2000 down to 900 in 2007) have been removed from the Victorian population.

9.3.4 Future Directions

This case study describes the overall approach taken recently in Victoria for the management of cockatoos and corellas, emphasising the importance of education, proactive relationships with stakeholders and consideration of alternative management techniques. Despite the success in managing a difficult and sporadic problem, there remains some fundamental deficiencies in the programme. The following recommendations are made to achieve best practice and further improve the programme:

1. Continue to encourage and support land managers in taking ownership of the problem by maintaining the existing training programme of pest bird behaviour, population dynamics and management techniques;

2. Increase emphasis on appropriate problem definition and assessments of damage at the local level;

3. Investigate the broader implications of existing management at the regional and industry level and on cockatoo species distributions and overall numbers in Victoria;

4. Evaluate existing management methods (lethal and non-lethal) by measuring damage and/or pest bird abundance before and after management actions; and

5. Investigate the cost effectiveness of alternative management methods in reducing damage.

Figure 9.2: *A tagged Adelaide rosella perched in a cherry tree. Photo: R. Sinclair.*

9.4 Rosella damage to cherries (*Prunus avium*) in the Mt Lofty Ranges, South Australia

(from Fisher 1991, 1992 and Sinclair and Bird 1987).

9.4.1 Define the problem

The Adelaide Hills in the Mt Lofty Ranges of South Australia provides a cool climate and well-drained soils suited to cherry growing. A major pest to cherry orchards in the area is the Adelaide rosella (Figure 9.2), which can cause severe damage to buds, flowers and ripening fruit. The following example illustrates a technique used in a three-hectare orchard for assessing bud damage to four cherry varieties: 'William's Favourite', 'Black Douglas', 'Lustre' and 'Makings'.

Select eight trees of each variety

Using paired random numbers (Appendix B), five cherry trees for each variety were identified.

A simple technique for achieving this was to allocate letters for rows and numbers for trees so that each tree had a unique combination, one letter and one number (for example; Row B Tree 7). Random numbers were selected until five cherry trees for each variety were allocated. The number of trees required depends on the number in the orchard and the severity of damage in each variety. Normally when damage is low, fewer trees and branches are required. Using an equal number of samples for each variety was a form of stratification that enabled better comparison between varieties. In this case, 'William's Favourite' was the most heavily damaged variety; therefore extra samples could be taken in these blocks.

Select eight branches on each tree

Each tree was divided into a low section (up to 2.65 metres — able to be reached when standing on the ground) and a high section (from 2.75–5.9 metres — able to be reached using a picker's ladder). A branch was selected on the north, south, east and west sides of each tree at each of these two levels. This overcame any bias associated with rosellas targeting a particular direction or height. For example, in this study, fruit on higher branches were damaged earlier than those lower down, so if only lower branches were sampled bird damage would have been underestimated.

Systematically select every fifth bud whorl on every fifth spur (or branchlet)

In the original study (Fisher 1991), all intact and damaged buds were counted on each of the selected branches. This is an intensive procedure but could be made more efficient by systematically selecting spurs and bud whorls and counting the number of damaged and intact buds on selected whorls. The size of the sample required depends on the level and variability of bird damage, the cherry variety, and the number of whorls per tree. As a starting point, every fifth spur (20%) and every fifth bud whorl on selected spurs should be sufficient to obtain an accurate estimate.

Count the number of damaged and intact buds on selected bud whorls

Damaged buds can be identified easily, as the base of the husk is left on the branch while the rest of the bud is removed. The number of damaged buds can then be expressed as a percentage of the total number of buds.

Cherries do not continue to initiate buds after summer, so an estimate just before flowering should provide an accurate estimate of bud damage. Bud damage is only one component of overall damage, which also includes damage to flowers and fruit. Compensatory growth of remaining buds and fruit may occur. For example, some bud damage may, in effect, be similar to the normal horticultural practice of thinning and may even result in economic benefits (Sinclair and Bird 1987). The initial study (Fisher 1991) focused on bud damage, but the same sampling procedure could be extended to include an estimate of damage to fruit.

Assess damage to fruit just before harvest

Just before harvest the selection procedure was repeated (Steps 1–3), but five clusters of cherries were systematically selected (Appendix B) on selected spurs in each of the eight selected branches on each tree. The number of missing and intact cherries on each cluster was counted. An overall percentage of damaged cherries was then estimated. Again, the number of cherry clusters sampled depends on a range of factors, but 20% of spurs and clusters can be used as a guide. To avoid selecting further samples of branches and spurs, these could be marked at the time of bud damage estimation.

In this example, as bud damage is measured as a percentage, consideration needs to be given to compensation and the difficulties of measuring it. Direct fruit losses to cherries can also be estimated at harvest by using the same sampling procedures but counting the numbers of damaged and intact cherries on each selected cluster.

Bird damage to buds was severe during 1986, 1987 and 1991. Mean block damage ranged from less than 10% to over 90%, and was particularly severe in 'William's Favourite'. Subsequent damage to fruit was considered to be at levels of little economic significance during these seasons.

9.4.2 Develop a management plan

Define management objectives and performance criteria

Reduce cherry bud damage by Adelaide rosellas down to 5% or less.

Select an appropriate management option

Strategic targeted control.

Formulate a management strategy

An integrated scaring programme was planned, with a combination of acoustic and visual devices and shooting. Targeted scaring was to take place during bud development, rather than during the ripening period.

9.4.3 Implement the management plan

Integrated scaring was implemented with a concerted effort to vary the placement and types of devices used.

9.4.4 Monitor and evaluate

Ongoing monitoring of bud damage indicated a lack of success of the scaring programme (see monitoring directions under 'Define the problem' (Section 9.4.1).

9.5 Bird damage to wine grapes in the Orange Region, New South Wales

John Tracey, Vertebrate Pest Research Unit, New South Wales Department of Primary Industries

9.5.1 Define the problem

Cool-climate grapes are grown in high-altitude (990 metres and above) vineyards surrounding Mount Canobolas, near Orange, New South Wales (Figure 9.3). The majority of vineyards are less than ten hectares and are interspersed with a diversity of vegetation types, including scattered eucalypts (*Eucalyptus macrorhyncha*,

Figure 9.3: *A vineyard in the study region, near Mount Canobolas, Orange, New South Wales. Photo: J. Tracey.*

E. seeana, *E. tereticornis*, *E. viminalis*), pine (*Pinus radiata*) plantations, mixed farming, apple and stone-fruit orchards and sheep and cattle grazing country. Bird species that damage fruit are equally diverse. The main pests include starlings, silvereyes, pied currawongs, crimson rosellas and eastern rosellas (*Platycercus eximius*), noisy friarbirds, red wattlebirds, yellow-faced honeyeaters (*Lichenostomus chrysops*) and a variety of other species. The following example illustrates a technique used in a five-hectare vineyard with four wine grape varieties; 'Cabernet Sauvignon', 'Merlot', 'Chardonnay' and 'Sauvignon Blanc'.

Systematically select ten vines from each outside edge from each block

The 'outside edge' here refers to the first and last two rows of the block and the first and last two vines in each row. Systematic sampling is where the first vine is selected at random (Appendix B) and then subsequent vines on that edge are selected at regular intervals. For example, with a random-start vine of six and an interval of ten, subsequent vines sampled would include

Figure 9.4: *75% (left) and 95% (right) damage to grapes. Photos: J. Tracey.*

16, 26, 36, 46, etc. A study conducted in the Orange region indicated that bird damage to wine grapes is always greater on at least one of the four outside edges than in the interior of the block, except when damage is less than five per cent (Tracey and Saunders 2003).

Randomly select one bunch from each of the ten vines

Bunches were randomly selected (Appendix B) to avoid over-sampling of more visible bunches. Techniques to overcome this bias are described by Sinclair (2000a, 2005) and Tracey and Saunders (2003).

Visually estimate damage to selected bunches

The selected bunch was studied and the bird damage visually estimated to the nearest 5% (Figure 9.4). The average bunch damage for each block edge was calculated. Visual estimates of bird damage in a variety of crops have been considered accurate for most purposes (Stevenson and Virgo 1971; Dolbeer 1975; DeHaven and Hothem 1979; Martin and Crabb 1979). Practice and calibration by estimating damage to bunches with known damage improves accuracy.

Re-sample if damage is greater than 10%

Where damage was less than 10% in each outside edge no further sampling was necessary, as this estimate can be considered a good indication of damage in the entire block, regardless of block size (Tracey and Saunders 2003). If damage was greater than 10%, then more samples were required. The level of damage determined the number of samples needed in each edge (Table 9.1). The same number of samples also needed to be taken from the interior of the block.

Calculate the overall damage

Mean damage for each block was calculated from estimates of damage within each edge and from the interior, if this was sampled. The number of vines in each sampled section needed to be taken into account. This was achieved by multiplying the average percentage damage in each section by the total number of vines in it,

Table 9.1: *Sample sizes needed to estimate percentage damage with 5% standard error.*

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

and dividing the sum of these for each section by the total number of vines in the block. The overall percentage loss was then converted to the cost of damage, using production figures.

In this study, the sampling technique allowed more blocks to be assessed with decreased effort. Grape losses were found to be up to 95%, with an average of 14% over 167 vineyard blocks. Using the average loss across vineyard blocks, although patchy, would equate to a cost of approximately $200 per tonne or $1954 per hectare. These figures assume a gross return of $1430 per tonne (14% × $1430 = $200 per tonne); 9.75 tonnes is produced per hectare with gross returns of $13 958 per hectare ($1430 per tonne; 14% × $13 958 = $1954 per hectare).

9.5.2 Develop a management plan

Define management objectives and performance criteria

Reduce bird damage to 1% using strategically placed drape-over netting.

Select an appropriate management option

Strategic targeted control.

Formulate a management strategy

Apply drape-over netting in vineyard blocks where damage was greater than 10% in the previous season.

9.5.3 Implement the management plan

Drape-over netting was applied to blocks and varieties where damage was most severe.

9.5.4 Monitor and evaluate

Estimates of bird damage were conducted in netted and un-netted blocks. A direct cost–benefit analysis incorporating the benefits and costs of netting suggests that drape-over nets will be cost effective over the life of the netting (Section 5.1.1). Continued monitoring in un-netted blocks was conducted to re-assess netting placement for the following season.

9.6 Parrot damage to apples and stone fruits in south-west Western Australia

(from Long 1985)

9.6.1 Define the problem

The majority of Western Australia's commercial fruit-growing enterprises occur in the lower south-west region and include pome fruits such as apples and pears; stone fruits such as nectarines, peaches, plums and apricots; and grapes. Many orchardists grow several fruit varieties, and orchards are often located adjacent to stands of jarrah (*Eucalyptus marginata*) and marri hardwood forests and livestock grazing country. Three main parrot and cockatoo species are reported to damage fruit: the red-capped parrot (*Purpureicaphalus spurius*), ringneck (*Barnardius zonarius*) and Baudin's black-cockatoo (*Calyptorhynchus baudinii).* This case study describes an intensive but simple method for measuring damage. It involves counting numbers of damaged fruit in, and under, every tree in six apple and stone fruit orchards over three seasons.

Count the number of damaged fruits on the ground beneath each tree

In this study monthly counts were conducted from December to June. This was to ensure that early damage to fruit was accounted for. Fruit was judged to be 'old' (brown and wrinkled) or 'new' (fresh-looking), and only new fruit was recorded in each successive count. If there was significant fruit loss from other causes such as mammals (for example, possums, bats or rodents), disease, hail, and wind, they were separated from counts of fruit damaged by birds. Close examination of fruit usually revealed the cause of the damage. Parrots took chunks from individual fruits rather than pecking. The size of the piece removed was relative to the size of the bird. In this study the removal of large chunks and evidence of split apples indicated damage by a large parrot, in this case the Baudin's black-cockatoo. Damage by mammals can usually be distinguished by the teeth marks in the fruit and was estimated in this study to be less than 1%.

Count the number of bird-damaged fruits in each tree

While standing underneath each tree an observer counted the number of bird-damaged fruits on the tree. This was done monthly, at the same time as the previous step, 'Count the number of damaged fruits on the ground beneath each tree'. Care was needed to ensure that all bird-damaged fruit on tall trees was counted.

Estimating total damage

Following harvest and/or packing, the total number of fruit grown for each variety was determined. The number of bird-damaged fruit over the total grown (damaged + harvested) provided an overall estimate of damage. If significant fruit loss occurred for other reasons, then these fruit losses were included in the total number grown. The cost of bird damage was then estimated from the numbers of each variety damaged.

This technique was time-consuming and could have been made more efficient by reducing the sample size, particularly in varieties suffering low damage. An example would have been to have systematically selected (Appendix B) every fifth tree and to have followed the same procedure. In the third year, Long (1985) reduced sampling in this way for the green varieties of apple and simply multiplied the total damaged by five. Estimates were similar to the results from counting every tree and significantly reduced sampling time.

On this occasion bird damage was found to be insignificant, with a maximum percentage loss over the six orchards of only 1.75%. During the period of the study the value of damage to fruit did not exceed $100 in any orchard (Long 1985).

9.6.2 Develop a management plan

Define management objectives and performance criteria

As bird damage during these seasons was insignificant, the objective was to continue monitoring damage and abundance. Management action could be re-evaluated if damage were to exceed 10% or if large increases in pest bird abundance were noted.

Select an appropriate management option

Do nothing. Costs of management would exceed the $100 lost to birds during the assessment period. Continued monitoring of damage levels and costs (monitor and evaluate section below) would enable management to be implemented when damage increased.

Formulate a management strategy

Not applicable.

9.6.3 Implement the management plan

Not applicable.

9.6.4 Monitor and evaluate

Monitoring damage levels was the most direct way to assess whether 'Do nothing' was the most cost-effective management option.

9.7 Cockatoo damage to peanuts in Lakeland Downs, Cape York Peninsula, Queensland

Stephen Garnett, Charles Darwin University, Northern Territory

9.7.1 Define the problem

Situated in the Laura River Valley of tropical North Queensland, Lakeland Downs has recently experienced regional development and expansion into various horticultural industries.

Historically a cereal grain cropping and dairy farming area, Lakeland Downs, with its high rainfall and well-drained ferrosol soils, now also successfully produces large quantities of peanuts, coffee, bananas and sugar. From the mid-1990s, peanut crops have received high levels of damage from red-tailed black-cockatoos (*Calyptorhynchus banksii*) and sulphur-crested cockatoos. These species pull the peanut shrub out of the ground by the stems and shell and retrieve the nuts. The birds cause further damage to irrigation systems. This example, taken from Garnett (1998) and Garnett (1999), illustrates a technique for assessing direct and indirect damage to irrigated peanut crops.

Estimate the area of crop damaged

In this situation cockatoo damage occurred intensively in certain sections of the crop and at negligible levels in most other areas. Damage was particularly severe within 200 metres of adjacent roosting habitat (Garnett 1999). Damage was therefore more easily measured by calculating the area over which it occurred rather than attempting to count individual plants. Areas were estimated by measuring the distances around damaged peanut shrubs using an odometer in a vehicle or from aerial photography.

Convert area to cost

Area was converted into tonnage loss by using an estimate of production and price received per tonne. In this study, an average of 0.607 tonnes of peanuts was produced per hectare, and an average price of $650 per tonne was received.

Record the costs of repairing irrigation systems damaged by cockatoos

In this study, cockatoos caused regular damage to pivotal irrigators by chewing through 20-millimetre poly-pipe casing and internal electrical wiring. The cost of repair included all labour involved. Cost of the damage to plants as a result of poor irrigation was more difficult to quantify but was added by estimating the area or number of plants affected.

Calculate total costs

The overall cost of cockatoo damage was estimated by simply summing the above costs.

In 1998, lost profits averaged 7.3% across seven blocks (range 0%–31.8%) and totalled $28 167 for one district. Further indirect costs to irrigators and crops from poor irrigation were estimated at $7500 for this district.

9.7.2 Develop a management plan

Define management objectives and performance criteria

The management objectives were defined as follows: to monitor crop and irrigation damage before and after control measures; reduce damage by using scaring, reinforcement and sacrificial crops; and monitor and re-evaluate as necessary.

Select an appropriate management option

Strategic, sustained control.

Formulate a management strategy

An integrated strategy of scaring, reinforcement (scaring combined with limited shooting) and sacrificial crops.

9.7.3 Implement the management plan

In 1999, an integrated strategy of scaring, reinforcement and sacrificial crops and concerted efforts by peanut growers, Queensland National Parks and Wildlife Service and the Peanut Company of Australia contributed to reductions in damage.

9.7.4 Monitor and evaluate

Damage was measured as described before and after control.

9.8 Netting enclosure over boysenberries in Hawke's Bay, New Zealand

Richard Porter, Havelock North, New Zealand

9.8.1 Define the problem

This property in Hawke's Bay, New Zealand, has grown boysenberries for about 15 years. At times bird damage losses have reached as high as an estimated 40%. An accurate measurement of losses was never conducted because there were no easy ways to do this. Although conventional scaring techniques and shooting were used, they met with very limited success. Great care had to be taken where bird shot landed from the shotgun, because the boysenberries are surrounded by pome fruit orchards, and it would have been totally unacceptable to have lead shot in these fruit. The cost of a full-time person to operate scaring devices and shoot birds per hour was $11–$13 per hour. During some parts of the harvesting season bird scaring took up to ten hours a day. Shotgun shells cost about $110 per hectare and other control devices about $50 per hectare. It was estimated that approximately $2500 per hectare per year was spent on shooting and other forms of bird control.

9.8.2 Develop a management plan

Define management objectives and performance criteria

Reduce bird damage to very low levels in half the crop by constructing permanent netting over it.

Select an appropriate management option

Strategic, targeted control.

Formulate a management strategy

The strategy was to cover half the crop with permanent netting to see how effective it was. Permanent netting was selected in preference to drape-over netting because drape-over netting has a short life and because boysenberries are harvested almost daily, making the removal and replacement of drape-over netting too labour intensive. In contrast, the permanent netting enclosure would allow easy access to the crop. Although permanent netting was expensive ($13 000 per hectare) it was expected to last for over ten years.

9.8.3 Implement the management plan

In 2002, half the crop was covered with the enclosure for the first season to see how effective it was compared with the uncovered boysenberry vines.

9.8.4 Monitor and evaluate

The results of covering the boysenberries were so good that the uncovered part of the crop was no longer needed to meet the market demand for the berries. The uncovered vines were removed, freeing up the land for other crops such as sweetcorn and maize. There was a huge saving on shooting and scaring devices. Less maintenance of vines and sprays was needed because half the crop was no longer being grown. Little sorting of fruit was required for removing damaged fruit. The netting is expected to remain in good condition for about ten years, because it is left in place out of harm's way. Finally, by using conventional control techniques it would take just over five years to catch up with the cost of covering the crop with permanent netting. This does not include the savings of maintenance of a smaller cropping area. Nor does it include the profits from cropping the area that was previously used to grow boysenberries.

9.9 Baudin's black-cockatoo damage to apples, pears and nashi fruit in south-west Western Australia

Tamra Chapman, Department of Environment and Conservation (DEC), Western Australia

9.9.1 Define the problem

The two major apple, pear and nashi growing regions in Western Australia are the Perth Hills and the south-west. The main parrot and cockatoo species reported to damage fruit in these orchards are Baudin's black-cockatoo, the ringneck and the red-capped parrot. Baudin's black-cockatoo damages fruit when it extracts seeds and discards the flesh.

Baudin's black-cockatoo has been known to damage fruit in apple orchards since the early

1900s. DEC files show that a number of means of protecting orchards from damage by Baudin's cockatoo have been employed in the past, including open seasons for shooting, paying bonuses for cockatoo destruction, and licensed trapping for the pet trade. It is now unlawful to kill Baudin's cockatoo to protect fruit crops, because they are listed as a threatened species under both State and Federal legislation. The only legal way to protect crops is to use non-lethal methods under a licence from DEC. Illegal shooting to kill still occurs, however, and is now one of the greatest threats to the bird's long-term survival. This study illustrates an attempt to conserve this threatened species while allowing fruit growers to protect their crops.

A survey was conducted to quantify the damage caused by Baudin's cockatoo to apple, pear and nashi crops in the south-west of Western Australia during the 2004–2005 season. These data were compared with those from surveys conducted in previous seasons. The cost of damage control was estimated and effective damage control techniques were identified for the future benefit of fruit growers.

Estimate the proportion of the crop damaged

Surveys were posted to 277 fruit growers registered as apple and pear growers with the Western Australian Fruit Growers' Association. Respondents were asked to fill in a table of:

- crop type (apple, pear or nashi);
- variety of fruit;
- area of planting for each variety (hectares);
- number of trees of each variety; and
- extent of the damage for each variety:
    1. None
    2. Low (< 10%)
    3. Moderate (10%–20%)
    4. High (20%–40%)
    5. Very High (40%–70%)
    6. Extreme (> 70%).

The farmgate value of the fruit per tree was calculated from the farmgate value of the fruit for the entire industry divided by the total number of trees in the industry.

Record the cost of damage

For each fruit grower, the total size of the orchard ranged from 0.4 to 50 hectares and averaged 6.8 hectares (standard error = 1.2, *n* = 55). The number of trees per grower ranged from nine to 50 000 and averaged 4446 (standard error = 977, *n* = 58 growers). The estimated farmgate value of the fruit per tree was $46.79 for apples and pears (excluding nashi). Therefore, the estimated farmgate value of the fruit grown by orchardists in the survey averaged $208 018 per property. Monetary loss estimated by growers averaged $12 453 (standard error = $3537, *n* = 53) per property, which equates to $1831 per hectare or 6% of farmgate income. This falls within the category of low loss of fruit (< 10%). Growers estimated that losses were very high (40%–70%) on the basis of their perception of the proportion of fruit damaged, which is an overestimate in comparison with the calculated monetary loss.

The low loss of fruit recorded during the 2004–05 season was similar to, albeit a little higher than, the 1.4% loss per orchard recorded by Long (1985) for the years between 1973 and 1975. Halse (1986) recorded 16.9% fruit damage in 1984, suggesting that damage can be high in some years and can also vary widely among years, varieties and regions. Halse (1986) analysed records of reports of damage and identified a pattern showing that damage was low in most years, but built up to moderate damage approximately once every 10 years. Accounts in newspapers and on DEC files revealed that damage was high in the early 1920s, early to mid-1930s, early to mid-1940s, early 1950s and 1969, and from 1982–1984 (Halse 1986). This shows that, although damage can be moderate in some years it is low in most years and there has been no evidence collected to show that the level of damage has increased over time since the early 1920s.

Estimate the cost of damage control

On average, growers estimated that they undertook pest bird control on 83 days during the 2004–05 season. About two hours were dedicated to pest control per day, at an estimated cost of $29 per hour. Thus, growers spent an estimated mean of $5041 (standard error = $104, sample size = 46 growers) on pest control per property during the 2004–05 season. This represents $741 per hectare, or 2% of farmgate income.

9.9.2 Develop a management plan

Define management objectives and performance criteria

Individual orchardists should compare the value of their loss with the cost of control to choose an appropriate objective and performance criteria, because of the high variation in damage between properties. Ideally, damage should be restricted to < 10% of fruit loss across the industry in Western Australia.

Select an appropriate management option

Growers with low levels of damage may choose the 'do nothing' option. Those with high, very high or extreme damage should consider the benefits of netting (strategic one-off control). For example, one grower lost an estimated $150 000 of farmgate value of fruit during the 2004–05 season. This four-hectare orchard had 5000 'Pink Lady' apple trees, and the farmgate value of the trees on this property was $233 951. These estimates show that 64% of farmgate value was lost. This grower estimated that the loss was very high (40%–70%) in terms of the proportion of fruit damaged, which is consistent with the calculated monetary loss. In this particular case, netting may be justified because the benefits gained would exceed the costs of netting.

If the pattern of damage for the majority of orchards is less than 10% loss of farmgate income in most years and a maximum loss of around 17% once every ten years, then elaborate and expensive control measures, such as netting, may not be justified in terms of loss of income and the cost of damage control. Thus most growers are likely to make the best use of time and money by using scaring techniques only in seasons when bird numbers are sufficiently high to cause unacceptable levels of damage (strategic targeted control).

Formulate a management strategy

The most effective combinations of techniques were: 1) gas guns as the primary technique in combination with motorcycle (harassment) and shooting to scare; or 2) motorcycle (harassment) as the primary technique in combination with gas guns and shooting to scare. Growers should make the most effective use of the time and money dedicated to damage control by using these techniques as part of a well planned and executed programme to prevent the cockatoos from establishing a habit of feeding in the orchard and from becoming habituated to the scaring methods.

9.9.3 Implement the management plan

Public education materials have been prepared by DEC to advise growers on how to employ an effective damage control programme. The use of bird-scaring devices can cause conflict between growers and residents in rural areas. Thus, these devices must be used with consideration for neighbouring residents and in accordance with relevant noise regulations. This issue has been addressed by a Western Australian Government Working Group, which has produced guidelines for the use of scaring devices in orchards (http://www.naturebase.net/plants_animals/living_with_wildlife/pdf/best%20_practice_guidelines.pdf).

9.9.4 Monitor and evaluate

Comparing damage caused in orchards using a range of techniques would be the most effective way to test the effectiveness of techniques. For example, compare the proportion of fruit lost in a 'do nothing' orchard with an orchard that has gas guns and shooting to scare, or record losses before and after beginning a damage control programme.

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PART B
Factsheets for growers

This part presents information on 20 species that can be significant horticultural pests. For each species information is given on names, identification, distribution, habitat, movement, foods and feeding behaviour, breeding, damage to horticulture, protection status and sources of further information.

Apart from these 20 species, there are many other bird species in Australia that can be pests (Table 2.1, Table 2.3). Information on these species' identification, distribution, habitat, diet and breeding can be obtained from many reliable sources including:

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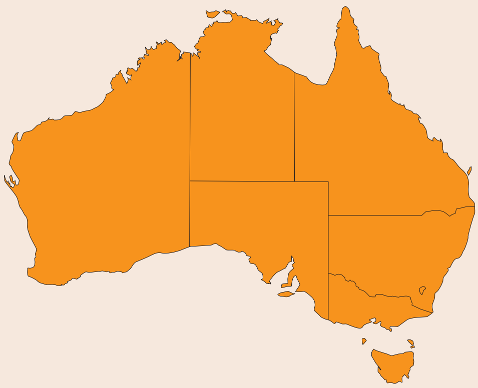
Factsheets:
Native species

Black-faced cuckoo-shrike
(*Coracina novaehollandiae*)

Other names

Blue jay; messenger bird; shufflewing.

Photo: Canberra Ornithologists Group.



Birds Australia Atlas (1998–2002)

Field identification

This is a medium-sized (33 centimetres head to tail) bird, soft grey in colour with a white belly and tail tip. It has a black face extending from behind the eye, down the cheek and across the breast; absent on immatures. The flight pattern is distinctive; undulating, with a wing shuffle on landing. Unrelated to cuckoos or shrikes, the black-faced cuckoo-shrike has, however, plumage comparable to that of cuckoos and a bill shape similar to that of shrikes. Surprisingly, DNA sequencing has linked it closely to the corvids (crows), despite morphological and behavioural differences.

Voice

'Plee-urk' and a descending, gentle 'quarieer quarieer quarieer'.

Habitat

This is one of Australia's most common birds, distributed throughout the country in most habitats. The black-faced cuckoo-shrike is particularly abundant in open sclerophyll woodland and forest, farmlands, roadside vegetation and tree-lined watercourses. Common also in suburban areas, parks and gardens and extends to arid regions along watercourses. Also occurs in rainforests and tall wet sclerophyll forest, but at lower densities and often for only short periods during migration.

Movements

Migratory, large-scale movements regularly occur with seasons. Northward movements start in mid-autumn and include many individuals who travel to New Guinea for winter. A number of individuals remain throughout the year in most populations, hence they were often considered sedentary. However, complete departures occur in some areas, particularly in the southern high-altitude ranges around Wollombi, Canberra and Jamieson regions. Altitudinal movements are evident in these areas, where populations take advantage of the milder climate and greater food availability in lowland areas during winter. Occasional nomadic movements outside seasons are also thought to occur in response to available food. Seasonal movements create regular increases in density in the north during winter, with corresponding decreases in the south. The opposite trend takes place during summer. In the eastern States, migratory movements have recently been identified as predominantly north-west, rather than directly northward. Hence populations from the south-east regions travel in a direction perpendicular to the coast of New South Wales. Migration patterns are less obvious in the west.

Foods and feeding behaviour

Black-faced cuckoo-shrikes have a diet predominantly of insects supplemented with seeds, fruit and vegetable matter. Caterpillars (Lepidoptera), beetles (Coleoptera), grasshoppers (Orthoptera), weevils (Curculionidae) and many flying insects are commonly consumed. Individuals, pairs or small groups often perch on exposed tree branches in the upper canopy, or forage amongst the outer foliage for a variety of insects. Black-faced cuckoo-shrikes rarely feed continuously on the ground, but will dive from perches, often landing to take insects and other food. Large flocks can occur, especially during migration in spring and autumn. For example, flocks of up to 45 have been observed in the vineyards of central New South Wales during April, where it was assumed that they were migrating north for the winter.

Breeding

A small, flat nest is carefully shaped from fine dry grass, twigs and bark, bound with spider webs and positioned in a horizontal fork of a tall tree, often a she-oak (*Casuarina*). Black-faced cuckoo-shrikes habitually build well-concealed nests 10–20 metres up in the canopy, although sometimes lower. Occasionally they utilise disused nests of other species, including mud nests of the magpie-lark (*Grallina cyanoleuca*). The flat nest often results in eggs or chicks falling out, for example during high winds. Two or three green eggs with brownish blotches (34 × 24 millimetres) are laid once a year, typically between August and January. This species breeds throughout its range, often following rain in arid areas.

Damage

Black-faced cuckoo-shrikes can damage orchard and vineyard fruit, including grapes, stone fruits, berries, pears and other soft fruits. Severe damage can be caused by migrating flocks taking advantage of these easily accessible energy sources. Birds damage fruit by squashing and tearing it and swallowing the pip, seeds and skin. However, they have a clear preference for insects and individual birds are likely to be beneficial in orchards and vineyards in many situations and during most of the year. For example, potentially detrimental insect pests such as vine moth caterpillars (*Hippotion celerio*) are known prey items.

Protection status

Protected.

Sources and further reading

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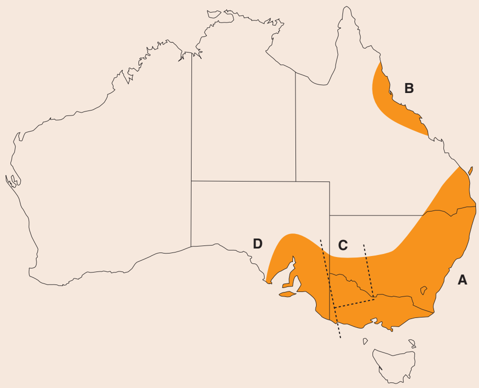
Crimson and Adelaide rosellas
(*Platycercus elegans*)

Other names

Blue-cheeked rosella (all subspecies); mountain lowry, red lory (*P. elegans*); Murray or yellow rosella, Murray smoker, Murrumbidgee parrot (*P. elegans flaveolus*). Note: the terms 'lory' and lowry' are used interchangeably.

Photo: B. Furby.



Birds Australia Atlas (1998–2002)

Field identification

This species now includes three rosella types that are quite distinct in geographic distribution and plumage colour. They were known previously as different species and locally by different common names: crimson rosella (*Platycercus elegans elegans* (A), and *P. elegans nigrescens* (B) of the north-east coast of Queensland); yellow rosella (*P. elegans flaveolus* (C)) and Adelaide rosella (*P. elegans adelaidae* (D)) (pictured above).

All types are medium-sized (35–38 centimetres head to tail), with prominent blue cheek patches and broad tails. The blue cheek complex is unique to this species, with the exception of the green rosella (*Platycercus caledonicus*), found only in Tasmania and some islands of Bass Strait. Females tend to be smaller than males with slightly smaller heads and bills. The crimson rosella (A) is a brilliant deep red with bright blue shoulder patches and tail. Juvenile plumage is olive green with patches of crimson on the forehead, breast and rump. The plumage of *P. elegans nigrescens* (B) is similar but darker. Yellow replaces crimson in the yellow rosella (C), except for a red frontal band. The Adelaide rosella (D) has plumage of varying amounts of orange and red which replaces the crimson or yellow of the other forms.

Voice

A loud 'kweek kweek' during flight, a smooth piping whistle ('psita-a-see') when perched, not unlike an alarm clock.

Habitat

The crimson rosella tends to prefer wetter forests and woodlands, which are commonly found in most types of rainforest and wet sclerophyll forest. Their occurrence in open habitats, farmlands, orchards, vineyards, urban parks and gardens and semi-cleared landscapes is usually associated with adjacent blocks of wet or dry *Eucalyptus* woodland or with riparian vegetation, or it can be attributed to the movements of immature post-breeding flocks. Adelaide rosellas are dispersed through a variety of open forest and cultivated habitats in the Mt Lofty ranges, including stringy bark and gum (e.g. *Eucalyptus obliqua, E. baxteri*, *E. leucoxylon*, *E. viminalis* and *E. fasciculosa*) habitats and orchard landscapes, but further north around the Flinders Ranges they are more restricted to river red gum (*E. camaldulensis*) communities. The distribution of the yellow rosella is even more closely associated with the occurrence of the river red gum. This subspecies is restricted to the riparian vegetation of the Murray–Murrumbidgee river systems and occurs away from watercourses only where the river red gum grows.

Movements

All types are sedentary, with only occasional nomadic movements at the fringes of their range, during winter, or by immature flocks. Local movements in winter may occur from *Eucalyptus* woodland to more open areas. Regional movement towards more dense vegetation communities often takes place before the onset of breeding.

Foods and feeding behaviour

Rosellas feed predominantly on plant material, including foliage, seeds, buds, flowers, fruit and nectar. However, insects and their larvae, including Christmas beetles (*Anoplognathus* spp.), aphids (*Aphis* spp.) and psyllids (Sternorryncha) often supplement their diet. Unlike many other parrot species, these rosellas forage commonly in tree and shrub canopies. Pairs and small groups forage in the foliage and branches of *Eucalyptus* spp., *Casuarina* spp., *Callitris* spp., *Acacia* spp., *Grevillea* spp., *Pinus* spp.(roosting only), fruit and nut crops, and introduced weed species such as wild olives, blackberry, lantana (*Lantana camara*), sweet briar (*Rosa rubiginosa*) and tobacco (*Nicotiana* spp.). The yellow rosella is often observed foraging high in the branches of flowering and seeding river red gums. The Adelaide rosella is preferentially a ground feeding bird. Dietary studies (Reynolds 2003) confirm that introduced Mediterranean pasture species make up the bulk of their diet in modified habitats throughout it's range. Ground feeding increases in frequency during the summer months and in open areas, where small flocks feed on pasture weeds, thistles (Asteraceae), dock (*Rumex* spp.), clover (*Trifolium* spp.) seed, onion grass (*Romulea rosea*), and spilled grain. Peak feeding time is in the early morning and late afternoon during winter, but is more constant in autumn. Feeding also occurs in mixed flocks with eastern rosellas (*Platycercus eximius*), superb parrots (*Polytelis swainsonii*) and ringnecks (*Barnardius zonarius*).

Breeding

Rosellas breed primarily in tree hollows of *Eucalyptus* spp. in woodland from September to January. They chew and strip existing bark, sticks and wood chips for nest lining, rather than bring in new material. Females select sites near those occupied in the previous season, sometimes also used and lined by other species. Females incubate four to eight white, oval eggs (28 × 23 millimetres) for 21 days, leaving the nest for short periods in the mornings and afternoons to be fed by the male. Young fledge after 35 days and remain with the parents for a further four weeks. Nests produce an average of 0.4 to three fledged young per clutch and clutches are usually larger in nests used in previous seasons. Nest failure is often caused by destruction of eggs by mammals or birds, including other crimson rosellas, or by desertion.

Damage

Various levels of damage occur to a wide variety of horticultural crops, including apples, cherries, stone fruits, almonds, chestnuts, bramble berries, grapes, pears (Figure B.1), plums, guava and quinces. Adelaide rosellas in particular can cause severe losses to cherry crops in the Mt Lofty Ranges by damaging buds, flowers and fruit. Bud damage can be considerable in some areas, with total losses resulting in some varieties. Crimson rosellas will also occasionally cause damage where they occur near orchards and vineyards. Vegetables and young wheat crops are also damaged in some areas. In the Riverland of South Australia, the yellow rosella causes damage to soft fruits such as grapes, cherries and pears.

Figure B.1. *Rosella damage to pears. Photo: J. Tracey.*

Protection status

Protected.

Sources and further reading

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Crows and ravens

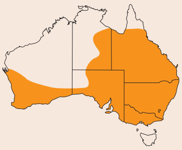
(Family Corvidae)

Other names

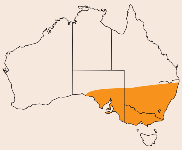
Australian raven (*Corvus coronoides*), little raven (*C. mellori*), little crow (*C. bennetti*), Torresian crow (*C. orru*), forest raven (*C. tasmanicus*).

Australian raven Photo: B. Furby.

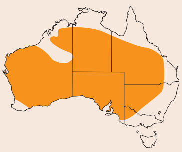
Australian raven



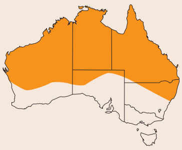
Little raven



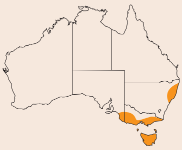
Little crow



Torresian crow



Forest raven



Birds Australia Atlas (1998–2002)

Field identification

Native Australian crows and ravens (*Corvus* spp.) are common, large (48–54 centimetres head to tail) black birds. They are the only members of the *Corvus* genus with white eyes. Five native species are recognised, all of similar size and appearance and difficult to distinguish: the Australian raven (*C. coronoides*), little raven (*C. mellori*), little crow (*Corvus bennetti*), Torresian crow (*C. orru*) and forest raven (*C. tasmanicus*). An introduced species, the house or Columbo crow (*C. splendens*), has also been observed in Fremantle, Rottnest Island and Port Hedland in Western Australia and near the Melbourne Zoo in Victoria, but as a result of efforts to remove them, individuals have not become established. This species is smaller (42–44 cm length), has brown eyes, and is grey-brown around the neck and breast. Native species can be distinguished by slight variations in plumage, habits and calls. The two crows have hidden white down at the base of their feathers; this down is grey in the raven species. Ravens also have more prominent throat hackles, which are especially long and pointed in the Australian raven. Other differences, particularly in their distribution and in their calls, flight pattern and flock size, can be used to distinguish species. Consult Higgins et al. (2006) for further details.

Voice

Crows and ravens utter a wide variety of calls that vary between species, regions and age groups. The territorial calls are the most commonly vocalised and can be used to distinguish between species where distributions overlap. The larger species, the Australian raven and the Torresian crow, utter higher notes than the other species, and have been described as tenors; while little ravens and little crows are described as baritones; and the forest raven as a bass. The territorial calls of each species are briefly described below:

Australian raven - a wailing 'aah aah aah aaaaaaah'.

Forest raven - a series of short, very deep, guttural notes 'korr korr korr korrrrr'; deeper and harsher than the calls of the Australian or little raven;

Little raven - a series of rapid short notes, 'aark aark aark aaaaark': shorter and twice as fast as the Australian raven and higher than the calls of the forest raven.

Torresian crow - more varied than other species with shorter and sharper notes than the Australian raven; a laughing or barking 'uk uk uk uk uk uk uk uk' or a 'ok ok ok ok ok ok' sometimes followed by gargling sounds. Notes can also change mid-call.

Little crow - a series of nasal and monotonous notes, 'nark nark nark nark nark nark' with less variation than the other species.

Habitat

These species occupy most types of habitat, particularly farmlands, dry open *Eucalyptus* woodlands and forests, open savannah and coastal and urban areas. Alpine areas, arid regions and watercourses and swamps are also frequented. The little crow is better adapted to drier habitats, including mallee (e.g. *E. diversifolia*, *E. rugosa*), mulga (*Acacia aneura*) and spinifex (*Triodia* spp.). All species avoid dense closed forests with the exception of the forest raven. This species is the only corvid found in Tasmania. It also is uncommon on the mainland with only a few isolated populations residing on the north-east coast of New South Wales and in the coastal regions of southern Victoria and South Australia. Expansion of agricultural development, particularly grazing, has facilitated increases in corvid distribution and abundance in many areas.

Movements

These species are all sedentary. No regular large-scale movements are evident, but the little raven and little crow display more nomadic traits. These two species often perform larger movements in response to water and food availability and they often become sedentary for only three months during breeding. For example, in the Murray-Darling region, large numbers of little ravens travel south-east in summer to higher rainfall areas, returning in autumn. Individual movements are also greater for the little raven (up to 352 kilometres) and little crow (up to 691 kilometres), in comparison with those of other species. Non-breeding birds travel farther and are the main component of corvid populations. Birds typically return to the same sites to breed. They establish territories that vary in size considerably between species and habitats, from 0.4 to more than 130 hectares.

Foods and feeding behaviour

Corvids are omnivorous scavengers and predators, consuming many types of insects, carrion and vegetable matter. Large insects usually comprise the majority of the diet, followed by carrion and plant materials, such as fruit, vegetables, seeds and foliage. Availability and hence quantities of different foods vary between habitats and season. Nestlings, eggs, small lizards and birds are also frequent prey items. Food is usually first located by aerial searches after sunrise, followed by long bouts of ground foraging. They will also occasionally consume fruit and beetles (Coleoptera), bugs (Hemiptera) and flying insects from trees and shrubs. Feeding around carcasses is most common and often includes caching surplus meat. These sites can be vigorously defended during food shortages and provide a range of insects, including dung (Scarabaeidae) and carrion (Silphidae) beetles. Spiders, grasshoppers and locusts (Orthoptera), weevils (Curculionidae), ants (Formicidae) and caterpillar (Lepidoptera) larvae are also common prey items. This predation on pasture and crop insect pest species would be beneficial to most farmers. Peak feeding occurs during the early morning and late afternoon with flocks returning to roost in the middle of the day. Crows and ravens regularly visit watering sites throughout the day, more frequently in arid areas. Mixed feeding flocks often congregate around food sources where distributions overlap; in some cases all three raven species have been observed feeding at one site.

Breeding

Corvids make large bulky stick nests occasionally bound with mud and lined with grass, bark strips and wool. They are usually constructed by both sexes in an upright fork of the uppermost canopy, but lower in arid areas. The little raven nests are typically much lower (at less than 10 metres height), occasionally even on the ground in cleared areas. A single brood of three to six is raised in a season (July–October). Egg size varies among species, little crows laying noticeably smaller eggs (39 × 26 millimetres) than other species (44–45 × 30–41 millimetres). The little crow also has a more variable breeding season and clutch size and is more likely to nest in response to rainfall. Females incubate for about 20 days, and both sexes feed the young, which fledge at about 40 days.

Damage

Corvids are known to consume various quantities of grapes, cherries, olives, plums, bramble berries, pineapples, passionfruit, potatoes, almonds, peanuts and grains. Corvids directly consume fruit or foliage and sever seedlings. In vineyards, crows and ravens remove or damage fruit they can reach when sitting on trellis posts or strong vine canes and have been observed pushing young vines to the ground to feed from them (Figure B.2). Although netting reduces their impact on grapes, if the netting is simply draped over the vines, they can weigh it down if they perch en mass and damage the grapes through the net. They can also perch on, and forage directly from, foliage, and this is evident in grain crops. Commercial grains and storage areas are often susceptible. Oats, wheat, sorghum, maize and rice are commonly consumed, often from stock feed and during sowing, but also from stubble paddocks following harvest. Crows and ravens are also frequently implicated in causing stock losses, and are known to prey upon lambs and injure sheep. However, losses are rarely significant, as these birds are most likely to injure lambs that are already sick, dying or mismothered. Some studies suggest that only the largest species (Australian forest ravens) are capable of inflicting damage. Unlike raptors, these species have difficulty penetrating mammal skin; hence soft parts are targeted (mouth, eyes, anus, umbilicus).

Figure B.2: *Crow damage to grapes: hollowed-out and torn berries. Damaged bunches are always high up and exposed, near canes large enough to support the weight of the large bird. Photo: R. Sinclair.*

Protection status

Protected, but unprotected in some States and regions (Section 6.1).

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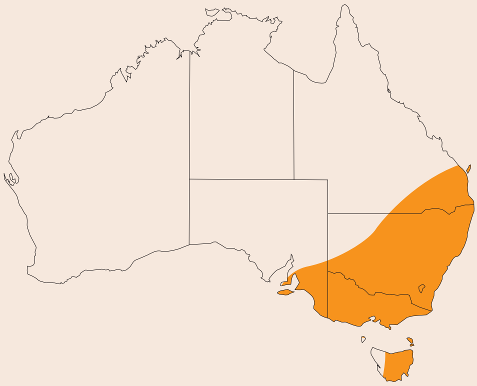
Eastern rosella
(*Platycercus eximius*)

Other names

Red-headed, white-cheeked or golden mantled rosella; Rosehill parrot.

Photo: G. Dabb.



Birds Australia Atlas (1998–2002)

Field identification

This species is a medium-sized (29–33 centimetres head to tail), broad-tailed colourful parrot. The head, upper breast and tail coverts are bright red, the cheeks are white, the belly and lower breast yellow, shoulders blue, and rump green to turquoise. Females and immatures are a little duller and have a slight green area on the rear of the crown.

Voice

Calls similar to, but higher-pitched than, those of crimson rosellas (*Platycercus elegans elegans*): rapid high-pitched 'pink pink' during flight and an ascending whistle or slow piping 'kwink kwink' when perched.

Habitat

Eastern rosellas replace and coexist with crimson rosellas in more open habitats but rarely inhabit rainforest or wet sclerophyll forest. They are common throughout their range in open woodlands, farmlands, orchards, cultivated croplands and suburban parks and gardens. However, in drier parts they reside close to creeklines or floodplains. Their occurrence in open forests is associated with grassy understorey or adjacent grasslands. Hence this species has benefited from the clearing of dense forest or replanting of grassy landscapes. They are also often observed along roadsides and perched on fence-lines or overhead wires.

Movements

Considered mainly sedentary, although some seasonal movements are thought to occur as a result of dispersal before (New South Wales populations) or after (South Australian populations) breeding. In the Australian Capital Territory certain populations exhibit altitudinal movements, where birds emigrate from higher to lower altitudes in winter. Typical of most parrot species, juveniles and sub-adults tend to be more mobile. Eastern rosellas occur singly, in pairs or in small groups and occasionally in larger groups of up to 100. Daily movements are usually confined to local areas and the birds often loaf in tree branches during the middle of the day.

Foods and feeding behaviour

Eastern rosellas prefer ground foraging on grasses, with seeds being the major component of their diet throughout the year. However, shrub and tree seeds (particularly *Eucalyptus* spp. and *Acacia* spp.), fruits, flowers, buds and nectar and a variety of insects, including caterpillars (Lepidoptera), lerp, psyllids, coccids (Sternorryncha) and galls on *Eucalyptus* leaves are also consumed when available. Foraging parties are usually small (less than 10 birds), largest in the morning, smallest during the middle of the day and intermediate sized groups in the afternoons. Foraging in the tree and shrub canopy for fruit, flowers, seeds or buds is often done opportunistically. A greater proportion of the day is spent feeding in the cooler months.

Breeding

Eastern rosellas usually nest in the hollows of mature *Eucalyptus* spp., but also in tree stumps, fence posts, nest boxes and hollows of a variety of other species, including *Casuarina* spp., figs, *Melaleuca* spp. and fruit trees. Suitable hollows in cleared and open woodlands, including orchards, are selected in August, and breeding usually occurs between September and December. Nests are often used by the same pairs in consecutive seasons. Hollows are often unlined, or may be lined with small amounts of chewed bark, wood and plant material. Four to seven white, oval eggs, distinguishable from those of other rosella species by their size (26 × 22 millimetres), are laid at two-day intervals. Females are fed by the males while incubating and when their young are newly hatched. Young are then fed by both sexes. Suitable nesting sites are often usurped by starlings (*Sturnus vulgaris*) and mynas (*Acridotheres tristis*). Nesting failure is also attributed to desertion, infertility or breakage of eggs, or predation by lace monitors, brush-tailed possums or rats.

Damage

Eastern rosellas are known to damage nuts, sunflowers, grain and a variety of fruit crops, including apples (Figure B.3), grapes, cherries, pears (Figure B.4) and plums. Impacts on viticulture include the chewing of growing vines and clipping of young vine stems. Eastern rosellas damage fruit by biting medium-sized chunks;

Figure B.3: *Rosella damage to apple. Photo: J. Tracey.*

Figure B.4: *Rosella damage to pear. Photo: J.Tracey.*

this often increases secondary losses caused by fungi such as botrytis (*Botrytis cinerea*) or by insects. Rosella damage is distinguishable from that caused by other species by the triangular-shaped marks made by the lower beak and by the small fragments (less than one centimetre in diameter) found underneath the fruit.

Protection status

Protected

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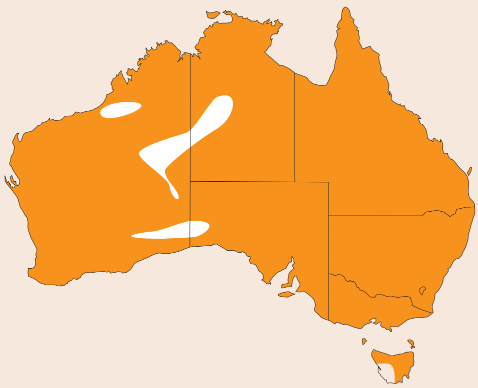
Galah

(*Elophus roseicapilla* syn. *Cacatua roseicapilla*)

Other names

Rose, rose-breasted or willock cockatoo.

Photo: M. Bomford.



Birds Australia Atlas (1998–2002)

Field identification

This species is an easily recognised, small (35–38 centimetres head to tail), pink and grey cockatoo. It is noisy and conspicuous, with an erratic flight pattern. Its generic name is derived from the Greek, 'dawn' and 'crest' referring to the rose-pink crest like the rising dawn. The species name comes from the Latin 'roseus' (rose) and 'capillus' (capped). Females are distinguished by pinkish skin around the eye; males and immatures have dark brown eye skin.

Voice

A loud, high-pitched 'chill chill' during flight, a shrill screech in alarm, and a softer hum while roosting or feeding.

Habitat

The galah occupies highly varied habitats throughout Australia in open savannahs, agricultural areas, open forests, woodlands, shrub-lands, mangroves, arid and semi-arid regions, sand-plains and urban areas. Galahs seldom occur in dense wet sclerophyll woodland or rainforests and avoid extreme desert regions, although in open country they prefer riverine or roadside habitat with remnant *Eucalyptus* or *Casuarina* woodlands. They are common in farming districts, urban parks, gardens and sporting fields. Their abundance and distribution have expanded dramatically and continue to expand owing to clearing and thinning of dense forests, expanding cereal cropping and improved access to water since European colonisation. In particular, the availability of grain from crops, storage facilities and stock feed has provided food during winter periods when it was naturally scarce. Galahs are now the most widely dispersed and probably the most abundant cockatoo in Australia. Highest densities occur in the Murray–Darling river system of south-eastern Australia and in the wheat belt of the south-west of Western Australia.

Movements

This species is generally sedentary, with nomadic tendencies in juvenile and non-breeding sub-populations and in certain habitats. Sedentary birds will concentrate their movements around their nest sites and return to hollows to roost travelling less than 10 kilometres for food. Nomadic sub-populations may traverse larger areas (over 1000 square kilometres) and will roost near food sources. Galahs rarely display large-scale seasonal movements. Exceptions are some populations of the far north, which are thought to move to the north coast in the dry season and away from it during the wet. Extreme climatic conditions and habitats with variable food and water availability can also result in large regional movements.

Foods and feeding behaviour

Seeds of grasses and herbs, especially cereal grains, comprise about 75% of their diet throughout the year. The remainder includes small quantities of nuts, fruits, berries, shoots, buds, flowers, tubers, corms, bulbs and insects. Galahs are ground foragers who search by sight, rarely digging except when seeds or rhizomes are close to the surface. Cultivated seed crops, particularly wheat, oats and barley, provide a stable food source in many areas. Grain is available from germinating crops, stubble, spillages around storage areas or along roadsides, and stock feed or (rarely) livestock dung.

Seeds of native and improved pastures and weeds, such as *Erodium* spp., clover, subclover (*Trifolium* spp.) and medic (*Medicago* spp.), wild oats (*Avena* spp.), wallaby grass (*Danthonia* spp.), western button grass (*Dactyloctenium radulans*), Flinders grass (*Iseilema membranaceum*) and Mitchell grass (*Astrebla lappacea*) are commonly consumed outside cropping areas and seasons. Winter and autumn crops such as sunflower and sorghum are also exploited, in some cases offering year-round access to commercial crops. Seed heads from introduced thistles (scotch (*Cirsium vulgare*), saffron (*Carthamus lanatus*) and white stemless (*Onopordon acule*)) and corms of onion (Guildford) grass (*Romulea rosea*) are also frequently eaten.

Feeding flocks of 500–1000 galahs are common in cropping areas and groups are larger when food sources are more concentrated. Larger flocks form during feeding rather than when roosting or flying, and while feeding on grain rather than on pasture or in orchards. Nomadic flocks will roost within two kilometres of feeding sites and visit them repeatedly while the food source remains. They will often forage with sulphur-crested cockatoos (*Cacatua galerita*), long-billed (*Cacatua tenuirostris*) and little (*Cacatua sanguinea*) corellas, Major Mitchell's cockatoos (*Cacatua leabeateri*), red-tailed black-cockatoos (*Calyptorhynchus banksii)* and mallee ringnecks (*Barnardius zonarius barnardi*), and respond to their alarm calls. Feeding forays usually last one to four hours and begin within an hour after dawn and within five hours of dusk. Shorter foraging periods of less than 30 minutes occur during the day, especially when temperatures are low and food is scarce, and while the birds are feeding young.

Breeding

Galahs can breed throughout the year. Breeding varies according to rainfall and food resources with peaks in February to May and August to November. Pairs form permanent bonds and remain loyal to nest sites which they both visit throughout the year. Hollows in *Eucalyptus* near water are selected in preference to other sites, although birds can nest in cliff crevices, logs and fence-posts. Unlike other cockatoos, galahs will line nests with *Eucalyptus* leaves. Two to six eggs (35 × 26 millimetres) are incubated by both sexes for about 23 days. Feeding of the young is also shared equally. Fledging occurs at around 50 days and the young remain partly dependent until 100 days. About 47% of eggs laid reach fledging, with about 19% of fledged young dying before independence. Adverse weather conditions, competition from other hole-nesting species and predation contribute to nesting failure.

Damage

The main damage galahs cause is to germinating cereal crops because of their dependence on seeds. Although they collect grain from other sources, damage is still known to occur to commercial crops of wheat, sorghum, barley, oats, maize (Figure B.5), sunflower, canola and safflower. Although they frequently damage almonds and occasionally eat soft fruits, damage to orchards, vineyards and nut plantations is usually by pruning of leaves, buds and flowers, chewing of young canes, clipping and pulling out of young plants, stripping bark, and splitting of fruit for seeds. Citrus, apples, stone fruits, wine grapes, walnuts, chestnuts, hazelnuts, pistachios and almonds are susceptible to this type of damage. Young *Eucalypt* — particularly those in revegetation programmes — and other native plant species, including saltbush and bluebush, can suffer similar damage. Impacts in urban areas to structures such as timber trellising, communications aerials, rubber insulators and cables also occur and are typical of the damage caused by large parrot species with curious and intelligent natures. Temporary covers of grain stores and haystacks are often torn exposing the contents to weather and spoilage. Rhizomes, corms, bulbs and clover seed often attract galahs to sports ovals, bowling greens and golf courses where large foraging groups destroy the turf.

Protection status

Protected, but locally unprotected in some States and regions (Section 6.1).

Figure B.5: *Galah damage to maize where husks were pulled right back exposing the kernels, which were then completely removed. Photo: P. Fleming.*

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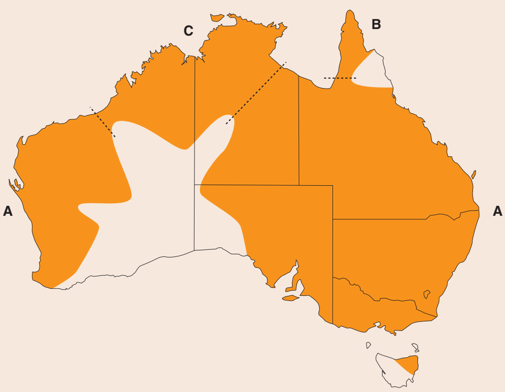
Little corella
(Cacatua sanguinea)

Other names

Bare-eyed, blue-eyed, Dampier's, short-billed corella or cockatoo.

Photo: P. Bird. Inset photo: G. Dabb.



Birds Australia Atlas (1998–2002)

Field identification

Little corellas (36–39 centimetres, head to tail) are found only in Australia and New Guinea. They have bare, bluish skin around the eye, a small erectile crest and a small whitish bill. The underwing and undertail, seen during flight, are sulphur yellow. *Cacatua sanguinea gymnopsis* (A) and *normatoni* (B) subspecies have a pink patch between the eye and bill, which is unnoticeable in the nominate *sanguinea* (C) subspecies. The long-billed corella (*C. tenuirostris*) and western corella (*C. pastinator*) are similar species: distinguished by a longer bill. The long-billed corella has a prominent crimson or salmon throat bar. The western corella has small traces of colour on the throat and a deep patch between the eye and the bill. Wing beats are shallower than the galah's (*Elophus* [*Cacatua*] *rosiecapilla*) but deeper than that of the sulphur-crested cockatoo (*C. galerita*). Little corellas are usually seen in large, noisy flocks.

Voice

Very raucous screeching calls during flight and while roosting. Calls are similar to, but distinguishable from, those of the sulphur-crested cockatoo. However, the calls are almost identical to (only slightly deeper than) the calls of the long-billed corella.

Habitat

Little corellas occupy a variety of timbered habitats including lightly wooded grassland, acacia shrubland, swamp sclerophyll forests, open sclerophyll, monsoon and riparian woodland and adjacent croplands, ploughed paddocks and grazing areas. Large flocks are also prominent in rural townships, around homesteads and grain silos. They have even moved into urban Adelaide and roost in gardens, sporting fields and recreational areas. They are prevalent in the arid and semi-arid rangelands and considered a dryland species, but are uncommon in areas without permanent water. In drier parts of Australia they are replaced by Major Mitchell's cockatoos (*C. leadbeateri*). In South Australia they are distributed along the Murray River and tributaries in association with the river red gum (*Eucalyptus camaldulensis*). Eucalypt species associated with watercourses are also occupied by little corellas in other areas including southwest Victoria and the Pilbara region of Western Australia. They also occupy other woodland areas with tall grasses and in close proximity to water, including open mallee (e.g. *E. diversifolia*), coolibah (*E. microtheca*), and woodlands of *Callitris* — *Casuarina* spp., *Eucalyptus* — *Allocasuarina* spp. and *Andansonia* — *Eucalyptus* spp. During food shortages local populations will venture into more marginal habitats, such as *Eucalyptus* — *Acacia* spp. or saltbush (*Atriplex* spp., *Rhagodia* spp.) shrublands or dry mallee and arid *Callitris* spp. stands. On Australia's mainland the distribution and abundance of little corellas have increased since European settlement, particularly in South Australia and the wheat belt of Western Australia, because of increased access to water, clearing of native shrublands and pasture improvement.

Movements

This species is mainly sedentary but displays larger movements in response to extremes in climatic conditions. However, it is more nomadic than the sulphur-crested cockatoo and perhaps the galah. Typically, there are no large-scale seasonal movements, but some populations exhibit regular local movements with seasonal patterns. Pairs will separate from flocks and travel to riverine habitat during the breeding season (May–October). Immatures and non-breeding adults are more mobile and can disperse up to 250 kilometres, particularly after the breeding season. Erratic movements often occur when they follow available water and food. For example, during droughts large flocks depart from the arid regions of western Queensland and New South Wales and seek refuge around the billabongs, dams and waterholes of the semi-arid and tableland regions. Conversely, large influxes of little corellas have appeared in other areas during floods and prolific breeding can occur in these areas (for example, in Melbourne during the 1974 floods). Despite little evidence of movement across the Bass Strait, populations have become established in Tasmania where they are now widespread in central farmland areas. However, aviary escapees are a likely contributing factor, being implicated in the establishment of populations in Perth and Adelaide.

Little corellas form large communal roosts of thousands, but leave in small groups (1–20) during the dawn period to travel to feeding sites and return before sunset. During the middle of the day they normally loaf and shelter in tall trees often beside water or feeding sites.

Flocks of up to 70 000 birds have been reported in the Kimberley, Western Australia. They also regularly occur with other species such as long-billed and western corellas, galahs and sulphur-crested cockatoos. Single birds and small flocks, in particular, will join flocks of other species. In the breeding season (May–October) flocks tend to be smaller as pairs remain close to their nest hollows.

Foods and feeding behaviour

Grass seed comprises the majority of the diet, with varying amounts of seed from other sources, as well as nuts, fruit, berries, buds, shoots, flowers, roots, bulbs, corms and occasionally insect larvae. Hence most foraging occurs on, or close to, the ground. Corellas become arboreal in some areas, particularly in urban and horticultural regions where open pasture is limited and exotic or cultivated fruit or nut trees are plentiful. In native and other agricultural environments they prefer to feed in woodlands with established perennial grasses over shrublands or shrubby woodlands with sparse grass cover. Preference for seeding grasses, herbs, shrubs and trees varies considerably with season and location. Oats, sorghum, wheat, *Acacia* spp., river red gum, spinifex (*Triodia* spp.) and rice grass (*Xerochloa* spp.) are commonly consumed when available. Particular weed species are also targeted, especially doublegee (*Emex australis*) tick-weed (*Cleome viscosa*) and hogweed (*Boerhavia* spp.). Wood borers of *Eucalyptus* spp. are also sought after, and individual birds will split bark and crack limbs to retrieve the insects. Like other large parrots, little corellas have a habit of chewing various objects, ranging from fabricated structures and cables to heavy defoliation of roost trees. Although they will consume leaves, bark, buds and other vegetative matter, chewing behaviour is more likely a result of their innate curiosity; hence they often target novel items in their environment. They may also chew for beak maintenance, to fill in time with displacement behaviour due to an abundance of food, or foliage thinning to help avoid predator attack.

Little corellas regularly form large noisy flocks in the hundreds or thousands, especially while feeding, drinking and roosting. Peak feeding occurs in the early mornings and late afternoons, when they may spend a great deal of time digging for buried seeds and roots, including freshly sown seed. They usually drink twice a day.

Breeding

Little corellas most commonly breed in hollows in riverine *Eucalyptus* spp., but hollows in bottle-trees and mangroves, crevices in cliffs and termite mounds are used occasionally. They can usurp galahs from nests and have been known to raise galahs' young. They often nest in the same hollow in consecutive seasons, sometimes with several pairs breeding in the same tree. Breeding season (usually May–October) and clutch size vary with climatic conditions, with multiple broods possible in good seasons and little or no breeding during drought. Two or three, and occasionally four, eggs (35 × 26 millimetres) are laid in unlined hollows. Often only one young is raised per nest because the other eggs do not hatch. Both sexes incubate the eggs, males during the day and females at night.

Damage

Little corellas can cause significant damage to fruit and nuts, particularly as their nomadic habits can result in large numbers arriving unexpectedly. Fruit damage typically occurs as a result of birds seeking seeds, rather than the fruits themselves. Citrus, apples and stone fruits are commonly damaged. However, young apples and pears and other pome fruits are also consumed directly. In some cases more fruit or nuts are knocked to the ground than are actually eaten. They seldom eat grapes but are known to prune vine foliage and actively growing canes, clip and pull out young vines and snip off entire bunches. Pruning and foliage destruction, including ringbarking, can also cause significant economic losses in nut orchards including chestnuts, hazelnuts, pistachios and almonds. Vegetable crops and peanuts are often dug up or pulled out of the ground. A variety of commercial cereal and oil seed crops suffer losses when little corellas dig up freshly sown seed, sever plants or attack seed heads. Crops targeted this way include oats, wheat, sorghum, rice, maize, canola, sunflower and safflower. When foraging in crops little corellas can hold seeds under their tongues for later de-husking and eating.

Their chewing habits can result in considerable damage to existing native vegetation and habitat restoration projects. For example, large roosting colonies (often exceeding 10 000 individuals) along watercourses of the Flinders Ranges are known to cause significant damage to many mature *Eucalyptus* spp., particularly river red gum (*Eucalyptus camaldulensis)*, but also native pine (*Callitris columellaris*), peppermint box (*E. odorata*) and long-leaved box (*E. goniocalyx*). Rows of planted native plants in revegetation projects appear more susceptible than naturally occurring plantings of a similar age, possibly because they represent something novel.

Silos, grain bunkers and fodder storage areas, co-axial cables, communication aerials and household wiring are also at risk of damage from little corellas. They sometimes form large seasonal roosts in rural towns or suburban areas (for example, in Adelaide) and cause considerable damage to infrastructure (particularly grassed areas such as ovals, golf courses, bowling greens and community swimming pools) and affect local amenity values through noise pollution and defoliation of, and damage to, local trees.

Protection status

Protected, but locally unprotected in some States and regions (Section 6.1).

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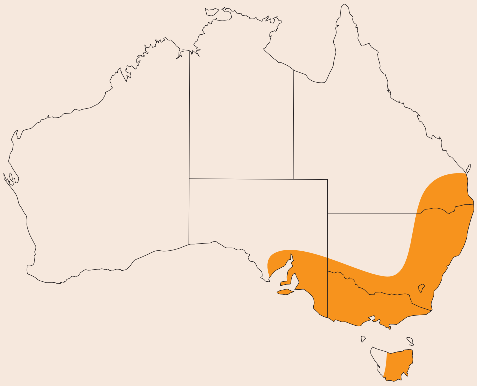
Musk lorikeet
(*Glossopsitta concinna*)

Other names

Red-eared lorikeet; red-crowned lorikeet; green keet; green leek.

Photo: P. Charles.



Birds Australia Atlas (1998–2002)

Field identification

The musk lorikeet is a green lorikeet with bright red cheeks and forehead, blue to turquoise crown, olive-brown on the lower back of the neck and yellow patches on the side of the breast. The bill is black with a red-orange tip. Large flocks are often seen racing through the high canopy or among dense foliage in the tops of *Eucalyptus* trees. Hence they are often confused with purple-crowned lorikeets (*Glossopsitta porphyrocephala*) or little lorikeets (*G. pusilla*), especially as they frequently occur together. However, size can be used to distinguish the species, as musk lorikeets are noticeably larger (22 versus 16 centimetres head to tail) than the other two species. Females are similar to but usually duller and slightly smaller than males.

Voice

A shrill metallic screech during flight; varied but continual noisy chattering while feeding.

Habitat

Musk lorikeets prefer sclerophyll woodlands, dry open forests, tall mallee (e.g. *Eucalyptus diversifolia*, *E. rugosa*) shrubland, and open parks and gardens with scattered *Eucalyptus* spp. They are also common in semi-cleared agricultural areas, including orchards, where remnant riparian or roadside woodland persists. They usually avoid wet sclerophyll woodlands and rainforest. Their preferences for particular vegetation types vary with flowering seasons, but some regional patterns have emerged. White box (*Eucalyptus albens*) and red ironbark (*E. sideroxylon*) communities are frequented to the north and west of the Great Dividing Range. Red bloodwood (*E. gummifera*) is favoured in East Gippsland, Victoria, and river red gum (*E. camldulensis*) near Melbourne. Musk lorikeets avoid brown stringybark (*E. baxteri*) in the areas surrounding Adelaide. Other vegetation types, such as *Angophora* spp., coastal woodlands and open heathlands, are occasionally utilised in good flowering seasons.

Musk lorikeets avoid logged forest, and gradual declines in abundance have been attributed to the clearing of *Eucalyptus* spp. for agriculture. However, native tree planting in suburbia, or increases in *Eucalyptus* spp. plantations in rural areas have increased local populations in some areas.

Movements

This is a classic nomadic species, and its movements are closely associated with the flowering of *Eucalyptus* spp. Its erratic movements are likely to be a result of variable nectar availability, although its movements can be more predictable than those of many other lorikeets. Musk lorikeets are common in the sclerophyll forests of south-eastern Australia, particularly Victoria, but increasingly rare in Queensland. Tasmania has considerable populations that commonly move large distances but exhibit little movement to the mainland. A small feral population became established in Perth but has since been removed. Suburban populations are thought to have altered their movement behaviour because of a continuous supply of flowering plants and they have become more sedentary. Influxes to suburban areas have also been attributed to surrounding bushfires or adverse weather conditions, including drought.

Foods and feeding behaviour

Unlike other parrots, lorikeets have no ventriculus to store grit to grind and digest food; instead they use a brush-tipped tongue for collecting nectar. Musk lorikeets are strongly arboreal and favour nectar from flowering plants, particularly *Eucalyptus* spp. Certain native plant species are preferred including river red gum (*E. camldulensis*), swamp mahogany (*E. robusta*), red ironbark (*E. sideroxylon*), *Angophora* spp., bottlebrush (*Callistemon* spp), *Banksia* spp., *Grevillea* spp. and paperbark (*Melaleuca* spp.). Plantations of sugar gum (*E. cladocalyx*) and South Australian blue gum (*E. leucoxylon*) are also regularly visited for nectar. Pollen, fruit, flower buds, seeds and insects are consumed as supplements in various quantities including the fruits of a variety of cultivated crops.

A very gregarious species, the musk lorikeet can form flocks of several hundred at feeding sites.

Feeding activity is often chaotic and noisy with birds excitedly flying backward and forwards among foliage. Peak feeding time occurs in the early mornings, but continuous feeding throughout the day is not uncommon. Musk lorikeets will also frequently feed in association with other lorikeets (rainbow, *Trichoglossus haematodus*; scaly breasted, *T. chlorolepidotus*; little and purple-crowned) and swift parrots (*Lathamus discolor*). Breeding pairs will often remain together within flocks during feeding and roosting. Roosting sites are in tall trees away from feeding areas.

Breeding

Musk lorikeets build basic nests in *Eucalyptus* spp. cavities, often with very small entrances (four centimetres diameter) through which the parents push their way. Two white, rounded eggs (25 × 20 millimetres) are laid on a small amount of chewed wood inside the cavity. The female incubates, but both sexes roost inside the hollow and then feed and raise the young. They have a 24-day incubation period, fledge at about 60 days and reach maturity at 13–14 months, but often they do not breed until they are two years old. Breeding usually occurs between September and November but is thought to depend on flowering in nectar-producing trees.

Damage

Musk lorikeets will invade gardens, orchards and vineyards for ripening apples, pears, nashi fruit, cherries, loquats, apricots, plums, peaches, nectarines, vegetables and wine and table grapes. Damage is particularly prevalent in

South Australia and Victoria and is perhaps more severe in stone fruits than in other horticultural industries. Because of their preference for flowering eucalypts, damage is most serious during poor eucalypt flowering seasons when large incursions to horticultural areas can occur. Damage to nuts, such as almonds and hazelnuts, can occur during bud development. Partly ripe grain crops such as sorghum, corn and wheat are also consumed, although significant damage to these crops is rare. Large feeding flocks in orchards can cause significant damage within short periods, often in localised areas. Hence damage occurs to many fruits on a single tree, rather than evenly over the crop. Musk lorikeets are persistent feeders. For example, in the Mt Lofty Ranges large flocks were observed to visit a pear orchard every day for three weeks until the crop was eliminated. Lorikeet damage is distinguished from that of other species by the horseshoe-shaped marks made by the lower beak and triangular marks made by the upper beak. Fruit and skin fragments under trees bearing damaged crops are similar or smaller than those left by rosellas (less than one centimetre in diameter).

Protection status

Protected.

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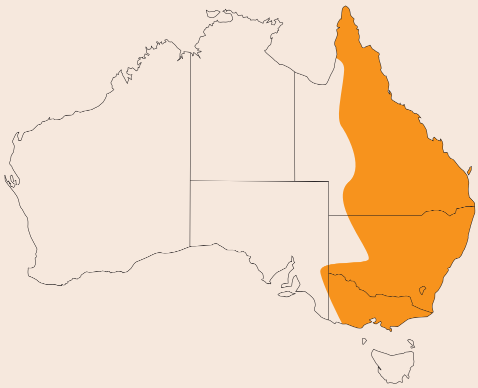
Noisy friarbird
(*Philemon corniculatus*)

Other names

Leatherhead; knobbynose; four-o'clock; monk.

Photo: G. Dabb.



Birds Australia Atlas (1998–2002)

Field identification

This species is a large (30–35 centimetres head to tail) brown-grey honeyeater with an obvious bald black head. There is a distinctive knob on the bill which is smaller on immature birds and absent from juveniles. It has a silver-grey crown, nape and throat and a white underbelly and tail tip.

Voice

Conspicuous raucous 'four o'clock'.

Habitat

The noisy friarbird inhabits open dry sclerophyll forests and woodlands, swampy woodland and heath, including coastal heath, mallee (e.g. *Eucalyptus diversifolia*, *E. rugosa*), brigalow (*Acacia harpophylla*), gidgee (*Acacia cambagei*), parks and gardens. Riverine habitats with river red gum (*E. camaldulensis*) and black box (*E. largiflorens*) or coolibah (*E. microtheca*) associations are also commonly occupied, including those that extend into arid areas. This species avoids rainforest, dense wet sclerophyll, sedgeland, open savannah, and pure stands of *Callitris* spp. or introduced pine (*Pinus* spp.).

Movements

The noisy friarbird can be migratory. Most populations also display nomadic movements following good quality nectar flows of flowering trees and shrubs. Southern populations have more pronounced migratory habits and large numbers regularly move to lower altitudes and north during winter, returning for spring and summer. The longest recorded movement was that of a bird that moved from Mudgee south to Mitta Mitta in north-east Victoria, a distance of 510 kilometres. In comparison, fewer movements are apparent in the northern extremities of their range where many individuals are sedentary.

Foods and feeding behaviour

Noisy friarbirds mainly feed on nectar but also fruits, flowers, pollen, seeds, insects, lerps, manna, honeydew and occasionally bird eggs and nestlings. Flowering trees and shrubs with abundant nectar are sought after and aggressively defended. Preferences for plant species fluctuate with flowering seasons. Favoured species include swamp mahogany (*E. robusta*), red ironbark (*E. sideroxylon*), yellow gum (*E. leucoxylon*), white box (*E. albens*), Blakely's red gum (*E. blakelyi*), red bloodwood (*Corymbia gummifera*), *Angophora* spp., paperbarks (*Melaleuca* or *Callistemon* spp.), *Banksia* spp. and *Grevillea* spp. They are mainly arboreal, foraging in the high canopy on flowers and foliage though they will also forage in the shrub layer and occasionally on the ground. They often hawk insects and during spring and summer can consume large quantities. Cicadas (Cicadidae and Tettigarctidae) are a preferred food source when available and are thought to influence breeding success in some areas. Noisy friarbirds feed in mixed flocks with lorikeets, red wattlebirds (*Anthochaera carunculata*) and other honeyeaters (Meliphagidae) until competition intensifies due to food shortages. Usually friarbirds feed in noisy small flocks of less than 20, but larger congregations can occur around food sources.

Breeding

Noisy friarbirds build basket-shaped nests from strips of bark, dry grass and long thin twigs carefully interwoven and bound together by spider webs. The nest cup has softer material including soft bark fibres, leaves, hair and wool. Nests are suspended by the rim amongst leafy branches of *Eucalyptus* spp., kurrajongs (*Brachychiton populneus*) or other species and are usually well concealed but more conspicuous than red wattlebird nests. Breeding adults will often return to the same nesting sites in consecutive seasons despite migratory habits. However, young are eventually forced from their natal areas if they do not disperse and seldom return. Two to four blotched pale pink to pink-brown eggs are laid up to four times a year, but more commonly three. Females incubate for around 16 days, but both sexes feed the young and defend the nest. Young continue to be fed until two or three weeks after fledging. Predation, abandonment during dry seasons, and parasitism by the common koel (*Eudynamys scolopacea*) and other cuckoos are the main causes of nesting failure. When successful, nests produce an average of about two fledglings. Adults are known to live for more than nine years.

Damage

This species is often a pest of orchards and vineyards, especially during nectar shortages in autumn. Significant losses can occur to grapes, cherries, stone fruit, pears, tropical fruit, blueberries, mulberries, bilberries, blackberries and figs. In some situations overripe or damaged fruit is targeted in preference to viable fruit. For example, greater numbers of birds have been recorded in blocks of freshly machine-harvested wine grapes than in adjacent unharvested blocks. The damage is similar to that of red wattlebirds, with large pecks and hollowed-out flesh.

Protection status

Protected.

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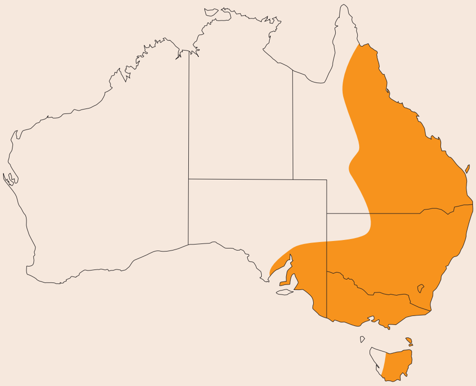
Noisy miner

(*Manorina melanocephala*)

Other names

Micky miner; southern black-backed miner; cherry eater; snakebird; squeaker; soldier bird.

Photo: B. Furby.



Birds Australia Atlas (1998–2002)

Field identification

The noisy miner is a pale grey, medium-sized (24–28 centimetres head to tail) honeyeater with a black crown, face and ear, a bare yellow patch behind the eye and a yellow bill. It has a darker grey wing, with an olive to yellow streak. The noisy miner is distinguishable from the yellow-throated miner (*Manorina flavigula*) and black-eared miner (*Manorina melanotis*) by the darker head plumage. This distinction is particularly important in the Murray mallee region of South Australia, Victoria and New South Wales. Work is under way to conserve the black-eared miner, now very rare in this region.

Voice

Distinctive, high-pitched and noisy 'tiee, tiee, tiee, tiee' in alarm, with a variety of other calls.

Habitat

Noisy miners prefer open woodlands and forests, particularly edges and isolated patches without a distinct shrub layer. For example, dry *Eucalyptus* woodlands, grassy forests, mixed dry sclerophyll with *Callitris* spp. and lightly timbered farmlands, parklands, gardens and pasture, orchards, vineyards and road reserves. Bird densities are known to increase with decreasing area of woodland; hence the birds are generally absent from large forest remnants (greater than 500 hectares) but are most abundant in small fragments (one to two hectares). Noisy miners are also occasionally found in remnant or planted fragments of wet sclerophyll, coastal heath, *Melaleuca* spp., *Acacia* spp., brigalow (*Acacia harpophylla*) and mulga (*A. aneura*). This species avoids dense forests and woodlands and has benefited from grazing, clearing and fragmentation of native vegetation.

Movements

Noisy miners are sedentary throughout their range. Most individuals remain within small, well defined territories with home ranges less than 200 metres in diameter. Female home ranges are even smaller, commonly less than 100 metres. Occasionally, larger movements of up to 18 kilometres have been recorded perhaps as a result of juvenile dispersals or the return of translocated birds to their previous territories. They are very sociable and are seldom observed singly or in pairs. Small groups of 6–30 birds aggressively defend core areas within a larger home range. Communal roosts are often at new sites each evening usually in the outer branches of feeding trees and shrubs.

Foods and feeding behaviour

Omnivorous feeders, noisy miners consume a variety of insects, nectar, fruit, seeds, vegetables and occasionally frogs and reptiles. They commonly forage in and defend high nectar bearing trees and shrubs, including *Eucalyptus* spp., *Banksia* spp., *Grevillea* spp., and *Camellia* spp. Arthropods are regularly consumed, especially spiders, beetles (Coleoptera), weevils (Curculionidae), bugs (Hemiptera) and wasps (Apocrita). Psyllids, lerps (Sternorryncha) and manna (bark exudates) are also occasionally gleaned from leaves and bark. Noisy miners, however, exclude many other bird species that are thought to maintain insect populations at lower levels. Fruits from orchards and from trees and shrubs such as native tamarind (*Diploglottis australis*), Moreton Bay fig (*Ficus macrophylla*), saltbush (*Rhagodia* spp.) and seeds of Poaceae, goosefoot (*Chenopodium* spp.) and peppercorn (*Schinus areira*), are also eaten opportunistically.

Active, aggressive and gregarious, noisy miners forage within colonies in sub-flocks (or coteries) of 6–30 birds, but hundreds can congregate in clumps of flowering plants. Noisy miners feed mainly in foliage, but also in the tree canopy, along branches, trunks, and on the ground. Mixed feeding groups rarely occur because of the birds' defensive behaviour, but birds may feed alongside other species in more structured vegetation.

Breeding

Two to six eggs (mean 2.9) are laid in a fragile bowl of sticks, bark and leaves lined with softer material such as hair or fur and held in a tree or shrub fork. Communal breeding takes place year round, but most commonly between June and September with up to 22 males and one female attending a single nest during a season. Twice as many nests have been observed during June and September as in the warmer months of October to January, despite the presence of fewer insects. This may be a strategy for limiting predation. Four broods can be raised in a year with the building of a new nest starting directly after the young are independent, at about 16 days after fledging. About 34% of eggs produce young that fledge, with an average of 0.89 fledged young per nest. Mortality is mainly due to starvation, abandonment, failure to hatch, predation and adverse weather conditions.

Damage

Noisy miners are known to damage horticultural crops, particularly soft fruits such as grapes (Figure B.6), plums, apricots, cherries, peaches, nectarines, pears, apples and berries. Using their brush-tipped tongues, they collect flesh and juice from sharp angular punctures in the fruit. Smaller fruits such as berries and grapes are often swallowed whole. They are known to swallow the seeds of weed species such as peppertree (*S. areira*), and blackberry, but their potential to spread environmental weeds is probably limited by their sedentary habits.

Figure B.6: *Distinctive noisy miner pecking damage to grapes. Photo: R. Sinclair.*

Although noisy miners occasionally remove insect pests, they are also associated with increased *Eucalyptus* spp. dieback. This has been attributed to the miners' aggressive exclusion of insectivorous birds. Removal of noisy miners in one area causes a significant increase in the abundance and diversity of other insectivorous birds and potentially decreases the impacts of defoliating insects. Most bird species entering the territories of noisy miners are mobbed and chased and in some cases killed.

Protection status

Protected.

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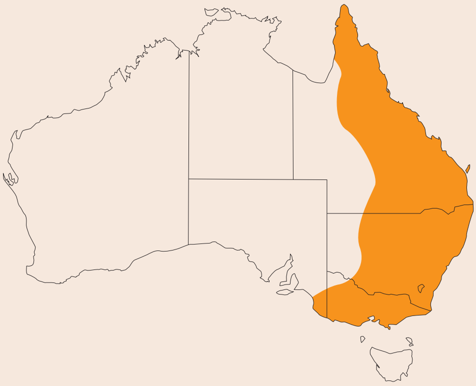
Pied currawong
(*Strepera graculina*)

Other names

Currawong; bell magpie; black magpie

Photo: H. Pollock.



Birds Australia Atlas (1998–2002)

Field identification

The pied currawong is a large (41–51 centimetres head to tail), mainly black bird with white patches on the wing and the base and tip of the tail. The wing patch is crescent-shaped and prominent during flight but also visible while perching. The intense yellow eye is distinctive and can be used to distinguish it from other large black and white birds. Similar species of the same genus, the black currawong (*Strepera fuliginosa*) of Tasmania and the grey currawong (*Strepera versicolor*) (Figure B.7) of southern and western Australia, are also known to damage horticultural crops. They occupy similar habitats and have comparable movements and feeding and breeding behaviours, but several differences have been identified (see below).

Voice

Distinctive ringing; deep guttural 'curra-wong'.

Figure B.7: *The grey currawong* (Strepera versicolor). *Photo: B. Furby.*

Habitat

Currawongs occupy a wide range of habitats, including open *Eucalyptus* woodland and forest, wet sclerophyll, rainforest, shrubland, coastal woodland, parks and gardens, orchards, vineyards and agricultural areas with scattered *Eucalyptus* species. The pied currawong is rare or absent from open savannahs and arid and semi-arid regions. This species is most abundant along the coasts of New South Wales and Queensland.

Movements

This is a nomadic species. No large-scale seasonal movements are evident, but many populations travel to lower altitudes during winter. These relatively short movements (less than 80 kilometres) are also associated with populations moving to urban areas, particularly in the south-east. Increases in abundance of pied currawongs in the Murray-Darling catchment indicate that many of them visit the region in winter. Altitudinal movement as well as a small northward shift is apparent in south-east Queensland, where there are large influxes of the birds to nearby low-lying areas during autumn and winter. Movements are confined during breeding (September–November) when pairs aggressively defend small territories. In Canberra and Sydney there are increasing numbers of pied currawongs that breed in urban areas and remain there throughout the year. Black and grey currawongs are more sedentary throughout their range.

Foods and feeding behaviour

Pied currawongs are omnivores, consuming a variety of insects, small birds, eggs and reptiles, fruits and vegetable matter. Proportions vary with availability, habitat and season. Insects and small invertebrates are the major dietary component during breeding. In some cases swarms of insects, particularly stick insects (Phasmatodea), cause large influxes of currawongs. Fruit from orchards and vineyards are increasingly consumed in agricultural regions during summer and autumn. Populations in urban areas during this period and also in winter often scavenge a variety of foods including vegetable scraps, pet food and garden fruit. Feeding flocks are conspicuous and range in size from solitary birds to large flocks. Large congregations are typical around food sources and during roosting. Up to 200 have been observed foraging on a single vineyard and in suburban gardens. Grey currawongs are more elusive and occur only in small flocks on the mainland; they are usually solitary or in pairs, and rarely in groups greater than five.

Breeding

A large but often shallow bowl of sticks lined with grass, bark and rootlets is assembled in an upright fork of the uppermost canopy. The tallest trees, often *Eucalyptus* spp., are selected in preference if they occur within small clumps. Isolated trees are rarely used. Permanent pairs return to nests of the previous season, establish territories and start nest building usually in August. Populations in northern Queensland often breed earlier than southern populations, but most breeding occurs between September and November. Two to four light-brown eggs (41 × 30 millimetres) with darker spots are laid and incubated for 21 days. One brood is raised per year. Males help by feeding the females during nesting and both sexes feed the young for about nine weeks after fledging. Breeding usually occurs in forested habitats, but increasingly in urban areas (see Movements).

Damage

Large flocks of pied currawongs frequently raid vineyards, orchards and market gardens for fruit, nuts and vegetables. Significant losses can occur to grapes, cherries, persimmons, olives, and nuts as well as other crops. Small plantations near favoured roosting habitat are particularly susceptible, in some cases sustaining 100% crop loss. Persistent and intelligent feeders, they have been observed consuming fruit through nets by landing and swinging on them (Figure B.8). The majority of smaller fruits are removed completely

Figure B.8: *Currawongs have been observed landing on nets and feeding through them. Photo: J. Tracey.*

and swallowed whole. They are also responsible for carrying the seeds of weed species such as camphor laurel (*Cinnamomum camphora*), *Cotoneaster* spp. and privet (*Ligustrum* spp.) and have a potential role in their dispersal. Pied currawongs are known to prey on large numbers of native birds including fairy-wrens, thornbills and honeyeaters (Meliphagidae). However, the decline of native birds is linked to many other factors. Introduced species such as starlings (*Sturnus vulgaris*) and sparrows (*Passer domesticus*) are also common prey.

Protection status

Protected. The Lord Howe Island sub-species *Strepera graculina crissalis* is listed as vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

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Rainbow lorikeet
(Trichoglossus haematodus)

Other names

Bluey, rainbow or coconut lory; Swainson's, blue-bellied or blue mountain lorikeet; blue mountain parrot.

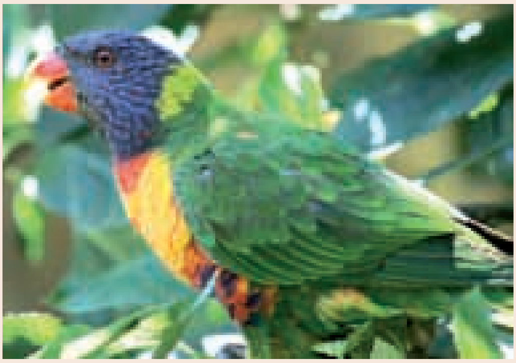
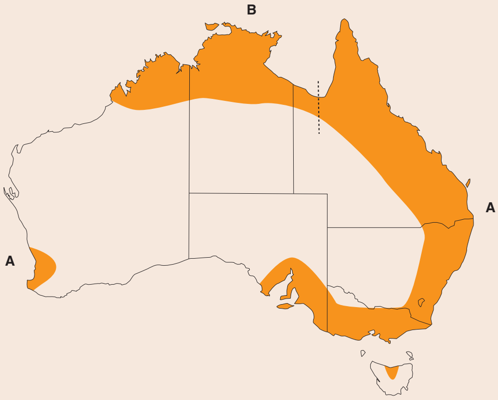


Photo: N. Morenos, Fruit Tree Media.



Birds Australia Atlas (1998–2002)

Field identification

Well known and brightly coloured, this is Australia's largest lorikeet (25–31 centimetres head to tail). Race '*haematodus*' (A) has a green upper wing, back and tail; dark blue head and abdomen; bright red bill and eye; red and dark grey underwing; yellow collar and under-tail; and a bright yellow stripe through the primary and secondary feathers. In the 'red-collared' race (*rubritorquis*)(B), red replaces the yellow collar that extends down the chest, and the abdomen is a darker blue-black.

Voice

Musical screech in flight, feeding chatter softer than that of other lorikeets.

Habitat

Rainbow lorikeets inhabit a diverse range of habitats, including tropical rainforest, wet and dry sclerophyll forest and woodlands, savannah woodlands, and farmlands. They commonly visit orchards and farmlands with remnant or replanted stands of *Eucalyptus* spp. They are abundant in suburban parks and gardens and widely dispersed through cities such as Adelaide, Brisbane and Sydney. Feral populations also occur in Western Australia. Rainbow lorikeets tend to prefer the riverine habitat of tall open *Eucalyptus* woodland at lower altitudes, following nectar flows into other habitats when suitable species are flowering. They venture into the fringes of rainforest and wet sclerophyll at higher altitudes for blossoms of suitable feed trees such as beach acronychia (*Acronychia imperforata*) and umbrella trees (*Schefflera actinophylla*) or where artificial food sources are present. Coastal plains and heath, mangroves and *Melaleuca* woodlands are also utilised for flowering species such as *Banksia* spp., *Xanthorrhea* spp., *Grevillea* spp. and *Callistemon* spp. However, the understorey structure appears relatively unimportant unless the plants are flowering. Populations reside in woodlands and forests with dense shrub layers or an exclusively grass and herb understorey.

Movements

The rainbow lorikeet is a nomadic species that often relocates to exploit nectar from a wide range of flowering plants. Abundance varies considerably between seasons. Mass departure takes place during some years and, conversely, peaks in abundance occur during ideal flowering conditions. As a result, no regular large-scale movements are apparent, although individuals and flocks are able to travel large distances. In areas with reliable food sources, particularly in suburbia, some individuals have become more sedentary. This is likely because of the availability of a diverse range of flowering plants and supply of artificial feeding stations. However, even in these areas large numbers of transient birds can arrive suddenly during peak flowering periods. Some local populations are suspected to have declined as a result of clearing for agriculture.

Daily movements usually involve travelling several kilometres from large communal roosts at dawn to feeding sites. Roosts can be comprised of several thousand birds. The birds feed throughout the day, often moving to other feeding sites; or they loaf in tall nearby *Eucalyptus* spp. Flocks are often seen darting among the canopy between feeding sites. They return to the roost before dusk where they remain in dense foliage or hollow branches.

Foods and feeding behaviour

Like other lorikeets, rainbow lorikeets prefer nectar and pollen from flowers but will also consume native and orchard fruit, berries, seeds and insects. Flocks gather in various habitats, utilising nectar from a wide variety of species, including red-flowering gum (*Corymbia ficifolia*), blue gum (*E. globulus*), northern woollybutt (*E. miniata*), forest red gum (*E. tereticornis*), blackbutt (*E. pilularis*), bottlebrush, paperbark (both *Callistemon* spp. and *Melaleuca* spp.), *Banksia* spp. and blackbean (*Castanospermum australe*). They also commonly feed on blossoms of introduced plants such as coral trees (*Erythrina* spp.), peppertree (*Schinus areira*) and palms (*Phoenix canariensis* and *Washingtonia filifera*); seeds from *Casuarina* spp., pine trees (*Pinus* spp.), lantana (*Lantana camara*) and *Solanum* spp., and fruit from orchards, figs, lilly pilly (*Acmena smithii*), camphor laurel (*Cinnamomum camphora*) and *Calytrix* spp.

Arboreal and agile foragers, rainbow lorikeets can hang upside down in the outer canopy to reach flowers or fruit with their brush-like tongues. High canopy branches are usually preferred. However, red-collared lorikeets will forage lower in the canopy during the dry season and many low shrubs are frequented. Feeding flocks range from solitary birds to thousands but they usually occur in groups of up to about 50. They will feed alongside scaly-breasted, musk and varied lorikeets but are usually partly segregated. Early morning and afternoon are favoured feeding times with brief forays during the middle of the day.

Breeding

Rainbow lorikeets usually breed from September to November, but this can extend from July through to January during ideal conditions when they occasionally produce double broods. Pairs, which may bond for life, prepare cavities in hollow branches or knotholes at the tops (up to 25 metres high) of tall trees, often along watercourses. Open woodland dominated by *Eucalyptus* spp., *Angophora* spp. or *Melaleuca* spp. is preferred for breeding. Two white, oval eggs (27 × 23 millimetres) are laid in a small layer of wood shavings. Females incubate eggs for 10 days during which time the males regularly visit and roost inside the hollows. Both sexes feed the young until two or three weeks after fledging and the birds reach sexual maturity after two years. Nest success has not been studied away from captivity but is thought to be affected by the presence of other hole-nesting species such as mynas (*Acridotheres tristis*), starlings (*Sturnus vulgaris*) and ringnecks (*Barnardius zonarius*).

Damage

When good quality nectar is unavailable, large flocks can cause significant damage to mango, custard apple, apple (Figure B.9), plum, cherry, peach, nectarine, apricot, pear, and citrus orchards. Wine and table grapes are also susceptible (Figure B.10). Fruit damage, as with other lorikeets, is characterised by horseshoe-shaped marks made by the lower beak and triangular marks made by the upper beak. Chunks (about one centimetre diameter) are taken from the fruit, squeezed for their juice, and the remaining pip and skin discarded directly from the tree. Rainbow lorikeets also occasionally damage ripening corn or sorghum crops in Queensland and Northern New South Wales, where flocks of thousands of rainbow and other lorikeets can feed opportunistically throughout the day. Nut crops are sometimes damaged, and growing shoots, buds and flowers can be clipped.

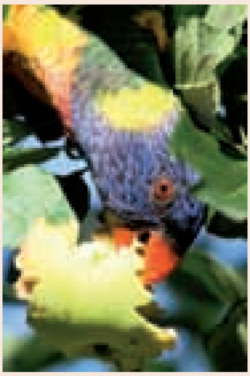


Figure B.9: *Rainbow lorikeet feeding on an apple. Photo: N. Morenos, Fruit Tree Media.*
Figure B.10: *Rainbow lorikeet damage to grapes. Photo: R. Sinclair.*

Protection status

Protected in all States and Territories except Western Australia. In Western Australia the rainbow lorikeet is listed as 'acclimatised fauna' under a Wildlife Conservation (Acclimatised Fauna) Notice, 15 September 1992 (*Wildlife Conservation Act 1950*). Rainbow lorikeets can be 'taken' (shot or livetrapped) on private property in the South-West Land Division, without the need to obtain a licence from the Department of Environment and Conservation (DEC), in accordance with an Open Season Notice, 25 August 1989 (*Wildlife Conservation Act 1950*). The lorikeets must be taken in a manner that does not cause damage to trees, and people trapping or attempting to trap the lorikeets must be licensed under the Wildlife Conservation Regulations 1970. Rainbow lorikeets may be kept in captivity only by a person holding a Regulation 12 aviculture licence which costs $10 per year (Wildlife Conservation Regulations 1970). The rainbow lorikeet is also a declared pest of agriculture in the South-West Land Division, excluding the Perth metropolitan area, under the *Agriculture and Related Resources Protection Act 1976*. To prevent the lorikeets from establishing new populations in the wild, any lorikeets that are seen outside the metropolitan area should be humanely destroyed or reported to DEC or the Department of Agriculture and Food Western Australia (Lamont and Massam 2002).

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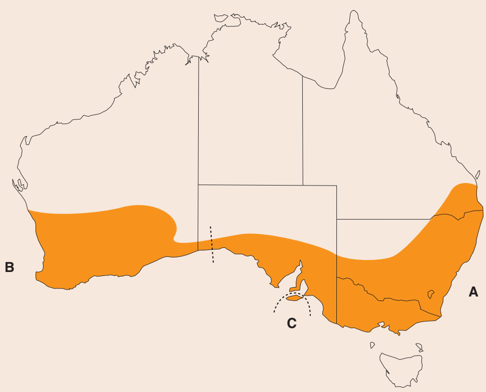
Red wattlebird

(*Anthochaera carunculata*)

Other names

Wattled honeyeater; barkingbird; gillbird; what's o'clock; chock.

Photo: L. Pedler.



Birds Australia Atlas (1998–2002)

Field identification

The red wattlebird is a large (32–36 centimetres head to tail) honeyeater with grey-brown plumage that is streaked white. Primary wing feathers and tail feathers have white edges that are obvious in flight. It has a silver-white cheek patch, red wattle and eye, and yellow underbelly. Juveniles are similar (but without the wattle or yellow belly) and have a red-brown iris. There are separate races in south-east (*carunculata*)(A) and western (*woodwardi*)(B) Australia, and an isolated population on Kangaroo Island (*clelandi*)(C).

Voice

Noisy harsh calls, 'tobacco box' or 'what's o'clock', grating 'chock'.

Habitat

Red wattlebirds occupy a range of habitats, including open sclerophyll woodlands, mallee (*Eucalyptus diversifolia*, *E. rugosa*), coastal heath and shrublands. They are common also in farmlands, parks, gardens, vineyards and orchards, particularly those with stands of remnant woodland or native regrowth. Occasionally they inhabit the edges of denser forests, including rainforest. This species is widespread and prominent in lowland open *Eucalyptus* woodland in the temperate zone. In particular, habitats with diverse shrubby understorey consisting of *Banksia* spp., *Callistemon* spp. and *Acacia* spp. are preferred.

Movements

Movements have not been well studied, but most populations are probably sedentary. Nomadic movements also occur often as a result of prolific flowering of shrubs and trees. Visiting migrants can also increase resident populations in various seasons. Regular altitudinal and latitudinal movements have been recorded in some areas, particularly in southern New South Wales and the Australian Capital Territory where some flocks are believed to migrate up the coast for winter with large numbers of yellow-faced (*Lichenostomus chrysops*) and white-naped honeyeaters (*Melithreptus lunatus*). Small east–west migrations also occur in Western Australia during some seasons.

Foods and feeding behaviour

Red wattlebirds are mainly nectivorous, preferring *Eucalyptus* spp., *Banksia* spp., *Angophora* spp., *Eremophila* spp., *Xanthorrhoea* spp., mistletoe, *Grevillea* spp., *Hakea* spp. and other native flowering plants with high nectar loads. Exotic trees and shrubs are also common sources of nectar, particularly in urban areas. A variety of insects are consumed regularly, with quantities varying according to the availability of nectar and other food sources. In some cases insects comprise the majority of their diet. The sugary outer coating and excretions of psyllids, scale, and coccids (Sternorryncha) such as lerps (Psylloidea) or honeydew, or tree exudates such as manna, are also frequently gleaned from plants, particularly *Eucalyptus*. Fruit comprises a small proportion of their diet but increases in importance during shortages of other food types.

Sometimes large flocks of more than 100 birds will congregate around favoured food sources. However, this species is usually solitary or in small groups when feeding. Their long bills and brush-tipped tongues are well suited for probing tubular flowers. However, inflorescences from species with shallow flowers are often selected in preference. Arboreal and active feeders, they are most commonly observed accessing blossoms in the outer canopy but also forage among foliage and bark and occasionally on the ground. They habitually establish feeding territories of up to 100 metres in diameter. Red wattlebirds aggressively defend their territories from many insectivorous and nectar-feeding species, including other wattlebirds. Peak feeding occurs in the early mornings and late afternoons, with less time spent foraging during periods of abundant nectar.

Breeding

Considerable effort is given to nest building, which can take several weeks. A small cup of fine grass, bark and twigs, lined with fur, hair or wool, is shaped within a larger nest of carefully intertwined long thin sticks and grass. Nests are usually well concealed within foliage of a tall shrub or tree, often *Eucalyptus* spp., mistletoe or *Acacia* spp. Two or three oval, speckled, pink eggs (33 × 22 millimetres) are laid two to five days after the nest has been completed. Two, or occasionally, three broods are raised in a season (July–February). Females, with occasional help from the males, incubate the eggs for 17 days until hatching after which both sexes feed the young until two or three weeks after fledging. In recorded studies, as few as 26% of young reach fledging, resulting in an average of 0.51 young per nest. Mortality is mainly due to adverse weather conditions and predation by goshawks (*Accipiter* spp.), currawongs (*Strepera* spp.), butcherbirds (*Cracticus* spp.), ravens (*Corvus* spp.), possums, cats and snakes. The age of the oldest recorded red wattlebird from banding records is 12 years, 11 months.

Damage

This species is often observed in vineyards and orchards and is known to cause damage to grapes (Figure B.11), peaches, plums, figs, cherries, olives, loquat, apples, apricots, pears and berries. The birds' sharp bills cause large angular punctures from which juice and flesh are extracted. Occasionally smaller fruits (less than 10 × 10 millimetres) are swallowed whole. Damage is more significant during shortages of nectar or insects. In some cases fruit consumption is evident only on overripe fruit left on trees.

Figure B.11: *Red wattlebird damage to Shiraz grapes. Photo: R. Sinclair.*

Protection status

Protected, but locally unprotected in some States and regions (Section 6.1).

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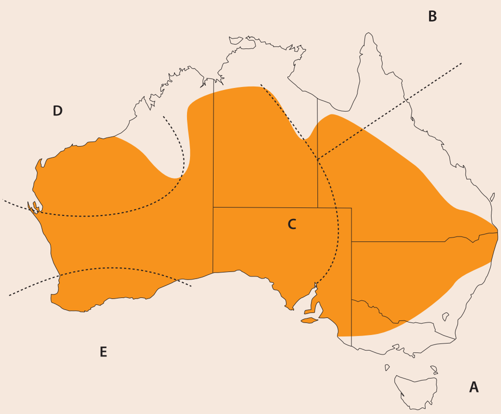
Ringneck
(*Barnardius zonarius*)

Other names

Port Lincoln ringneck; twenty-eight parrot; mallee ringneck.

Photo: G. Dabb.



Birds Australia Atlas (1998–2002)

Field identification

The ringneck is a small to medium-sized (28–44 centimetres head to tail) parrot with mostly green plumage and a prominent yellow 'ringneck' half-collar. Hence the specific name is derived from the Latin 'zona' (girdle or belt). The five distinguished races,' mallee ringneck' (*barnardi*) (A), 'Cloncurry ringneck' (*macgillivrayi*) (B), 'Port Lincoln' (*zonarius*) (C), *occidentalis* (D), 'twenty-eight' (*semitorquatus*) (E), differ in appearance, vocalisations and distribution. The green-headed races (mallee and Cloncurry ringnecks) are rarely implicated in damage to agriculture except in the Riverland of South Australia; hence this section focuses on the dark-hooded races. The 'Port Lincoln' and 'twenty-eight' parrots both have black heads, dark blue cheeks, and blue leading edges to otherwise green wings. The 'twenty-eight' race has a unique red frontal band above the beak and the 'Port Lincoln' has a yellow belly and flank.

Voice

Repeated melodious whistling as a contact call (or a trisyllable 'twent-ti-eight' for the 'twenty-eight' race), and a series of clamorous calls when alarmed, usually in flight. The species was first described in Western Australia by the French, and an alternative interpretation of their call is that it is a two-syllable 'vingt-huit' rather than 'twent-ti-eight'.

Habitat

Although races of ringnecks occur in a diverse array of vegetation communities, these birds' habitat requirements are generally similar. They prefer open woodlands, shrublands and grasslands and often reside in remnant vegetation along watercourses, particularly in arid areas. The 'Port Lincoln' is a very successful race. It is the most common parrot in Western Australia's wheat belt and utilises all types of timbered habitats. It occurs in abundance in any arid areas that have river red gums (*Eucalyptus camaldulensis*). There are few stands of mallee in eastern Australia without populations of 'mallee ringneck' although some populations are thought to have contracted as a result of clearing and settlement. Similarly, populations of 'Cloncurry ringnecks' appear to have retreated to remnants following the expansion of farmlands. In contrast, the dark-hooded races are increasingly observed in orchards and croplands and in gardens in towns and cities, including Perth. The 'twenty-eight' occurs in denser vegetation of the southwest including tall stands of jarrah (*E. marginata*), karri (*E. diversicolor*), marri (*Corymbia calophylla*), and wandoo (*E. wandoo*), and is displaced by the 'Port Lincoln' race where this vegetation has been cleared. Habitat clearing is a major factor in the increasing range and abundance of the 'Port Lincoln' race.

Movements

A mainly sedentary species, but population influxes are known to take place in wetter areas during drought. Regular movements occur in arid areas in response to rainfall. Hence ringnecks are often more nomadic in drier areas, irregularly visiting desert regions. They frequently occur in mixed flocks with other species such as rosellas (*Platycercus* spp.), red-capped parrots (*Purpureicaphalus spurius*), red-rumped parrots (*Psephotus haematonotus*) and blue bonnets (*Northiella haematogaster*), particularly at water or feeding sites. They leave the roost at sunrise, perch in trees during the heat of the day and return to roost before sunset. In drier areas they are observed at watering points before feeding and roosting, although this is uncommon in the wetter areas of the southwest of western Australia.

Foods and feeding behaviour

Ringnecks prefer feeding on seeds of grasses, herbs and low shrubs, but they often consume bulbs, corms of onion grass (*Romulea rosea*), berries, flowers, beetles, lerp, insect galls and larvae and grain from crops, spills or storage areas. Some populations are more arboreal, regularly feeding in the outer branches of orchard trees and *Eucalyptus* spp. during flowering and fruiting seasons. The fruits of *Eucalyptus* spp., *Angophora* spp., mistletoe and cultivated crops are often consumed when available. These birds will also chew tree and shrub foliage for food and beak maintenance including *Xanthorrhea* spp. and a range of *Eucalyptus* species. In suitable trees they will consume sap which often has a similar sugar content to nectar. They gain access to the sap by stripping the bark and scraping the exposed cambium and phloem with their beaks.

Unlike red-capped parrots and other species that split fruit for their seeds, ringnecks usually avoid unripe fruits. Hence this species tends to cause greater damage to orchards closer to harvest. When feeding in orchards, birds enter soon after first light, reaching peak numbers after an hour and then dispersing within three hours after sunrise. Undisturbed birds will often remain in orchards or nearby roosting habitat throughout the day, feeding occasionally. Feeding frequency is higher again before sunset. Certain populations, predominantly of the green-headed races, are quite timid when appropriate refuge habitat is absent. Pairs or small groups of up to 12 are usually observed feeding, but much larger groups occur at water sources and favoured feeding sites. They often feed in association with other parrot species.

Breeding

Females prepare hollows in tree branches, trunks or logs, often showing preference for *Eucalyptus* spp. within dense copses. In the drier parts of their range they retreat to remnant *Eucalyptus* spp. along watercourses to breed, particularly in river red gums. The breeding season varies noticeably among races and distributions and with rainfall in the more arid regions, but it generally occurs between September and December or March and May. The same hollows are often occupied in consecutive years. Ringnecks reach sexual maturity at two years and lay four to six (average 4.6) white eggs directly on the wood inside hollows or in a small bed of bark shavings, grass or leaves. Incubating females are fed by the male, who remains close to the nest. Eggs hatch after about 20 days, and hatchlings are fed by both parents. During suitable conditions broods have high fledging success (more than 65%), but the number of nests and brood size declines dramatically during drought. Nesting success is also influenced by starlings (*Sturnus vulgaris*), goannas, honeybees and occasionally galahs (*Elophus* [*Cacatua*] *roseicapilla*).

Damage

The majority of damage by ringnecks in horticulture is attributed to the 'Port Lincoln' and, to a lesser extent, the 'twenty-eight' parrots. The other races are generally declining in range and abundance and rarely occur in populations large enough to cause economic impact. The dark-headed races, however, can cause significant damage to apples, pears, plums, peach, nectarines, cherries, grapes, blueberries, blackberries, *Citrus* spp., olives, almonds, vegetables and cultivated flowers. A preference for red-skinned apple varieties and pears, plums and nectarines is evident in some regions. Fruit damage occurs when ringnecks tear chunks of fruit and remove and discard the skin, but they will also consume fallen fruit. Secondary losses also occur with fungal and other infections. Ensuing damage is also done by western rosellas which more often consume fruit already attacked by ringnecks or red-capped parrots. Ringnecks are also known to damage cereal crops, garden plants and forestry plantations. Damage to plantations of York gum (*E. loxophleba*), Tasmanian blue gum (*E. globulus*) and wandoo (*E. wandoo*) is common; damage to the trunks, foliage and young shoots can cause deformities. The greatest economic damage occurs when trees are young and the base sawlog is vulnerable. Young plants in revegetation programmes and native plants and shrubs such as *Xanthorrhea* spp. or farm trees are also at risk. Damage is particularly severe during seasons of poor *Eucalyptus* spp. flowering.

Protection status

Protected.

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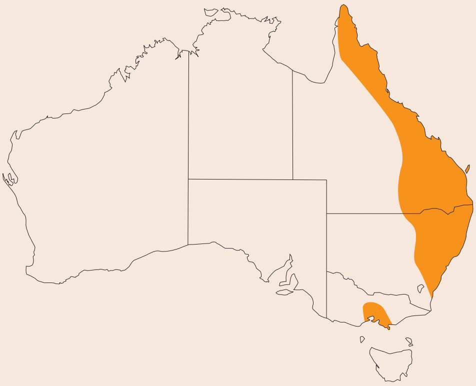
Scaly-breasted lorikeet

(*Trichoglossus chlorolepidotus*)

Other names

Green, green and gold, or green and yellow lorikeet; greenie; lory; green keet.

Photo: G. Chapman.



Birds Australia Atlas (1998–2002)

Field identification

This is the only lorikeet with a completely green head. The scaly-breasted lorikeet has a bright red bill. There are yellow borders to the neck and breast feathers, giving a scaly appearance, but otherwise it is a uniformly leaf-green lorikeet, with an orange-red underwing. The spectacular underwing colour is often used to distinguish species during flight. Scaly-breasted lorikeets exhibit similar habitat use, movement, feeding and breeding patterns to rainbow lorikeets (*Trichoglossus haematodus*). They often co-occur in mixed flocks and also occasionally interbreed.

Voice

Resembles the call of the rainbow lorikeet but is often sharper and louder.

Habitat

Scaly-breasted lorikeets occupy a similar distribution and habitats to rainbow lorikeets in eastern Australia, but are more prevalent in open agricultural and coastal lowland areas. They avoid rainforest. Scaly-breasted lorikeets are common in woodlands and heaths dominated by *Eucalyptus* spp., *Melaleuca* spp., dry *Casuarina* spp., *Xanthorrhea* spp., *Banksia* spp. and *Callistemon* spp. They are widespread in suburban parks and gardens and horticultural areas.

Movements

Like other lorikeets, scaly-breasted lorikeets are nomadic and their population densities fluctuate in accordance with the flowering patterns of plants and shrubs. They utilise mainly coastal habitats, occasionally travelling inland along river systems. No substantial north–south movement is evident with the seasons, but flocks can traverse large distances in short periods. The scaly-breasted lorikeet is predominantly a lowland species, more so than the rainbow lorikeet, although northern populations will venture to higher altitudes. Some individuals display more sedentary traits, especially in urban areas. An isolated breeding population has become established around Melbourne from aviary escapees and these are also largely resident birds. The species is gregarious, particularly when feeding and roosting. They travel from roosting sites at dawn and congregate in feeding trees, usually high in the canopy. Typically, the scaly-breasted lorikeet loafs in nearby trees during the middle of the day, before it begins its pre-roost feeding activities.

Foods and feeding behaviour

Primarily nectivorous, scaly-breasted lorikeets feed from a range of native plants, particularly *Eucalyptus* spp., *Melaleuca* spp., *Tristania* spp., *Banksia* spp., *Callistemon* spp. and *Xanthorrhea* spp. Trees and shrubs planted in urban areas are also commonly visited for their blossoms and include coral trees (*Erythrina indica*), flowering rain trees (*Pithecolobium saman*) and umbrella trees (*Schefflera actinophylla*). Fruit, flowers, pollen, seeds and insects also comprise various proportions of their diet. Fruits of figs, mistletoes (for example, *Notothixos cornifolius*), native elms (*Celtis paniculata*) and horticultural cultivars are commonly consumed when available.

Mixed flocks with rainbow, musk and little lorikeets often form at feeding sites where large groups (more than 500) can congregate. Typically, feeding groups are smaller, averaging about five. Scaly-breasted lorikeets are acrobatic feeders, but because of their leaf-green plumage they are usually first acknowledged by their noisy chattering, rather than by sight. They habitually forage in the outer canopy branches where blossoms are often more abundant. Occasionally pairs or individuals may defend food trees, driving away other species such as other lorikeets and noisy miners, although this is uncommon, particularly in areas of abundant fruit or nectar. Groups will feed throughout the day, but peak feeding usually occurs in early mornings and late afternoons.

Breeding

Breeding can occur at any time during the year, possibly in response to abundant flowering, but it usually takes place between July and November. Tree hollows with small entrances, high in *Eucalyptus* spp. trees, are prepared by both sexes by chewing entrances and lining nests with a fine layer of wood dust. Considerable effort is given to removing decaying wood and any nesting material of other species. Two, or rarely three, eggs (25 × 20 millimetres) are laid and then incubated by the female for about 25 days. Both sexes feed the young and may roost inside the hollow for the eight weeks until the young leave the nest.

Damage

Scaly-breasted lorikeets, often in association with other lorikeets, can cause damage in vineyards and peach, nectarine, orange, mandarin and custard apple orchards. Damage can be severe, particularly in localised areas of Queensland, where large flocks cause considerable damage in short periods. They are likely also to damage a variety of other stone and pome fruits, including plums, cherries, apricots, apples and pears. Large flocks also invade grain crops, causing damage to *Sorghum* spp. and maize fields in Queensland and northern New South Wales. Chewing and consumption of buds, flowers and leaves of horticultural crops is common; hence cultivated flowers are also susceptible.

Protection status

Protected.

Sources and further reading

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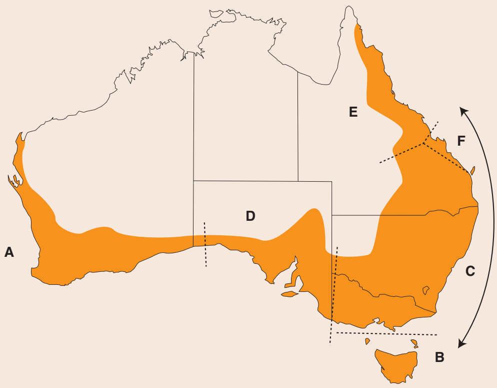
Silvereye
(*Zosterops lateralis*)

Other names

Wax-eye; white-eye; grey-breasted white-eye; ring-eye.

Photo: L. Pedler.



Birds Australia Atlas (1998-2002)

Field identification

Small, evasive and fast moving, silvereyes are the smallest (10–13 centimetres head to tail) pest birds of horticulture. They have olive yellow to olive green on the head, upper surface of the wings, rump and tail with the abdomen varying from dull cinnamon through grey-brown to grey or white with the under tail being white or light yellow. Their name comes from their characteristic white eye-ring and they have a short, sharp-pointed bill. They are often seen in large flocks flying at height or darting between foliage of shrubs and trees. Eight races are now recognised in Australia and are distinguishable only by slight variations in colour, behaviour and distribution.

All races are grey-backed, except the Western Australian race '*chloronotus*'(A), which has an olive-green back, green-yellow throat, and pale buff flanks. Grey-backed races include '*lateralis*'(B), which has deep rufous flanks and breeds in Tasmania and migrates, overlapping the mainland races and extending as far north as Rockhampton (shown by arrow); '*cornwalli*'(C), which has pale rufous flanks and occurs from south-east Queensland to Victoria; '*pinarochrous*'(D), which is the same as '*lateralis*' but duller and resides in south-east South Australia; and '*vegetus*' (E), the same as '*cornwalli*' but smaller and lives in coastal north-east Queensland. Isolated island populations are those of '*chlorocephala*'(F), the largest of the races, which has a heavier bill and is restricted to the Bunker and Capricorn islands off Gladstone, Queensland; '*tephropleurus*' of Lord Howe Island; and '*ochrochorus*' of King Island in Bass Strait. Another possible race, '*westernensis*', replaces '*cornwalli*' in south and south-east Victoria. The following sections focus on the mainland races and '*lateralis*', as they are the ones that cause damage to horticulture.

Voice

A characteristic high, sharp 'tseep' as a contact call; other calls vary from a series of shrill short notes to softer drawn-out mimicry.

Habitat

Silvereyes frequent a diverse range of habitat types, including wet and dry sclerophyll forest and woodland, rainforest, mallee (e.g. *Eucalyptus diversifolia*, *E. rugosa*) shrubland, coastal heath, mangroves, farmlands, parks, gardens, orchards and vineyards. Some regional preferences are evident, with favoured habitats including marri (*Corymbia calophylla*) and coastal heath in Western Australia; manna gum (*Eucalyptus viminalis*)/peppermint (*E. radiata*) associations and red ironbark (*E. sideroxylon*) in the eastern States; *Banksia* spp. and *Grevillea* spp. shrublands; and fruiting trees and shrubs from suburbia and horticultural areas. Open savannah and arid areas are avoided.

Movements

This species is mainly migratory, travelling large distances, particularly along Australia's east coast, where movements of up to 1600 kilometres have been recorded. Southern populations, especially '*lateralis*', exhibit clear migratory patterns, regularly traversing Bass Strait in early autumn and extending as far as Rockhampton, Queensland, by May. In eastern Australia, seasonal movements increase with latitude; hence northern races such as '*vegetus*' rarely migrate large distances. Instead, they are mainly sedentary or display regional nomadic movements in response to fluctuating food supplies. In Western Australia, silvereyes ('*chloronotus*') are also primarily nomadic. This race travels inland when coastal food sources diminish and return to utilise spring flowering species, rather than displaying innate migratory movements. In comparison, numerous individuals of the south-eastern mainland races regularly move north during winter and are replaced by the Tasmanian race as they advance north. Most migrate at night following established routes and visit particular sites in consecutive seasons. Some pairs and individuals will not migrate and certain silvereyes migrate in some years but not others.

Daily movements vary highly with food availability. During the breeding season (August to February) males and females establish small territories which they defend, but they often traverse a larger home range and occasionally congregate around important food sources. They will also travel to distant food sources despite the presence of equivalent locally available food. Perhaps this is for the benefits of communal feeding or to detract predators and other silvereyes from their nesting sites. Despite occasional forays for food, home range size during breeding is often confined to less than one hectare. After January large flocks congregate including many juveniles that disperse natal areas or begin annual migration.

Foods and feeding behaviour

Silvereyes are generalist feeders, favouring insects, nectar and fruit. They prey upon a variety of insects and consume nectar, fruit and seeds from a range of native and introduced plants. High volumes of invertebrates are regularly consumed in larvae and adult form, particularly moths (Noctuidae), bugs (Hemiptera), scale insects (Sternorryncha), spiders, beetles (Coleoptera), wasps (Hymenoptera) and flies (Diptera). They also often exploit nectar and fruit, preferring native trees and shrubs such as marri (*Corymbia calophylla*), karri (*Eucalyptus diversicolor*), red ironbark (*E. sideroxyloni*), *Leptospermum* spp., *Callistemon* spp., seaberry saltbush (*Rhagodia candolleana*) and native rose (*Boronia serrulata*). Introduced species, including coral trees (*Erythrina* spp.), lantana (*Lantana camara*), holly (*Ilex europaeus*), wild tobacco (*Nicotiana* spp.), cape gooseberries (*Physalis peruviana*) and many cultivated fruits, are utilised especially when nectar from native species is scarce. Food scraps in suburban areas are also consumed on occasion.

Frequently arboreal, they access lower branches of trees and shrubs, hawking insects and gleaning psyllids (Sternorryncha) and other insects from leaves and twigs. Ground and high canopy feeding is also common. During migration, silvereyes travel large distances daily to visit feeding sites. Sedentary sub-populations often move short distances but vary their daily travel according to food accessibility. Extremely large flocks can arrive at feeding sites. Although flock size varies with latitude, the largest flocks usually occur following the influx of juvenile birds after January.

Breeding

Both sexes build a small nest cup from hair, fine grass and spider-web, which is well concealed in the outer foliage of shrubs, low tree canopy or grape vines. Two to four pale blue eggs (17 × 13 millimetres) are laid, usually twice, but up to four times, in a season (August–February). Hence, populations can increase rapidly in ideal conditions with maximum numbers of juveniles during January. The ten-day incubation period and the feeding of young are shared between sexes. High mortality rates following breeding are likely but difficult to measure in migratory populations. The main causes are probably vulnerability to exposure and fatigue during migration and predators such as birds of prey, goannas, mice, rats and cats. Silvereyes are known from banding records to live up to 11 years in the wild, but the average age is two.

Damage

Silvereyes probably cause the greatest damage to Australian horticulture of any native bird. They frequently damage wine and table grapes (Figure B.12), cherries, peaches, nectarines, plums, blueberries, apricots, apples, pears, tropical fruit, olives, tomatoes and capsicum. Losses are particularly severe when native nectar sources are unavailable and during migration when high-energy food sources are sought. Nectar and native fruit are preferred over horticultural crops but are often in short supply due to clearing of native vegetation, during dry seasons through lack of flowers, or in excessive wet periods when nectar may become diluted. Although variable, higher nectar yields often occur following warm autumns and springs. Cooler temperatures during nectar production also increase nectar yields.

Figure B.12: *Silvereye pecking damage to grapes (left). Photo: R. Sinclair; and silvereyes feeding on persimmon (right). Photo: W. Taylor.*

Silvereyes puncture fruit with their sharp bills, creating small diamond-shaped holes and they lap at the flesh with their brush-tipped tongues. This often causes secondary losses by attracting insects such as wasps (Hymenoptera), bees, and ants and promotes the growth of fungi including *Botrytis cinerea*, yeast and other infections. They will also feed on fallen and previously damaged fruit, in some cases targeting these in preference to unspoiled portions. They also potentially contribute to the dispersal of weeds such as bridal creeper (*Asparagus asparagoides*), lantana (*Lantana camara*), bitou bush (*Chrysanthemopides monilifera*) and privet (*Ligustrum* spp.). However, they often avoid swallowing large fruit, so they may be inefficient at dispersing seeds of large-fruited weed species.

Outside or during the early stages of the ripening period, silvereyes can be important predators of insects. For example, they are known to consume large volumes of codling moth (*Cydia pomonella*) larvae, a serious pest in apple orchards, and are implicated in controlling the potato moth (*Phthorimaea operculella*), a vector of the granulosis virus.

Protection status

Protected, but locally unprotected in some States and regions (Section 6.1).

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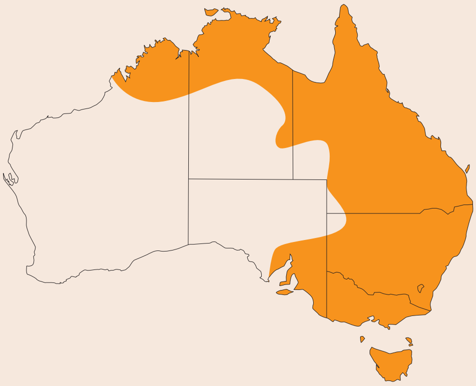
Sulphur-crested cockatoo
(*Cacatua galerita*)

Other names

White cockatoo; greater sulphur-crested cockatoo.

Photo: M. Bomford.



Birds Australia Atlas (1998–2002)

Field identification

This species is a large (48–55 centimetres head to tail) white bird with a prominent yellow crest that curves forward (downward over the beak when the crest is raised). Both sexes are similar, differing slightly in size and iris colour. This species has a distinctive uneven flight pattern, with a series of wing beats followed by a glide. Often seen in large flocks and communal roosts, but also occurs in pairs and small groups, particularly in the tropics and during the breeding season. They associate with galahs (*Elophus* [*Cacatua*] *roseicapilla*) and corellas (long-billed (*Cacatua tenuirostris*), western or little (*C. sanguinea*)) while feeding. Corellas can be distinguished by their smaller and leaner stature and shallow wing beats during flight.

Voice

A single distinctive screech as a contact call; an occasional high-pitched call while roosting or feeding, and a series of harsh screeches when alarmed.

Habitat

Sulphur-crested cockatoos are common in a variety of habitats in eastern, northern and southern Australia in sclerophyll forests, pine forests and rainforests; *Eucalyptus* and *Casuarina* woodland; cultivated areas; parklands; and open savannas. Open pasture and croplands, where vegetation persists along watercourses, are preferred. Hence this species has benefited from clearing, cropping and improved access to water. They often roost in tall, dense stands of *Eucalyptus* spp. where water is close by, but will move some distance to feeding sites.

Movements

Considered mainly sedentary, this species seldom moves large distances between seasons, although it may occasionally relocate for breeding or food or to escape adverse climatic conditions. Local movements usually occur along watercourses, but flocks can transverse large open areas for food. Despite daily movements of up to six kilometres, they maintain fidelity to roosting sites. They form larger flocks and travel further in autumn, when not breeding. During this period flocks are often more likely to travel into cleared or cultivated areas. Similarly, during the breeding season birds are more dispersed and tend to be resident. Highest densities occur just after breeding.

Foods and feeding behaviour

Sulphur-crested cockatoos have a varied diet of grass and plant seeds, nuts, fruits, green leaves and stems, flowers, bark, roots, bulbs, rhizomes and insect larvae. Where available, seeds, grain and onion grass (*Romulea rosea*) corms comprise the majority of their diet. Hence birds are mainly observed feeding in open areas. They are also attracted to fruit, seeds and flowers of trees more common in northern parts of Australia.

Larger flocks form while feeding, rather than when day-time roosting or flying, where groups can consist of a few birds to several hundred. Feeding flocks also tend to be larger in more open habitats. The majority of feeding usually occurs in the morning and afternoon. Morning feeding usually takes place around one hour after sunrise and in the afternoon in the two to three hours before sunset. Larger flocks gather during the afternoon session. Feeding forays usually last one to two hours, but this varies with the season and region. For example, in some regions feeding is more common in the middle of the day, especially during the cooler months. Conversely, midday feeding is rare in summer, when temperatures are highest.

Breeding

Breeding normally occurs from July to December. Hollow entrances and linings are chewed in branches or trunks of mature trees. Most commonly, nest hollows occur at 5–20 metres height in *Eucalyptus* spp. trees, in close proximity to water. Nesting also occasionally occurs in cliff faces and in mature *Melaleuca* spp. and *Angophora* spp. trees. A single pair of cockatoos will nest in each tree despite the regular occurrence of multiple hollows. They have, however, been recorded sharing trees with other species, including galahs, kookaburras (*Dacelo novaeguineae*), barn owls (*Tyto alba*) and starlings (*Sturnus vulgaris*).

Males and females usually visit hollows throughout the year. Both sexes prepare the nest, incubate eggs (which takes about 30 days) and feed the young. Two or three white eggs are laid on a bed of wood chips 2–10 centimetres deep. However, pairs average less than one fledgling per year as a result of egg infertility, egg predation by lace monitors, possums, and carpet pythons, nest occupation by bees and trapping for aviculture. Fledging occurs at around 10 weeks, but juveniles are fed by their parents for a further six weeks after leaving the nest. From banding studies cockatoos are known to live beyond eight years in the wild, but many are likely to be older as captive birds have lived beyond 100 years.

Damage

Damage to horticulture is often to buds, shoots and growing stems, rather than fruit. However, sulphur-crested cockatoos are well known for removing large chunks of, or splitting, pome and stone fruit to get at the seeds. Seeds of citrus fruits are also consumed. The size of the bitten-off pieces can be used to distinguish cockatoo damage from damage by smaller species. Damage to fruit occurs when the birds consume fruit on the branch and knock others to the ground or remove whole fruits and fly to an adjacent roosting tree. They also damage nuts, such as hazelnuts, almonds, walnuts, pecans, chestnuts and pistachios, by cracking the shells.

Figure B.13: *Cockatoo damage to sunflower. Photo: P. Fleming.*

Cockatoos also chew buds and young shoots including those of cherries, grapevines and peanut shrubs; and they chew bark and foliage and strip it from orchard trees. Significant damage to limbs and fruiting spurs can occur when a flock lands in a single orchard tree, simply due to the weight of the birds. Mature grape bunches are often snipped directly from the vines. The birds also damage a range of cereal grain and oilseed crops (e.g. sunflower, Figure B.13) by digging up sown seed and feeding on seed heads. Vegetable crops are also susceptible to cockatoo damage and the birds can cause havoc in nurseries by damaging seedling stock.

Cockatoo and parrot species chew on various materials to maintain their beaks. Damage to infrastructure such as irrigation systems, coaxial cables, electrical insulators, radio and television aerials and red cedar building materials for beak maintenance is common.

Protection status

Protected, but locally unprotected in some regions (Section 6.1).

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Factsheets: Introduced species

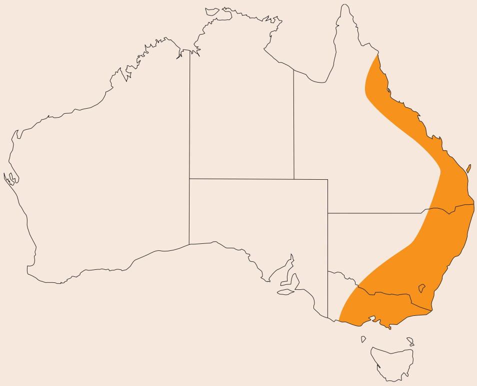
Common myna

(*Acridotheres tristis*)

Other names

Indian, Calcutta or house myna; mynah.

Photo: M. Bomford.



Birds Australia Atlas (1998–2002)

Field identification

The myna is a medium-sized (25–26 centimetres head to tail) but heavily built bird with mainly brown plumage. It has a dark brown to black head with a bright yellow patch behind the eye, and a yellow bill, legs and feet. The wing patch, under-tail covets and tail tip are white. Mynas have a distinct strut or exaggerated hop when moving across the ground and can be in small to very large groups.

Voice

Varied repertoire: a coarse 'karrarr'; a high tri-syllable 'weeo'; and a brisk 'seeit' in alarm.

Habitat

The common myna is a common inhabitant of urban areas, savannah, cleared agricultural lands, cultivated paddocks, plantations, canefields and roadside vegetation. Mynas are closely associated with human development, especially following initial introductions. Colonisation of surrounding agricultural areas and open woodlands can occur gradually, usually starting along roads or railways. The birds also have potential to colonise areas away from human settlement, such as coastal mangroves, flood plains and open forest, but are usually at lower density in these areas and avoid dense forests. In the Atherton Tablelands (Queensland) they now occupy all habitats except thick rainforest and populations are steadily expanding into agricultural areas of New South Wales and Victoria. Once the birds are established, dramatic increases in density are apparent. For example, in urban centres such as Canberra, Melbourne and the inner and surrounding areas of Sydney, mynas have proliferated. Preferred roosts are well-sheltered sites, particularly introduced trees and shrubs with dense foliage such as phoenix palms (*Phoenix canariensis*) or introduced pines where they are often observed with starlings (*Sturnus vulgaris*) and sparrows (*Passer domesticus*). Large communal roosts of up to 5000 can occur, but smaller roosts of 40–80 are more typical in Australia. Roosting behaviour involves loud calling at dawn and dusk and occasionally during the night.

Movements

This species is sedentary. No seasonal move ments and only localised dispersal patterns are evident in Australia. Local fluctuations in density are most likely due to high rates of juvenile mortality, which is typical of highly fecund species. Density is therefore highest after the young leave the nest between December and March and lowest during the early stages of breeding in the following season. Intermittent juvenile or adult dispersal can occur along main roads and railways and may become more frequent as populations increase. Daily movements are also confined to small areas, often within three kilometres of a roost site. Pre-roosting flocks assemble in the late afternoons in cleared areas or perching on powerlines, antennae, bridges or other manufactured structures.

Foods and feeding behaviour

Mynas are highly adaptable omnivorous scavengers and feed on a variety of food scraps, fruits, vegetables, grains, seeds, flowers, nectar, young birds, eggs and invertebrates and their larvae. Unlike starlings, which commonly probe for invertebrates below the ground, these birds are 'surface-feeders'. Their diet varies considerably with availability. Insects are regularly consumed in large quantities, particularly beetle (Coleoptera) and moth (Noctuidae) larvae, locusts, grasshoppers (Orthoptera) and flies (Diptera). They are frequent dwellers of rubbish dumps and often consume food scraps around buildings and food-processing plants and along roadsides. Mostly they forage in pairs or small family groups on the ground, but larger groups can feed in trees and shrubs for fruit and seeds. Mynas rarely feed far from roosting or nesting sites and in some urban areas they will restrict foraging to within 100 metres of the roost.

Breeding

Mynas are hole-nesting species. They have similar breeding habits to starlings but are more dominant. Pairs mate for life and vigorously defend territories and nest sites during the breeding season which extends from August to March. Untidy nests of sticks, leaves, paper and other items are prepared in tree hollows, in the tops of palm trees, or in walls and ceilings of buildings. Two, or sometimes three, broods are raised per season, with 3–6 young per brood. Eggs are similar to those of starlings but marginally larger (31 × 22 millimetres) and a brighter blue.

Damage

Mynas can cause considerable damage to ripening fruit, particularly grapes, but also figs, apples, pears, strawberries, blueberries, guava, mangoes and breadfruit. Cereal crops such as maize, wheat and rice are susceptible where they occur near urban areas. Roosting and nesting commensal with humans create aesthetic and health concerns. Mynas are known to carry avian malaria and exotic parasites such as the *Ornithonyssus bursia* mite which can cause dermatitis in humans. The myna can help spread agricultural weeds: for example, it spreads the seeds of *Lantana camara* which has been classed as a Weed of National Significance because of its invasiveness. Mynas are regularly observed to usurp nests and hollows, kill the young and destroy the eggs of native bird species including seabirds and parrots (see list below) and kill small mammals although the extent to which these actions reduce native populations remains unquantified.

List of threatened species that may be adversely affected by the myna:

Regent parrot[1,4]	*Polytelis anthopeplus*
Coxen's double-eyed fig parrot[1,3]	*Cyclopsitta diophthalma coxeni*
Turquoise parrot[1,3]	*Neophema pulchella*
Glossy black cockatoo[1,3]	*Calyptorhynchus lathami*
Little tern[2,3]	*Sterna albifrons*
Hooded plover[2,3]	*Thinornis rubricollis*
Flesh-footed shearwater[2,3]	*Puffinus carneipes*
White tern[2,3]	*Gygis alba*
Sooty tern[2,3]	*Sterna fuscata*

1 Competition for nest hollows.
2 Potential predation of eggs or direct attacks.
3 Occurs within the current distribution of the myna.
4 Occurs within the potential distribution (Martin 1996) of the myna.

Protection status

Unprotected; introduced species.

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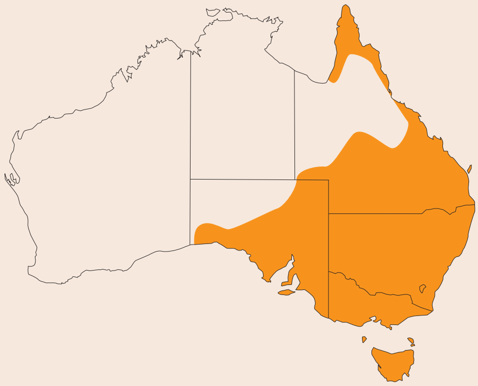
Common starling
(*Sturnus vulgaris*)

Other names

Starling; European or English starling.

Photo: T. Waite.



Birds Australia Atlas (1998–2002)

Field identification

A dark-coloured medium-sized (20 centimetres head to tail) bird, with a sharp pointed bill, relatively short tail and pointed wings. In the breeding season starlings turn a glossy black with metallic purple or green tints, slightly duller in females. The bill turns dull yellow with a blue base on males and a salmon pink base on females, and the legs of both sexes turn from a dark colour to an orangey hue. In non-breeding plumage both males and females are brown and speckled, with a dull grey bill and legs. Females have a darker inner eye ring surrounded by a lighter iris ring, whereas males do not have the light ring. Under-wing coverts are very dark or black in adult males and brown or grey in females, but this can vary among individuals. Males (73–96 grams) generally weigh slightly more than non-gravid females (69–93 grams). Juveniles are uniform grey-brown above and lightly flecked below, with dark bills and grey eyes. They moult into non-breeding adult plumage over summer.

Voice

The call is a collection of wheezy whistles, clicks and scratching notes. Starlings also have the ability to mimic other birds.

Habitat

Starlings are adapted to a variety of habitats and are one of the most common species in lowland suburban and cleared agricultural areas of the south-east mainland and Tasmania. They also occur in open woodlands, irrigated pasture, feedlots, mulga (*Acacia aneura*), mallee (e.g. *Eucalyptus diversifolia*, *E. rugosa*), reed-beds, coastal plains and cliffs, and occasionally in alpine areas. They avoid dense dry sclerophyll woodlands, wet *Eucalyptus* woodlands and forest, rainforest and arid regions. Populations are more marginal in the northern parts of their range, where climate may partly limit their establishment. Water availability appears important and hence high rainfall regions, irrigated areas, temporary surface water and flooded drainage swamps attract high densities.

In Western Australia the climate is suitable for range expansion, but to date, starlings have failed to colonise this suitable habitat because of the barrier offered by the Nullarbor Plain and concerted efforts to eradicate colonising populations. Recently, a population has been discovered around Esperance, and, at the time of writing, the feasibility of eradication, or at least containment, was being considered.

Preferred night roosts are introduced plants with dense foliage including Africa boxthorn (*Lycium ferocissimum*), firethorn (*Pyracantha* spp.), hawthorn (*Crataegus momgyna*), plane trees (*Platanus orientalis*.), palms (Palmae), willows (*Salix* spp.), cypress (*Cupressus* spp., *Chamaecyparis* spp. or *Callitris oblonga*), pines and cedars (Pinaceae), oak (*Quercus* spp.) and reed beds, or concealed cavities in human structures or cliffs. Prominent areas such as powerlines, dead trees, building roofs and aerials are often used throughout the day for perching and preening.

Movements

Following fledging, young starlings disperse in search of food and shelter. Juveniles may move great distances to feed. For example, Cabe (1999) found that the average distance moved by juveniles in the USA was 104 kilometres, although distance varied greatly among individuals. Just over half the birds returned to their birth sites to breed (Cabe 1999). One study of banded juveniles found 20% moving more than 100 kilometres from their birth sites, whereas another 20% from the same colony moved less than ten kilometres (Feare 1984).

In contrast to the migratory populations in northern Europe and North America, starlings in Australia display no large-scale seasonal movements. Australian starlings are generally sedentary, with an average movement of two kilometres recorded from banding recoveries and a maximum of 987 kilometres. Although starlings will shift regionally, movements are generally more localised than those of nomadic lorikeets and honeyeaters (Meliphagidae) which travel larger distances seeking nectar from flowering plants. However, Australian starlings commonly make small regional movements according to food availability, particularly in cultivated and cleared agricultural areas. In urban areas starlings are more sedentary, with seasonal fluctuations in abundance because of high juvenile mortality and dispersal rates.

Foods and feeding behaviour

Starlings have an extremely diverse diet that varies seasonally, geographically, and with the age of individuals. Food items range from fruits and seeds to skinks, worms and snails, with arthropods being the most numerous and diverse group of organisms eaten by starlings in Australia. However, starlings are highly adaptive and in time of food scarcity will eat almost anything, including garbage. Their diet is restricted by both the size of food items and by amounts, since the bill is more suited to probing and the gut lacks a crop that would usually facilitate gorging. Starlings need to drink water daily.

Invertebrates generally make up about half the starling's diet and are especially important for laying mothers and their young. Olives, when present, are also a food staple for adults and young during the breeding season. Juveniles tend to eat more plant foods, most likely because of inexperience in foraging for insects.

Starlings prefer to feed in short grass, primarily in cow and sheep paddocks or on lawns. They often forage in large flocks, taking insects disturbed by grazing animals, and they also take larvae, insects and herbage directly from the ground. Starlings also probe the bark of trees for insects and 'oxpeck' sheep, as well as catching flying insects on the wing. Starlings may be beneficial in some agricultural areas, taking crop-damaging larvae with their probe-like bill, but this benefit has not been scientifically confirmed. Other feeding sites vary seasonally and include orchards, vineyards, cereal crops, feedlots and rubbish sites. Feeding duration in cereal and horticultural crops, where birds can rapidly eat a large quantity of food, is usually shorter than the time spent in other feeding areas. Once a feeding pattern is established, starlings will use the same sites for extended periods, but unlike other bird species they have no consistent peak feeding times.

Starlings feed in large flocks of up to 20 000; this is thought to improve their feeding efficiency and to decrease predation by birds of prey. As the breeding season approaches, feeding flocks become progressively smaller as more time is spent at feeding sites that are close to the nest.

Breeding

Sexual activity and nest building peak in early spring (August–September). Starlings form pairs and nest in tree hollows, holes in the ground and gaps or crevices in cliffs, tree stumps, fence-posts and eaves and under roofs of buildings. They frequently reuse the same hollows for initiating second broods. The male builds a small cup-shaped nest within the hollow. Both inter- and intra-specific aggression is used during the breeding season to acquire and defend nest sites. Males may even kill each other in such encounters. Nest usurpation, whereby starlings aggressively take over the active nest of another species, has also been documented.

A suite of factors influences laying date, including day length, food availability, social cues and climate. In Australia, laying generally begins in August–September and continues until December–January. Incubation lasts 12 days, during which time females spend 80% of their time on the nest. Males also help in incubation for short periods. A female may have up to three broods a year, and clutch size ranges from one to seven eggs with a mean range of 3.8–4.9. Nestlings fledge at 20–23 days.

Damage

Starlings cause significant damage to horticultural industries, particularly cherries, grapes (Figure B.14), blueberries, olives, stone fruits, apples, pears (Figure B.15) and a range of vegetable crops. Dried fruit industries are also susceptible, with damage evident in currants, sultanas, raisins and dried stone fruits; birds occasionally remove fruit from drying racks. Fruit damage can start up to six weeks before harvest but increases in severity during ripening. Upper branches with sparse vegetation often attract the heaviest damage. Whole berries from olives, grapes and cherries are removed and swallowed; larger fruits display a series of sharp peck marks.

Cereal crops are susceptible when grain is freshly sown and during ripening. Starlings also take grain from feedlots, storage areas, piggeries, dairies and poultry farms.

Figure B.14: *Starling damage to grapes, where whole grapes are removed, leaving a brush-like stalk. Photo: J. Tracey.*

Starlings can carry many parasites and diseases, raising concern in food factories and industrial areas and are a potential risk to livestock industries. For example, they are implicated in carrying (and in some cases transmitting), salmonella, cryptococci, Newcastle disease (poultry), transmissible gastroenteritis (pigs), eastern encephalitis (horses) and foot-and-mouth disease (ungulates), although the risks remain unquantified. Damage to infrastructure is commonly reported, particularly the fouling of roof cavities wth faecal matter and with nesting material. Environmental impacts, particularly the usurping of nest hollows, is potentially serious for some native species, for example, Coxen's double-eyed fig parrot (*Cyclopsitta diophthalma coxeni*) and the turquoise parrot (*Neophema pulchella*). The spread of environmental weeds such as olives by starlings is also an emerging issue. Aesthetic problems are also common because of the formation of large noisy roosts in urban areas.

Protection status

Unprotected; introduced species.

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Figure B.15: *Juvenile starling feeding on Nashi pear. Photo: J. Tracey.*

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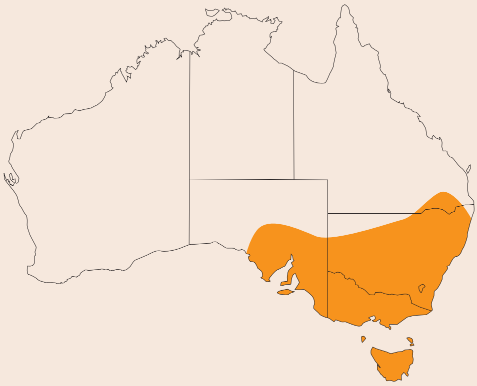
European blackbird

(*Turdus merula*)

Other names

Common Eurasian, European or Fennoscandian blackbird; ousel.

Photo: Sannse/Wikipedia.



Birds Australia Atlas (1998–2002)

Field identification

The male European blackbird is a uniformly black, medium-sized (25 centimetres head to tail) bird with a yellow to orange bill and eye-ring. The bill is almost red-orange in forested habitats. The tail is long and rounded, obvious in flight. Females are dark brown with faint streaks on the chest and also have a duller yellow-brown bill. Juveniles are similar to females but have a tinge of rufous on the chest plumage. Blackbirds tend to be a shy species, spending much of their time close to cover either foraging in leaf litter, mulch or grass or in shrubbery. Movement across the ground is by jerky hops often followed by wing and tail flicks. They tend to fly fast but undulating and low to the ground when flushed to rapidly regain cover. Native of Europe, North Africa and southern Asia, the European blackbird is a member of the Muscicapidae family (true thrushes). It shares a genus with the song thrush (*Turdus philomelos*), which was also introduced to Australia in the late 1850s.

Voice

Musical fluting song; a high, harsh 'tsee tsee' in alarm.

Habitat

The European blackbird is common in most habitats of south-eastern Australia, displaying a preference for urban bushland, parks, gardens and horticultural areas. Unlike the song thrush, which is restricted to the urban areas of Melbourne, the European blackbird has colonised many types of natural habitat, including riverine vegetation, rainforest, wet sclerophyll, dry *Eucalyptus* woodlands, coastal heath and even mallee (e.g. *Eucalyptus diversifolia*, *E. rugosa*). Their distribution continues to expand, particularly along the Murray-Darling river systems to the north. Vegetated river systems in other areas are also thought to aid dispersal. Local densities are generally stable, although slight decreases are evident in suburban Canberra. Birds of this species often prefer areas with a combination of open or cleared pasture and a dense shrub layer.

Movements

The European blackbird is sedentary in Australia, with few movements greater than 10 kilometres recorded. They are known to be partial migrants in Europe, particularly in the northern extremes of their range. In Australia large movements of up to 500 kilometres can occur, but are likely to be made by juveniles dispersing after the breeding season. Solitary or in pairs, small territories are defended year round, but particularly during the breeding season. European blackbirds roost in the thick foliage of shrubs and trees, forage in open areas, shrubs and leaf litter during the day, and return to roost in the late afternoon.

Foods and feeding behaviour

Blackbirds predominantly rely on arthropods, including ground invertebrates, flying insects, earthworms, snails and spiders, but they also consume variable amounts of fruit, small reptiles and vegetable matter. Foraging mainly on the ground, they rake at leaf litter and probe open pasture and lawns in urban areas. European blackbirds are occasionally arboreal and consume native (for example *Exocarpus cupressiformis*) and cultivated (for example, olive, blackberry, grape, fig) fruits. European blackbirds are implicated in spreading some of these species into new areas. They vigorously defend territories and are aggressive towards other bird species, especially for several weeks leading up to, and during, their breeding season, but they are more tolerant during other times of the year.

Breeding

Three to five pale blue-green eggs with reddish brown spots (34 × 23 millimetres) are laid in a large, deep bowl of dry grass, bark strips and leaves bound by mud. Nests are usually well concealed and suspended from less than one metre to as high as 12 metres, in the top of a stump or log or in an upright fork amongst bracken fern or other dense tree or shrub foliage. Eggs are incubated by the female for 12–14 days. European blackbirds continue to raise broods under ideal conditions, mostly from August to February. Nesting failure is often caused by predation, particularly by the pied currawong (*Strepera graculina*). Replacement clutches are usually laid — in one case five unsuccessful attempts were recorded during a season.

Damage

If fruit is available European blackbirds will consume it throughout the year. Grapes (Figure B.16), cherries, peaches, nectarines, figs, olives and berries are particularly susceptible. Damage to vineyards and orchards is often associated with the presence of adjacent shrubs and dense garden plants. Hence damage is concentrated around these features. Small fruits, including

Figure B.16: *Blackbird damage to grapes, showing cleanly plucked berries on hidden bunches inside the canopy. Most damage occurs at ends of rows near cover. Photo R. Sinclair.*

grapes, cherries, olives and figs, are usually taken whole and consumed in nearby vegetation. Although sedentary, European blackbirds have been implicated in the spread of weed species including blackberries, olives and sweet pittosporum (*Pittosporum undulatum*). They also have the potential to compete with native bird species, including the closely related bassian thrush (*Zoothera lunulata*) and the grey shrike-thrush (*Colluricincla harmonica*).

Protection status

Unprotected; introduced species.

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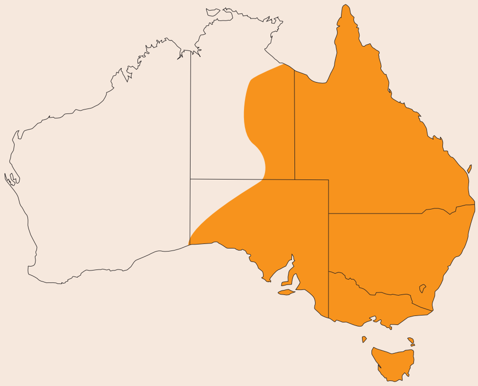
House sparrow
(*Passer domesticus*)

Other names

English or Eurasian sparrow.

Photo: G. Dabb.



Birds Australia Atlas (1998–2002)

Field identification

This small (14–16 centimetres head to tail) bird is sexually dimorphic. Males have a grey crown, a chestnut back and neck and chestnut wings with black tips, white cheeks, and a grey rump and tail. Their black bib is increasingly prominent with status, particularly during breeding. Dominant males display the largest bibs. Females are a uniform pale grey, with dark streaks on the wings. Males and females are a similar size.

Voice:

Continual, jangly 'cheerup' and chirps when feeding or perching; a high-pitched 'treeee' in alarm.

Habitat

Commensal with humans, sparrows inhabit most continents throughout the world. They were introduced to Australia in the 1860s by acclimatisation societies and are now abundant in cities, towns, rural areas and around farm buildings, particularly in the south-east of Australia. They are closely associated with humans and populations are known to decline in towns that have been deserted. They avoid unsettled areas and forested habitats. Their failure to colonise Western Australia may be due in part to the barrier of the Nullarbor Plain and lack of continuous human habitation. Eradication of invading house sparrows also occurs. For example, more than 70 house sparrows were destroyed at Wanneroo in 1994 and 15 were destroyed near Fremantle harbour in 2005 (Government of Western Australia). In rural areas, densities are greatest when properties are small and hence human activity more concentrated. Sparrows roost in trees with dense foliage, including introduced species such as palm trees (*Phoenix* spp.), and in reed beds, roof spaces, or the ivy (*Hedera helix*) surrounding buildings or trees. In urban areas they are more common in the centres of towns and cities rather than in suburban garden areas.

Movements

House sparrows are sedentary and no seasonal movement patterns are evident throughout their range. However, they can disperse rapidly, initially colonising parts of Australia at a rate of over 100 kilometres a year. Conversely, dispersal is limited and gradual in unsettled areas, particularly in drier regions where colonisation can occur at a rate of less than seven kilometres per year. Highly sociable and gregarious, they usually form small colonies but can also congregate in large flocks of several thousand, particularly following the breeding season. Established colonies do not usually move more than a couple of kilometres.

Foods and feeding behaviour

Sparrows feed predominately on seeds and scavenged food waste, but they will also consume flowers, buds, fruits and insects. Vegetable matter, bread, grain and grass and weed seeds, are regularly consumed. Small groups (usually less than 20) forage on the ground along walkways, near rubbish sites and in open areas. This small bird will often aggressively defend feeding locations from smaller species, but it can co-occur with starlings (*Sturnus vulgaris*), mynas (*Acridotheres tristis*) and European blackbirds (*Turdus merula*). Occasionally they forage in the tree foliage, where they catch flying insects and remove and peck fruit.

Breeding

House sparrows build untidy grass and stick dome nests lined with feathers, mainly in gaps of buildings, often under eaves, and between and beneath roofing material. Occasionally they nest on tree branches or in tree hollows, including those of *Eucalyptus* spp. Two to six white to pale grey eggs with dark grey and dark brown spots are incubated for 10–14 days. Young fledge after 14–17 days. They have a long breeding season, which can extend from July to April, with peak breeding between September and February. Two or three broods are commonly raised during this season. Males often switch partners between broods but remain loyal to nest sites, which are aggressively defended from other males and smaller native species.

Damage

Sparrows are considered the most significant pest of crops in New Zealand and commonly cause damage to fruit, vegetable, grain and oilseed crops in Australia. Significant losses have been recorded in pear, apple, berry, cherry, grape (Figure B.17), nectarine, apricot, plum, peach, and loquat orchards. Vegetables and cereals such as tomatoes, lettuce, lucerne, peas, wheat, maize, sunflower, soya bean and rice are often damaged and germinating shoots and seedlings removed. Pecked fruit may often result in secondary losses because the exposed flesh encourages insects and fungal diseases which can spread damage throughout the crop. Considerable amounts of grain can also be lost at feedlots, piggeries and poultry farms. Aesthetic problems arise as a result of faecal deposition in roosting and nesting areas. Drains and gutters can become blocked with nesting material. Sparrows are also susceptible to a range of potential diseases, including salmonellosis, tuberculosis, and *Giardia* and *Cryptosporidium* infection. The prevalence of infection and the bird's importance as a vector for transmission are, however, largely unknown. They are known to usurp native species from nest hollows, although normally they prefer to nest in buildings.

Protection status

Unprotected; introduced species.

Figure B.17: *Pecking damage to grapes by sparrows. Photos: R. Sinclair.*

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Factsheets:
Managing the impacts of birds in horticulture

Introduction

Many native and introduced birds in Australia can cause significant damage to cultivated fruit, nuts, olives and grapes. The main problem species are starlings, sparrows, European blackbirds, silvereyes, parrots and lorikeets, cockatoos, honeyeaters and corvids.

There is a diverse range of options for managing pest birds. They have variable effectiveness and no single solution is applicable to all situations. Most crop damage occurs during the ripening season, which coincides with the busiest time for growers. As a result, bird management is often not initiated until after considerable damage has already occurred. Integrated pest management is a concept well understood for insect and disease problems, but birds are rarely managed in the same strategic way.

Rather than focusing simply on killing as many pests as possible, it is now realised that, as with most other aspects of agriculture, bird management needs to be carefully planned and coordinated. Bird control is just one aspect of an integrated approach to the management of production. Many birds are highly mobile and can readily replace those that are killed in control programmes. Unless actions are well planned and coordinated they are unlikely to have a lasting effect. When planning bird management there are some important steps that should be considered.

What is the problem?

In the past, the pest was usually seen as the only problem. Hence the solution was to kill as many as possible. We now know that the situation is more complex. First, determine what the problem is. It may be reduced crop yields, secondary losses causing downgrading of fruit, complaints from neighbours, or emotional stress from worrying about the next attack. Several things impact on each of these problems and controlling birds is often only part of the solution.

The following questions will help define the problem:

- Where is the problem?
- How severe is the problem?
- Will the problem change with time?

Identify the birds involved

Implementing an effective bird control programme requires a basic understanding of the ecology and biology of the targeted pest species and (in some cases) those species affected directly (non-targets) or indirectly (prey species) by a control programme. Control strategies can be targeted at particular groups of birds. For example, some species such as rosellas, sparrows and European blackbirds are largely sedentary and may live in and around a crop throughout the year. Trying to prevent them from entering and damaging the crop only during the time it is vulnerable is very difficult without applying some out-of-season management of these species. This is in contrast to the control strategies appropriate for species such as silvereyes and many honeyeaters that are highly migratory and only move into crops during specific periods. Their control needs to be initiated only if any of these periods coincide with the time that the crop is vulnerable to damage. Native birds need to be identified because most of these species are protected and permits are required for their control. Furthermore, most native birds are beneficial or desirable, so it is important that management does not affect these species. Conversely, some birds can be both beneficial and pests. Honeyeaters for example, can become a more serious problem in orchards during seasons of poor *Eucalyptus* flowering, but also consume many damaging insects throughout the year. Other information sheets are available on individual pest bird identification, biology, movements, habitat, feeding behaviour and the damage they cause.

Estimate the damage caused to production

Estimating the amount of damage and calculating the cost will provide a basis for deciding how to best reduce pest bird impact and how much the grower can afford to invest in any control effort. The percentage of crop damaged by birds in an orchard block can be estimated by randomly or systematically sampling rows, plants, and individual fruit or bunches. Bird damage to individual fruit or bunches can be estimated by counting, weighing or by using a visual estimate. Often sampling and calculating damage for the edges of a crop separately will increase the efficiency.

Identify any key constraints

Consider legal, social and environmental issues. For example, will scaring devices be acceptable to the local community, and are the techniques legally and/or environmentally responsible and acceptable?

Decide when the most cost-effective time is to implement the plan

Even when good information is available it is often not practicable to be immediately responsive to short-term fluctuations in bird numbers or the damage they cause. When damage becomes significant it is usually too late to implement control. For example, effective use of scaring often requires a 'start early' approach to prevent birds establishing a feeding pattern. Likewise, investment in netting cannot be simply withdrawn for those seasons in which damage is below the cost–benefit threshold. Instead, we may need to look at costs and benefits over a longer time frame and make decisions accordingly. If damage in the area is likely to be high or there is a history of high levels of damage, the grower should be more inclined to invest in continuing management action. Measuring damage this year will help in selecting the optimal management option next year and beyond.

Develop the most appropriate bird management plan

Importantly, the management plan must have details of what will be done, who will do it, when it will be done and how much it will cost. Options can include individual techniques or combinations, and different levels of application. The plan must have long-term, year-to-year strategies to prevent damage and short-term reactive strategies to cope with sudden increases in damage. For example, in the long term, managers may use netting on a small part of their crop every year. In the short term, when damage is higher, they may also implement a scaring programme.

Monitor and evaluate

Has the management been successful? Estimating damage is the most direct way to measure the effectiveness of a management programme. All costs and labour of implementing control should also be considered. For example, nets may have significantly reduced bird damage, but if they are repeatedly removed for maintenance or spraying of the crop there will be additional costs to consider. What worked; what didn't; what can be improved for next year? Evaluating management will enable improved decision-making for future strategies and allows actions to be modified to maximise economic return.

There is no one simple solution for managing birds effectively. However, the following information may help growers decide on the most appropriate actions for their situations.

Management options

Scaring

Many visual and sound devices have been used by managers in an attempt to scare birds. These include LPG gas guns, electronic devices, radio, flashing or rotating lights, scarecrows, reflective mirrors or tape, helium- or air-filled balloons, and predator models or kites. Habituation is the main drawback of all types of scaring. Birds can quickly become accustomed to noise or visual cues and start ignoring them.

Best results for scaring are achieved when:

- combinations of techniques are used;
- scaring starts before birds establish a feeding pattern;
- the sound is reinforced by shooting or a threat; and
- the timing and placement of devices are changed frequently, but not at regular intervals.

The following suggestions may improve or prolong the effectiveness of scaring:

- combining a mix of visual and sound devices;
- loud sounds are more aversive than quiet sounds;
- sounds with a wide frequency range are more aversive than pure tones;
- loud sounds produced by simple cheap methods may be just as effective as sounds produced by expensive devices;
- visual devices are most effective if they incorporate movement such as flashing or flapping;
- devices are more effective when used for the shortest time necessary for a response; discontinue their use when birds are not feeding in the crop or the device is no longer effective;
- adult birds are generally more easily scared than juveniles;
- all species habituate to nearly all sounds tested;
- ultrasonic devices are ineffective, as most birds cannot hear ultrasound (≥ 20 kilohertz);
- broadcast alarm and distress calls can be effective but can result in habituation, as for other sounds; some are species-specific and may cause a 'mobbing' rather than a flight response; and
- birds of prey rarely call when hunting; hence pre-recorded raptor calls are no more likely to scare birds than any other novel sound.

Birds of prey

Attracting birds of prey or the use of falconry is often perceived to be of value in scaring birds or reducing pest numbers. However, although falconry has been used previously at airports to reduce bird strikes, it is impractical in most situations. Falconry is strictly regulated in Australia, requires skilled handlers and considerable training, and is labour intensive.

Encouraging raptors to specific areas is difficult, as different species occupy different ecological niches. For example, sparrowhawks and goshawks prefer hunting among trees and tall shrubs to surprise prey; most falcons prefer open country; and Australian hobbies prefer lightly timbered country along watercourses. The most effective predators of adult birds are unlikely to be attracted by carrion or other food sources. Species that may be attracted (e.g. wedge-tailed eagles, little eagles and whistling kites) do not normally hunt birds in flight. Some studies have shown that providing perches increases the numbers of birds of prey. However, this has not yet been demonstrated to reduce the number of pest birds or the damage they cause. More investigation is required.

Lethal control

Many attempts to kill birds, despite alleviating frustration, often do not reduce damage. The techniques used are usually labour intensive and may have legal, welfare and social concerns. Permits from national parks and wildlife agencies are required for controlling most native species. Pest birds, particularly introduced species, have high population turnover rates and high rates of natural juvenile mortality. Attempts to reduce populations in the long-term need to remove a greater number than are being replaced. Therefore, greater effectiveness may be achieved if the breeding population is targeted.

The use of traps requires considerable labour and is therefore often cost prohibitive. However, trapping may be of benefit in situations where a single resident species is involved and a large proportion of the population can be trapped. A multitude of different trap designs is available, including remotely operated nets, cage and roost traps, funnel-entrance traps, modified Australian crow traps and nest box traps. The success of trapping varies according to the skill of the operator and the time of year. For example, large numbers of starlings can be captured after the breeding season, between late December and May, when many juveniles are congregating. However, this may have little long-term effect on the population size owing to the high breeding potential of starlings, which can produce an average of two clutches of four to five chicks each season. In contrast, removing breeding adult birds during the breeding season (August to November) may result in the capture of fewer individuals but potentially creates a greater reduction in population size for the following summer and autumn.

Shooting is most beneficial when employed as a part of a scaring programme. If regarded as a bird training tool rather than a method of population control, it can educate birds to associate noise with a real threat. To reduce habituation, shooting should be done at the same time scaring devices are used. This establishes a connection between the scarer and danger.

Although some lethal poisons are registered for use in some States (contact the agriculture department in each State or see http://www.apvma.gov.au), their use is strictly regulated. For example, there are products that may be applied only for controlling introduced species, in or around buildings. They can only be used by licensed pest control operators and require site permits from national parks and wildlife agencies.

The reduction of breeding success by removing eggs or nests or applying oil to eggs has not been adequately investigated. This method may be appropriate for highly fecund species and it has the advantage of reducing the need to kill large numbers of birds. Permits must be obtained for native species. Various fertility-control chemicals have been investigated for controlling birds, but none has been sufficiently field tested, nor are any commercially available.

Orchard management and habitat considerations

A range of landscape and habitat factors influence the number of pest birds and the damage they cause. These factors can be considered when the grower is attempting to minimise losses. The varieties grown and timing of maturity can be important. For example, growing varieties that mature simultaneously can help to alleviate the damage to individual growers. Depending on the birds involved, sites with adjacent roosting habitat or powerlines can have higher losses. The numbers of pest birds and the levels of damage will vary according to the preferred habitat of different species. For example, mynas prefer urban environments; cockatoos and starlings are most abundant in cleared agricultural and peri-urban areas; and most native species prefer native vegetation. These factors can be considered before planting new crops.

Providing alternative food sources by decoy or sacrificial planting may be effective in some situations. This relies on knowledge of the feeding habits of the main pest birds involved. A decoy planting ideally will produce food of equivalent or enhanced nutritional value and attractiveness for birds. It should be available just before and during the time that the crop is susceptible to damage. For honeyeaters and lorikeets, revegetating areas with local native trees and shrubs will increase the availability of their preferred food source. This may offer a long-term solution in reducing damage and has obvious environmental benefits. Birds, such as starlings, that prefer insects may be attracted to irrigated areas where large numbers of insects are available. However, supplying alternative foods may also attract more pest birds to the area. Hence, for honeyeaters and lorikeets, a more regional approach to revegetation, rather than localised plantings, may be required. Additionally, a scaring programme is likely to be more effective if alternative food sources are available.

Netting

Exclusion netting using drape-over or permanent nets has high up-front costs but may be appropriate where high-value crops are grown and levels of damage are high. A range of netting options is available. Machines can be used to install and remove drape-over nets of varying width (for example, covering one, two or four rows). ‘Lock-out’ netting provides a continuous cover of netting by joining draped nets without the need for poles and cables. Nets can also be used on infrastructure to prevent birds roosting or nesting. If maintained, netting with ultraviolet stabilisers can provide between five and ten years of protection.

Drape-over netting is more easily damaged than permanent netting and often does not provide as much protection. Permanent netting is easier to maintain and allows easier spraying of vines and trees. Netting overcomes many of the legal, environmental, social and animal welfare concerns of other techniques. The decision to net is mainly an economic one. Will the increase in returns from excluding birds be beneficial over the life of the netting? As an example, cost–benefit analyses on vineyard netting suggest that drape-over nets are cost-effective when damage is consistently greater than 10% and permanent nets are cost-effective when damage is over 25%. The value of the crop and the practicalities of netting must be considered.

Roosting deterrents

A variety of spikes, coils and wire products are available to exclude birds from perching on buildings and infrastructure. Electrified wires, which can be attached to the tops of vineyard trellises, are also available. These wires give birds a small electric shock but do not harm them. Monofilament lines have been successful for deterring larger birds from fish farms but are ineffective for deterring smaller birds from fruit or nut crops.

Chemical deterrents

There are several chemical deterrent products commercially available in Australia. Check with the Australian Pesticides and Veterinary Medicines Authority for up-to-date registration information (http://www.apvma.gov.au/pubcris/subpage_pubcris.shtml) and appropriate app lications. Some deterrents are based on polybutene, which is a tactile roosting repellent; aluminium ammonium sulfate, which acts on a sense of smell and taste; or methiocarb, which is an insecticide that causes conditioned aversion.

Polybutene is a sticky substance that irritates bird's feet and can prevent them from roosting on infrastructure; hence is applicable for buildings and urban areas. Aluminium ammonium sulfate may be applied to vegetables, nuts, fruit, orchard trees and vines, provided that the guidelines on the permit are adhered to (e.g. thorough washing before consumption). However, there is no evidence of its efficacy in deterring birds from feeding. Methiocarb is a secondary repellent that causes birds to become ill, creating a learned aversion to the food. This product may be applied only to ornamental plants, and it is not registered for use on edible fruit or nuts. Garlic and chilli sprays have been used to deter birds from feeding, but again, there is no evidence that they are effective.

Summary of the main points to consider

- Identify the birds causing the damage
  - ⇒ Consider behaviour, movements and legalities.
- Measure the damage
  - ⇒ How much is bird damage actually costing the grower?
- Apply integrated control
  - ⇒ Consider using multiple techniques
  - ⇒ For scaring, start early and use persistence, variation and reinforcement.
- Review the bird management strategy
  - ⇒ Do the benefits outweigh the costs?
  - ⇒ If not, change tactics or do nothing other than monitoring in case damage worsens.

Sources and further reading

This factsheet is based on national guidelines for managing pest birds developed by the Bureau of Rural Sciences and NSW Department of Primary Industries, with assistance from the Natural Heritage Trust and the Australasian Pest Bird Network. The following references are particularly relevant:

Bomford, M. and O'Brien P. (1990) Sonic deterrents in bird damage control: a review of device tests and effectiveness. *Wildlife Society Bulletin* 18: 411–422.

Bomford, M. and Sinclair, R. (2002) Australian research on bird pests: impact, management and future directions. *Emu* 102: 29–45.

Braysher, M. (1993) *Managing Vertebrate Pests: Principles and Strategies.* Australian Government Publishing Service, Canberra.

Braysher, M. and Saunders, G. (2002) *Best Practice Pest Animal Management.* AgNote DAI 279. NSW Department of Primary Industries, Orange NSW.

Kay, B.J., Twigg, L. E., Nicol, H. I. and Korn, T.J. (1994) The use of artificial perches to increase predation on house mice (*Mus domesticus*) by raptors. *Wildlife Research* 21: 95–106.

Sinclair, R. (2000) Guidelines to best practice bird control to minimise losses in vineyards. *Australian Viticulture* Mar/Apr: 60–85.

Sinclair, R. (2005) *A grower's guide to managing birds in South Australian vineyards.* Phylloxera and Grape Industry Board of South Australia, Adelaide.

Tracey, J. (2004) Managing bird pests in orchards. In *Orchard Plant Protection Guide for Deciduous Fruits in NSW 2004/05* (Hetherington, S. D., Bright, J.D. and Thwaite, W.G. eds). NSW Department of Primary Industries, Orange NSW: pp 2–5.

Tracey, J. and Saunders, G. (2003) *Bird damage to the Wine Grape Industry*. Report to the Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry. NSW Agriculture, Orange NSW.

Bird Management Plans

A bird management plan provides a grower with the appropriate information on which to base decisions on how best to manage losses due to pest birds. The level of detail required for a plan will vary according to the nature and scale of both the property and the bird problem.

Set out below is a checklist of the type of information a grower needs to collate to develop a property specific plan, followed by a sample plan for a fictitious property. These are provided as guides only and are neither exhaustive nor intended to be prescriptive.

Checklist of information to develop a bird management plan

Note: detailed guidance on options for measuring and managing bird damage can be found in Chapters 3–7 and Appendix A*.

Property map

Prepare a property map (see Figure FS.1) showing the location of:

- different crops grown;
- varietal blocks;
- surrounding vegetation;
- property features relevant to bird damage
  - powerlines
  - roads and tracks
  - dams, damp or swampy areas, other watering points
  - sheds and farm buildings, especially those used for grain or fodder storage;
- sensitive areas such as
  - property owner's house(s)
  - neighbours' houses
  - nearby townships
  - horse stables and dairys;
- where most damage occurs on individual blocks;
- bird flight lines;
- areas most frequented by birds ;
- areas of high human activity; and
- alternative feed.

Bird problem

Which species cause damage

- list the pest bird species known to visit the property;
- note which species are causing damage in each crop or varietal block;
- rank them in order of importance based on estimated damage caused; and
- determine a pattern of presence for each species
  - those present most of the year (resident)
  - those present only as the crop ripens (migrant/nomad)
  - those present at other specific times.

When does damage occur?

- record expected harvest dates for each crop or varietal block;
- record when damage starts; and
- if possible, compare the data to previous years to establish any patterns.

* Where this factsheet is provided separately, please note that it is an extract from, and makes reference to: Tracey, J., Bomford, M., Hart, Q., Saunders, G. and Sinclair, R. (2007) *Managing Bird Damage to Fruit and Other Horticultural Crops*. Bureau of Rural Sciences, Canberra

What is the cost of bird damage on the property?

If the information is available, collate:

- record(s) from previous years experience; and
- an ongoing record of what is happening in the current year/season.

Estimate for each year:

- the tonnage of crop lost due to birds;
- the total value of the tonnage lost; and
- the value of loss due to dockage for reduced quality of fruit due to birds.

Estimate the cost of bird control activities including:

- depreciated cost of any equipment used for bird control;
- consumable items (fuel, ammunition, gas etc.); and
- labour (include own labour costs).

From the above, calculate the annual cost of bird damage to the business (see Table FS.1).

Management resources

List the bird management resources/techniques available for use on the property, for example:

- visual scarers; e.g. hawk-kites, scarecrows, eye-spot balloons, plastic bags on poles, streamers, shiny tape, air-filled 'scarey-man';
- static noise scarers; e.g. firearm, gas gun, electronic and bioacoustic bird scarers;
- noise scarers combined with movement; e.g. motor bike without a muffler, model or real aircraft, barking dog trained to scare birds;
- exclusion netting;
- habitat management; e.g. decoy feeding, sacrificial crop, strategic mowing, pasture management, irrigation, revegetation; and/or
- culling.

Management and monitoring strategies

Select management strategies to address damage caused by resident and migrant/nomad pest bird species.

Aims

Set a quantifiable aim(s) against which results of management can be compared to measure success; for example, a defined percentage for:

- reduction in the loss of crop;
- increase in yield;
- reduction in current control costs; and
- increase in profit.

Management actions

Prepare separate action lists for resident and migrant/nomad pest bird species.

List the actions to be taken to achieve the aim(s):

- what resources/techniques (of those listed above) will be used to manage the main pest species;
- when will these resources/techniques be used;
- how will these resources/techniques be used (e.g how often, in what order);
- how will the ongoing effectiveness of each resource/technique be maintained;
- where will the resources/techniques be used; and
- who will be responsible for ensuring that these actions are carried out.

Monitoring

Document the monitoring of:

- the management resources/techniques used;
- the actions that have been implemented; and
- what needs to be done to improve the effectiveness of both the resources/ techniques and the actions.

Monitoring records could include:

- an estimate of loss from the same place(s) within the crop on regular occasions throughout the season/period; and/or
- a regular estimate of the number and species of birds feeding on the crop at a particular time of the day.

Communications

The following information should be recorded as part of the plan:

- list all neighbours to the property and their contact details; and
- list with contact details facilities that may be affected by management actions (particularly noise) on the property e.g. schools, hospitals, horse studs.

Record what information will be supplied to neighbours:

- name(s) of property owner/manager; and
- contact details including mobile and after hours phone numbers.

List what action will be taken to notify neighbours:

- prior to implementing the management plan;
- while the plan is activated; and
- if unusual circumstances arise.

List the method of communication to be used:

- phone call
- fax/e-mail
- personal visi
- letterbox drop
- record the date neighbours are contacted.

List what action will be implemented as a result of a complaint by a neighbour and record what action was undertaken.

Sample Bird Management Plan*

This sample plan for a *fictitious* property has been prepared to assist growers in developing their own property-specific bird management plan. It contains more narrative and greater detail than most growers would be willing to set down on paper because the intention of presenting it this way is not to tell growers what to do, but rather to suggest the type of information that could be put into a plan of their own. Although the plan is for a vineyard, the principles it contains will be similar for most horticultural properties.

BIRD MANAGEMENT PLAN
FOR "ORANA" VINEYARD

O'Briens Rd, Ashenville SA 5111
Owner/Operator: J & C Smith
Ph: (05) 8390 0000

"Orana" is a 25 hectare property with 15.5 hectares of grapes in a grape growing district of South Australia. A small seasonal creek runs through the middle of the property. There are open pasture paddocks to the west, native scrub and a powerline on the east, a neighbouring vineyard owner's house to the north-west and a non-producer's residence to the north-east across O'Briens Road.

PROBLEM DEFINITION

a) Where does damage occur on my property?

So that I can see where to put my major effort and devise suitable management actions, I have marked a map of my property (Figure FS.1) with the:

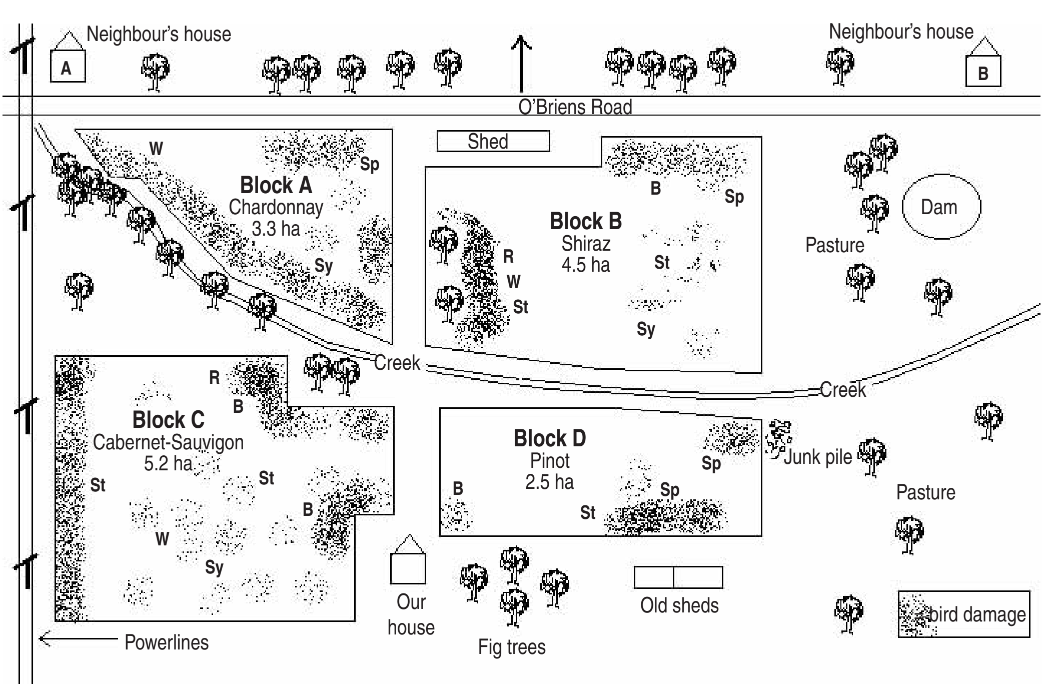
- different varietal blocks;
- features that I think contribute to damage — e.g. a powerline; patches of native scrub along the creek; other structures birds use as cover before entering the crop (e.g. road-side feral olives and boxthorns, a junk pile with a lot of old wire netting, an old shed where sparrows and starlings roost in the roof etc); several large isolated trees used as launch sites;
- features that I think reduce damage (e.g. areas of high human activity near the packing and machinery sheds);
- areas that might offer alternative food (several old fig trees and a pasture paddock adjacent to a dam); and
- potential noise sensitive areas such as the neighbours' residences.

I know from previous years, which parts of the different blocks get the most damage and the areas that seem to be in birds' flight paths – these have been shown on the map.

b) Which species cause damage and what damage do they cause?

Last year I spent some time early in the mornings when the grapes were ripening to watch and record who was doing what in the vineyard. This allows me to prioritise species against which to direct my best efforts. I recorded rosellas, wattlebirds, starlings, silvereyes, crows, grey currawongs, magpies, blackbirds, sparrows, red-rumped parrots and goldfinches in the vines. I did not see magpies, red-rumped parrots or goldfinches doing any damage. Although I could hear currawongs calling and occasionally saw them in the vines, I decided that they, like the crows, were few in number and I could give them a low priority. In the table below, I have ranked the main species according to nature of the damage they cause and my visual estimation of the amount of that type of damage in each block in previous years. I noted whether I thought birds were residents or migrant/nomads.

* Where this factsheet is provided separately, please note that it is an extract from, and makes reference to: Tracey, J., Bomford, M., Hart, Q., Saunders, G. and Sinclair, R. (2007) *Managing Bird Damage to Fruit and Other Horticultural Crops*. Bureau of Rural Sciences, Canberra



Block	Species	Resident or Migrant	Priority	Grape damage
A	Wattlebird	M	1	Neat 3-5 mm peck or hole or completely hollowed out fruit leaving skin only
	Rosella	R	1	Bite across fruit, often leaving seeds
	Silvereye	M	2	Small 1-2 mm triangular peck or hole
	Sparrow	R	2	Skin torn, fruit partly squashed, damaged fruit on ground under vine
	Blackbird	R	2	Fruit cleanly plucked off
B	Starling	M	1	Fruit cleanly plucked off
	Silvereye	M	2	
	Rosella	R	3	
	Wattlebird	R	4	
	Blackbird	M	4	
	Sparrow	R	4	
C	Starling	M	1	
	Blackbird	R	2	
	Wattlebird	M	3	
	Rosella	R	3	
	Silvereye	M	3	
D	Sparrow	R	1	
	Starling	M	2	
	Blackbird	R	3	

MAP KEY

B = Blackbird
R = Rosella
Sp = Sparrow
St = Starling
Sy = Silvereye
W = Wattlebird

Figure FS.1: *"Orana" property map and species prioritisation.*

Starlings and blackbirds together probably account for more individual fruit loss (i.e. plucked fruit) than do wattlebirds, rosellas, silvereyes and sparrows (pecks, bites and tears) but the damage from these latter birds probably costs me more because they leave the damaged fruit on the vine to be harvested. In addition, the damaged grapes allow rots to develop which spread to undamaged grapes and this can be sufficiently widespread to result in significant down-grading of fruit at the winery.

c) When does damage start?

The first signs of damage on each of the four grape varieties on my property usually appear 6-7 weeks before harvest. I have noted on a calendar below when to expect damage as this allows me time to prepare management actions including:

- purchasing scaring items such as eye-spot balloons and hawk-kites;
- constructing scaring devices like scare-crows;
- testing existing equipment, e.g. gas-gun, electronic scarer;
- obtaining a Destruction Permit from the relevant State Government agency (see Appendix E*) in case I need to shoot a few rosellas; and
- talking to my neighbours to give them information about what I will be doing, when it will happen and why I need to do it and to give us the opportunity to sort out any relevant issues.

d) How much do birds cost me?

The amount I am willing to spend on bird management is governed by the losses I am sustaining. This is made up of the value of the yield lost, dockage by the winery for reduced quality and current control costs. Based on last years figures:

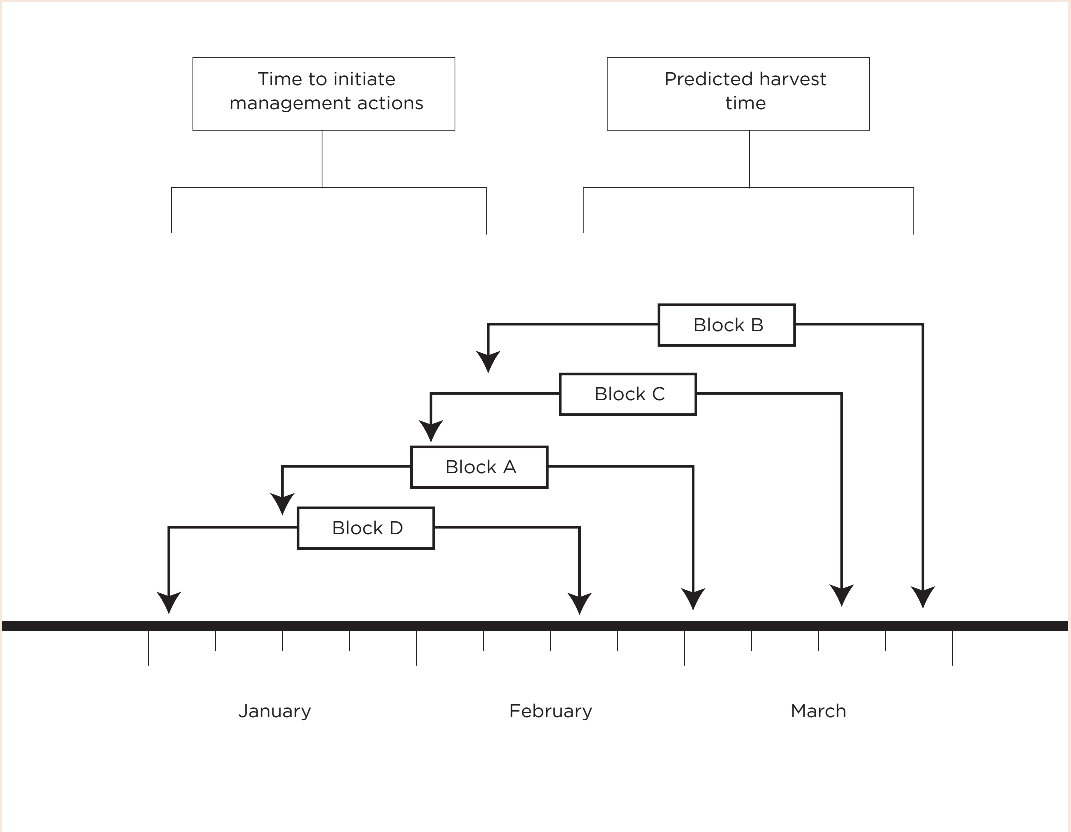


Table FS.1: *Yield lost and dockage.*

BLOCK	Area (ha)	Total yield (t)	Damage (%)	Tonnes lost	$'s lost
A	3.3	11.6	9	1.1	4,490[1]
B	4.5	21.7	6	1.3	2,470
C	5.2	20.2	3	0.6	1,100
D	2.5	9.0	5	0.5	600
TOTAL				4.4	**8,660**

1 This loss includes a $250/t dockage at the winery for excessive bird-damaged fruit and botrytis.

Table FS.2: *Current control costs*[2]

Capital Items	**Cost**
1.5 ha Bird netting (10 m wide x 3000 linear m x $0.30/m²)	(over 6 yrs) $1,500
2 x Gas-guns with timers @ $1,000 ea	(over 10 yrs) $ 200
1 x Shot gun @ $600	(over 10 yrs) $ 60
1 x Electronic scarer @ $1,500	(over 10 yrs) $ 150
2 x hawk-kites @ $200 ea	(over 4 yrs) $ 100
4 x eye-spot balloons @ $75 ea	(over 4 yrs) $ 75
Running costs	
1 x person for bird control (4 hrs x 6 days/wk x 11 wks @ $15.00/hr)	$3,960
Net application and removal costs (labour + equipment)	$ 700
800 km mileage (depreciation, fuel, insurance) for 4WD ute @ $0.58/km	$ 460
Labour to make 2 scarecrows	$ 75
Consumable items	
Gas for gas-guns	$ 100
1000 x Shot gun shells	$ 250
100 x Birdfrite cartridges	$ 400
1 x 12v battery	$ 75
2 Reels reflective tape	$ 35
TOTAL	**$8,140**

Therefore the total cost of bird damage and bird management is **$16,800**.

2 Costs include the requirement to harass resident species throughout the year. Ideally capital item costs would be 'depreciated' (see Chapter 5*), but even the rough non-depreciated estimates in this table will give a general indication of the costs versus benefits of bird management.

MANAGEMENT RESOURCES AVAILABLE

a) Visual scarers

- 2 hawk-kites
- 4 eyespot balloons
- 2 scarecrows
- metallic reflective tape
- 30 plastic shopping-bags on 3 m bamboo poles

b) Noise scarers

- 2 double bang gas-guns with timers
- 1 side-by-side 12 gauge shot gun
- 1 electronic bird scarer with 8 speakers

c) Noise and movement scarers

- Farm ute and truck with radios
- Old motorbike without a muffler
- 4 red tee-shirts for property staff

d) Exclusion

- 3,000 m of 10 m wide bird netting

e) Additional labour

One person employed part-time to run bird control programme — person has appropriate drivers licence, gun licence and knowledge of the Code of Practice for Humane Destruction of Birds (see Section 7.4*).

f) Other resources

Destruction Permit to shoot 20 rosellas if necessary.

MANAGEMENT STRATEGIES

a) Aims

In the past, my bird control has been somewhat haphazard, poorly directed, begun too late and lacked evaluation. However, I am aware that several of the species that are a major problem for me are not easy to control and I want to be realistic in setting an objective for my plan. Therefore my aim is to reduce my dollars lost by approximately $4000 and I will attempt to do this by reducing the amount of grapes lost to birds and improving the quality of my produce (fewer bird-pecked grapes going to the winery) without significantly increasing my control costs. I want to achieve this in an economic, safe and socially acceptable way.

b) Management actions

The management techniques available to me are deterring and scaring birds, excluding birds and some property management to modify bird habitat or the availability of alternative foods.

I use a different approach with the two types of birds (residents and migrant/nomad) that cause me problems in my vineyard. Residents (rosellas, blackbirds and sparrows) require some management over much of the year because they are permanent residents who appear to make my property part of their territory. I have been harassing rosellas and blackbirds (chasing/ disturbing them, shooting at them) throughout the year to discourage them from using the vineyard blocks as safe places to feed. I have left them alone elsewhere on the property in the hope that they will learn to use alternative foods there. During winter and spring I have been removing as much of the sparrow harbour as possible and destroying blackbird nests particularly in and around the garden surrounding my house.

I only need to use short-term control techniques against visitor species (red wattlebirds, silvereyes and starlings) because they are only here in large numbers after veraison. Being transient, they do not have territorial claims on my vineyard and are generally easier to move on than resident species.

Nonetheless, because most bird management work needs to be done after veraison (my busiest time of the year), I will employ someone part-time as a bird-control person (BCP) specifically to run my management programme. Generally the person will work for 3 hrs in the morning and 2 hrs in the afternoon, 6 days per week. BCP will start the work in early January, approximately 6-7 weeks before the Pinot harvest.

Scaring

BCP will 'train' birds to be afraid of humans and human activities. The training will involve shooting at or close to birds initially whilst on foot and then from a range of different vehicles used on the property (motorbike, ATV, ute, truck, tractor). BCP will vary the route taken when patrolling the property. To add to the variability, BCP will sometimes wear a red tee-shirt and sometimes not. Sometimes other people working on the property will also wear a red tee-shirt. I have two life-like scarecrows dressed in similar clothes to those BCP wears when shooting. The scarecrows also hold a gun-like stick. They too will sometimes wear a red tee-shirt. Every 1-2 days they will be moved around the vineyard but will be kept in a shed when not in use.

On occasions, harassment-shooting will be combined with the sudden appearance of a novel visual scaring devices such as eye-spot balloons, plastic shopping bags on bamboo poles or strips of reflective tape tied to similar poles. As with the scarecrows, these devices will be moved regularly. The hawk-kites fly from a 5-metre pole mounted on wheels for easy re-location – these too will be used sparingly and only moved to places where damage is occurring when it becomes apparent that additional scaring is required.

BCP might use the gas-guns or the electronic scarer from time to time but only after the initial 'training' period and only on an infrequent and irregular basis. These devices will be used in accordance with relevant State guidelines on the use of noise-generating devices and relevant local government by-laws. They will only be used when birds are trying to feed in the crops i.e. usually in the mornings and afternoons and definitely not all day nor every day. The two gas-guns will be set to fire at approximately the same time so that it will sound like a shooter is moving through the area, but they will not fire more than 5 times an hour and for not more than 2-3 consecutive hours. They will be situated where birds are trying to enter a block and usually in the crop pointing out rather than outside of the crop pointing in. The gas-guns will not be left out in the vineyard when not in use. They will not be used at all in Block B because it is too close to Neighbour B's house. If they are used on other blocks, at no time will they face towards Neighbour B's house.

Both the ute and the truck have car radios and from time to time one or both of these will be parked with the radio on near places where bird pressure is high. They will be moved regularly.

BCP will use the old motorbike that does not have a muffler on occasions both when shooting and when patrolling.

BCP will visually assess birds' reactions to all scaring devices on a daily basis. At the first sign that a device's effectiveness has waned ie birds seem to ignore it, its function will be modified or it will be moved or swapped for some other device. In Block B where silvereye damage can be worst, no scaring might be the best option. This is because silvereyes become very 'flighty' when frequently harassed and tend to put one peck only in each grape before moving on to another place in the crop - if not harassed they might stay in the area near cover and not spread damage through the block.

Netting

I will again use bird netting to protect the western section of block C against starlings that drop into the vines off the powerline. I will leave the first 3 rows uncovered (as a sacrificial crop) and then cover the next 14 rows, 2 rows at a time. It takes 5 people 4 hours to put the net on and fix the bottom of the net and 4 people 2.5 hours to get it off and pack it away. When necessary, scaring will also be carried out in the eastern part of the block but care will be taken to minimise disturbance on the western side; otherwise the starlings may overfly the netting.

I might need to consider purchasing more throw-over netting because in Block B there are several stony rises where the soil is shallow and leaf cover is always thin and starlings often attack these areas first.

I will use wire bird-netting to keep sparrows and starlings out of the old shed rooves.

Property management

There are two aspects of property management available to me to alter bird behaviour. I have been reducing the favourability of certain habitats for sparrows by removing feral olives and boxthorns on the roadside, removing or burying old rolls of wire-netting especially in the junk pile near Block D and bird-proofing the shed rooves. I also want to try to improve habitat for some other species so as to provide an alternative food to lure them away from my grapes. Roughly once a week, I will slash a strip through the pasture paddock to lower the vegetation height and make weed seeds available to rosellas. As they are also used to eating apples on nearby orchards, I will try to encourage them away from the vines by putting chopped apple on the strip and then, if they are accepted, I will try oats or sunflower seeds. By irrigating some small slashed areas close to my dam (and well away from the vines), I will promote weed seed production for rosellas and provide moist ground where starlings and crows can dig for insects.

The old fig trees east of my house produce ripe fruit at about the same time as the Pinot begin to ripen so I will endeavour to not disturb birds that feed on them as they are an attractive alternative to grapes.

c) Monitoring and evaluation

As already stated, BCP will monitor the effectiveness of scaring devices on a daily basis. This will simply entail closely watching (using binoculars) how birds react in the vicinity of each device. In addition, BCP will set up monitoring ‘posts’. There will be four of these within each block and each will be an area where at least 30 randomly selected bunches will be examined for damage once per week. An estimate will be made of the total number of grapes either missing (plucked off) or damaged (bitten, squashed or torn) for each bunch and an average calculated for all bunches at the ‘post’. These records will allow me to regularly monitor how damage is progressing and provide me an opportunity to review the management programme if I think too much damage is occurring and a change is required.

Finally, just before each block is harvested, BCP will sample at least 100 bunches taken throughout the block to make a quantitative estimate of the percentage of grapes lost due to birds. I also intend to keep good records of how much money I spend on my management activities. A record will also be kept of any dockage for bird damaged fruit at the winery. These figures will help me to determine if my aims have been achieved and assist decisions for next year.

COMMUNICATION

Pro-active

There are only two residences within 500 metres of my vineyard. On December 25th I rang neighbour A and neighbour B to tell them that I will need to be initiating my bird management programme in the next two weeks and I would be making limited use of two gas-guns, an electronic scarer, shooting and a motorbike without a muffler. I briefly explained why I needed to do this and roughly what I was planning to do, in particular with respect to the gas-guns. I could not be precise in saying when and where various devices would be used as their use depends on changing things around in response to birds’ reactions to them. I asked if they had any objections to this. Neighbour A had no objections as they have their own vineyard to protect and no-one would be home during the day. Neighbour B on the other hand, who is a non-farming resident, was concerned about noise impacts especially from the use of the gas-guns. I agreed not to use them in Block B ie the block closest to their house, not to use them every day (not that I had planned to do so) and not to use them on Sundays. They thought that the electronic scarer would not concern them as much and would not object to it being used, at least infrequently in Block B. I suggested they let me know if it did worry them.

Reactive

It is possible that even though I use noise scaring devices infrequently, neighbour B might complain to the Local Council that he is being subjected to amounts and levels of noise from me and other growers in his immediate vicinity that are in excess of the legal limits. If this occurs, I will contact the other growers with some suggestions as to how we, collectively, could minimise the noise impact on neighbour B. The sorts of suggestions might be to have a roster nominating who could use their noisy devices in the mornings or in the afternoons or on which days, or we could double the time between bangs or halve the number of devices in use at any one time. We may well need to contact our local industry representative to assist in setting up such a co-operative scheme.

PART C
Appendices and sources

Appendix A: List of State and Territory contacts and links

Relevant government agencies

Australian Government:

Department of Agriculture, Fisheries and Forestry
Natural Resource Management
— www.daff.gov.au/nrm

Department of Agriculture, Fisheries and Forestry
Bureau of Rural Sciences
— www.brs.gov.au

Department of the Environment and Water Resources
— www.environment.gov.au

State Government:

Queensland

Department of Primary Industries and Fisheries
— www.dpi.qld.gov.au

Environmental Protection agency/Queensland Parks and Wildlife Service
— www.epa.qld.gov.au

New South Wales

Department of Primary Industries
— www.dpi.nsw.gov.au

Department of Environment and Climate Change
— www.environment.nsw.gov.au

National Parks and Wildlife Service
— www.nationalparks.nsw.gov.au

Australian Capital Territory

Department of Territory and Municipal Services
— www.tams.act.gov.au

Victoria

Department of Primary Industries
— www.dpi.vic.gov.au/dpi

Department of Sustainability and Environment
— www.dse.vic.gov.au/dse

Parks Victoria
— www.parkweb.vic.gov.au

Tasmania

Department of Primary Industries and Water
— www.dpiw.tas.gov.au

Department of Infrastructure, Energy and Resources
— www.dier.tas.gov.au

Parks and Wildlife Service
— www.parks.tas.gov.au

South Australia

Department of Water, Land and Biodiversity Conservation — www.dwlbc.sa.gov.au

Department for Environment and Heritage
— www.environment.sa.gov.au

Department of Primary Industries and Resources
— www.pir.sa.gov.au

Parks and Wildlife
— www.parks.sa.gov.au

Western Australia

Department of Agriculture and Food
— www.agric.wa.gov.au

Department of Environment and Conservation
— www.dec.wa.gov.au

Northern Territory

Department of Planning and Infrastructure
— www.ipe.nt.gov.au

Department of Primary Industry, Fisheries and Mines
— www.nt.gov.au/dpifm

Department of Natural Resources, Environment and the Arts
— www.nt.gov.au/nreta

Local Government:

Australian State, Territory and Local Governments
— www.gov.au

The Australian Local Government Association links to local governments
— www.alga.asn.au/links

Appendix B: Random and systematic sampling

For estimating bird damage in horticulture, **random sampling** means that every plant, branch, bunch or individual fruit has an equal chance of appearing in a sample. **Systematic sampling** requires a random number as a starting point and then selection of units at regular intervals. For example, to select a sample of 10% of the trees from an orchard row with 212 trees we might select a random number of between one and ten (say, seven) to choose the first tree and then select every tenth tree thereafter, for example, 7, 17, 27, 37, 47, and so on. Systematic sampling therefore requires the selection of only one random number to start with. This method of sampling distributes the sample evenly over the orchard or crop and therefore is often more accurate. A potential disadvantage of systematic sampling occurs when the orchard or crop contains regular variation and the interval between successive samples happens to fall on, or between, the cause of variation. For example, if bird damage occurs around regularly placed irrigation outlets, sampling may occur either near an outlet (which would result in overestimation of damage) or between outlets (which would result in an underestimate). However, the effects of this type of bias can be reduced by being aware of any potential causes and selecting random numbers more often — for example, a different random number at the beginning of every row.

Table B.1 overleaf can be used to select a random sample. Many other sources of random numbers can be used, including the 100th of a second digit on a stopwatch, the random button on a scientific calculator, the last digits of phone numbers in a telephone book, and random number tables in statistical texts (Snedecor and Cochran 1967; Cochran 1977).

Table B.1: *Randomly selected digits for selecting orchard rows, vines or branches for estimating bird damage.*

34380016	09061251	53683584	80919523	79614856	86261788
77692190	12472610	22052980	04092532	02914212	14771569
25653859	30878018	49827265	32163457	33465377	32004151
38354442	27351299	87813654	72599872	89211707	23063753
63453475	73487045	87525254	41969054	27018952	67518540
06690878	17858821	05765252	32251350	43834040	46009400
03664052	20764794	00447707	83353069	09028291	23102206
72819605	65189367	07654958	11904050	68054140	56386303
49709159	64035768	49964599	16304209	87324747	61824702
72509232	23599353	16015809	78008057	10335704	05355998
88766747	83303629	81348003	49047212	45070040	60748009
03416852	71663259	60440382	65851314	52606891	13700369
18042848	18520768	30056764	29262978	27018952	72196112
81364483	03521226	63813288	40834681	46498306	23088473
71012299	60835902	67979980	85366375	55746330	64986114
76538591	50134892	78576617	39694815	19597461	77313150
63664968	33825190	29672231	07737358	87918027	25697806
89794000	80524003	72973418	81773736	51705985	63546861
80762963	34770043	08621784	69987793	70520646	59915769
68867153	63027741	77293924	00252693	61074862	83594775
82092349	85888241	53488571	50189825	87135228	43471480
44644307	76557817	60130009	83424482	40658895	15128636
48698386	55584277	44361400	52150945	54169744	83704642
07405011	51832331	74629658	05910825	24384899	62972808
39156468	29707938	18998688	66642354	47110813	80710776
53079318	52642598	44732200	09945677	53373211	50302438
65807367	52804651	49096652	72660298	86786401	08583331
79480270	17092502	01436506	16609088	52203131	59945982
61006195	49354839	26510819	48673666	15590075	16677755
22569353	38857082	49038972	87072054	65167394	85591601
23387860	15029756	79537950	73879818	03768426	80848109
02710959	18424635	61382488	73855098	42507401	43067721
74099551	27950072	89140294	69441206	65634327	14694662
20904874	34349803	08116398	82078616	76681417	51582385
63057955	79922483	15208289	79741203	25837886	20841700
15046236	84503922	10939970	30713218	08591571	84965361

References

Cochran, W.G. (1977) *Sampling Techniques*. John Wiley and Sons, New York.

Snedecor, G.W. and Cochran, W.G. (1967) *Statistical Methods. 6th Edition*. Iowa State University Press, Ames, Iowa, USA.

Appendix C: Some native plants that attract birds

Note: some Australian native plants can be invasive outside their natural range. Refer to your State department of environment, or local Bushcare or Landcare group for a list of plants suitable in your region.

Plant species	Common name	Flowering period
Epacridaceae		
Astroloma humifusum	Cranberry heath	May – Jun
Astroloma pinifolium	Pine heath	Sept – Feb
Epacris impressa	Common heath	Mar – Nov
Epacris longiflora	Fuchsia heath	Dec – May
Eupomatiaceae		
Eupomatia laurina	Native guava	Sept – Feb
Haemodoraceae		
Anigozanthos flavida	Kangaroo paw	Sept – Feb
Anigozanthos viridis	Green kangaroo paw	Sept – Feb
Malvaceae		
Hibiscus huegelii	Blue hibiscus	Sept – Feb
Mimosaceae		
Acacia implexa	Lightwood	Dec – Mar
Myrtaceae		
Beaufortia elegans	Elegant beaufortia	Sept – Feb
Beaufortia sparsa	Swamp bottlebrush	Dec – Feb
Callistemon comboynensis	Cliff bottlebrush	All year
Callistemon 'Guyra Hybrid'		All year
Callistemon montanus	Bottlebrush	Sep – Feb
Callistemon pachyphyllus	Wallum bottlebrush	All year
Callistemon pallidus	Lemon bottlebrush	Nov – Feb
Callistemon pinifolius	Pine-leaved bottlebrush	Dec – Feb
Callistemon polandii	Gold-tipped bottlebrush	All year
Callistemon speciosus	Albany bottlebrush	Nov - Feb
Callistemon viminalis	Weeping bottle brush	All year
Calothamnus gilesii	Giles net-bush	Sept – Feb
Calothamnus pinifolius	Apple green	Dec – Feb
Darwinia citriodora	Lemon-scented myrtle	Sept – Feb
Darwinia fascicularis		Jun – Feb
Eucalyptus erythrocorys	Red-cap gum	Feb – Mar
Eucalyptus globulus	Tasmanian blue gum	Sept – Feb
Eucalyptus leucoxylon rosea	Pink flowered yellow gum	Mar – Aug
Eucalyptus macrandra	Long-flowered marlock	Dec – Feb
Eucalyptus macrocarpa	Mottlecah	Sept – Jan
Eucalyptus nicholii	Nichol's gum	Mar – May
Eucalyptus obliqua	Messmate stringybark	Sept – Feb
Eucalyptus ptychocarpa	Swamp bloodwood	Dec – May

Plant species	Common name	Flowering period
Eucalyptus robusta	Swamp mahogany	Dec – Feb
Eucalyptus setosa	Roughleaf bloodwood	Dec – May
Eucalyptus tetraptera	Square-fruited mallee	Sept – Feb
Eucalyptus viminalis	White gum	Jan – May
Eugenia australis	Brush cherry	Dec – May
Eugenia luehmanii	Small-leaved lilly-pilly	Dec – Feb
Melaleuca alternifolia	Medicinal tea-tree	Sept – Feb
Melaleuca armillaris	Green globe	Sept – Feb
Melaleuca diosmafolia	Green honey myrtle	Sept – Feb
Melaleuca elliptica	Granite honey myrtle	Sept – May
Melaleuca erubescens		Dec – Feb
Melaleuca linariifolia	Narrow-leaved paperbark	Sept – Feb
Melaleuca quinquenervia	Broad-leaved paperbark	Mar – May
Melaleuca styphelioides	Prickle-leafed paperbark	Sept – Feb
Melaleuca thymifolia	Feather honey myrtle	Dec – May
		Sept – Feb
Melaleuca viridiflora	Weeping tea-tree	All year
Pittosporaceae		
Pittosporum revolutum	Yellow pittosporum	Aug – Sept
Pittosporum rhombifolium	Diamond pittosporum	Mar – Aug
Proteaceae		
Banksia aemula	Wallum banksia	Mar – Jun
Banksia brownii	Feather-leaved banksia	May – Jul
Banksia caleyi	Caley’s banksia	Nov – Dec
Banksia coccinea	Scarlet banksia	Jun – Feb
Banksia compar		Jan – Jun
Banksia marginata	Silver banksia	Sept – Feb
Banksia media	Golden stalk banksia	Dec – Aug
Banksia robur	Swamp banksia	All year
Banksia serrata	Saw banksia	Dec – Jun
Banksia speciosa	Showy banksia	Dec – May
Buckinghamia celcissima	Ivory curl flower	Feb – Mar
Grevillea arenaria	Grey grevillea	All year
Grevillea banksia	Kahili	All year
Grevillea banksii	Red silky oak	Sept – Feb
Grevillea baueri	Bauer’s grevillea	May – Dec
Grevillea bipinnatifida	Grape grevillea	Nov – Jan
Grevillea chrysophaea	Golden grevillea	All year
Grevillea dimorpha	Flame grevillea	Mar – Jun
Grevillea illumina		Jun – Nov
Grevillea lavandulacea	Lavender grevillea	All year
Grevillea leucopteris	White plumed grevillea	Sept – Feb
Grevillea robusta	Silky oak	Nov – Feb
Grevillea ‘Robyn Gordon’		All year
Grevillea sericea	Silky grevillea	Mar – Nov
Hakea cristata	Snail hakea	May – Sept
Hakea laurina	Pincushion hakea	Mar – Aug

Plant species	Common name	Flowering period
Hakea nodosa	Yellow hakea	Apr – Aug
Hakea suaveolens	Sweet hakea	May – Aug
Lomatia silaifolia	Wild parsley	Dec – Feb
Stenocarpus sinuatus	Firewheel tree	Dec – May
Telopea oreades	Gippsland waratah	Dec – Feb
Rutaceae		
Correa alba	White correa	May – Aug
Correa backhouseana	Australian fuchsia	Mar – Aug
Correa baeuerlenii	Chefs cap	Mar – Aug
Correa glabra	Rock correa	Mar – Aug
Correa mannii	Mann’s correa	Mar – Nov
Euodia elleryana	Pink euodia	Dec – Feb

Appendix D: Roles of government agencies and legislation relating to pest birds

Agency	Relevant legislation and strategies	Role
Commonwealth		
Australian Pesticides and Veterinary Medicines Authority; Department of Agriculture Fisheries and Forestry	*Agricultural and Veterinary Chemicals Code Act 1994*	To protect the health and safety of human beings, animals and the environment by putting in place a system to regulate agricultural chemical products and veterinary chemical products. An agricultural chemical, in part, is used as a means of directly or indirectly destroying, stupefying, repelling, inhibiting the feeding of, or preventing infestation by or attacks of, any pest in relation to a plant, a place or a thing.
National Drugs and Poisons Scheduling Committee	*Agricultural and Veterinary Chemicals Code Act 1994*	The National Drugs and Poisons Scheduling Committee considers the threat category of any agricultural chemical.
Department of the Environment and Water Resources	*Environment Protection and Biodiversity Conservation Act 1999*	Review key threatening processes for endangered species and prepare Threat Abatement Plans as required. No bird species are currently considered a key threatening process.
Department of the Environment and Water Resources	*Environment Protection and Biodiversity Conservation Act 1999*	In part, to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance. Also to govern management of pests in Commonwealth national parks. The Minister may issue permits for the export of live native birds if the proposed export would be an eligible non-commercial purpose export (within the meaning of section 303FA). Regulates the import of potential harmful environmental pests and restricts the export of native birds.
National Industrial Chemicals Notification and Assessment Scheme	*Industrial Chemicals (Notification and Assessment) Act 1989*	An Act to establish a national system of notification and assessment of industrial chemicals, to provide for registration of certain persons proposing to introduce industrial chemicals and for related purposes.
Environmental Protection Authority	*National Environment Protection Council Act 1994*	To provide for the establishment of a National Environment Protection Council, and for related purposes. This Act includes the objective to ensure that, by means of the establishment and operation of the National Environment Protection Council, people enjoy the benefit of equivalent protection from air, water or soil pollution and from noise, wherever they live in Australia.
Australian Customs Service, Australian Quarantine Inspection Service (AQIS); Department of Agriculture Fisheries and Forestry	*Quarantine Act 1908*	Regulates the importation of exotic birds that have the potential to become pests.

Agency	Relevant legislation and strategies	Role
Department of the Environment and Water Resources	The National Strategy for Ecologically Sustainable Development	Promotes the rapid completion and implementation of national and regional strategic plans for the management of pests and reviews legislation for the control of pests, including birds.
Department of the Environment and Water Resources	The National Strategy for the Conservation of Australia's Biological Diversity	Promotes the adoption of ecologically sustainable agricultural and pastoral management practices in the interests of encouraging and sustaining biological diversity.
Department of Agriculture Fisheries and Forestry		Responsible for developing and implementing strategies for ecologically sustainable development, including pest bird management. Coordinates vertebrate pest management at the national level.
Australian and New Zealand Environment and Conservation Council (Advisory Body)		ANZECC provides a forum for member governments to exchange information and experience and develop coordinated policies in relation to national and international environment and conservation issues.
New South Wales		
National Regulation Authority	*Agricultural and Veterinary Chemicals (New South Wales) Act 1994*	To apply certain laws of the Commonwealth relating to agricultural and veterinary chemical products as laws of New South Wales; and for other purposes.
Department of Primary Industries	*Animal Research Act 1985*	Protects the welfare of animals used in connection with research by requiring persons or organisations carrying out animal research or supplying animals for research to be authorised under this Act and by regulating the carrying out of animal research and the supply of animals for research by those persons or organisations. This Act covers those keeping animals with intention of using them for animal research, and those unlawfully supplying animals for use in connection with animal research.
Environment Protection Authority	*Environmental Hazardous Chemicals Act 1985*	To provide for control of the effect on the environment of chemicals and chemical wastes. This Act includes the consideration of substances that may produce harmful effects in organisms or biological systems (human, plant, animal or otherwise), and substances that may affect the soil or any other physical feature of the environment.
NSW Department of Primary Industries	*Exotic Diseases of Animals Act 1991*	To provide for the detection, containment and eradication of certain diseases affecting livestock and other animals and for other purposes. This Act, in relation to animals, applies to all animals, whatever their status and whether or not the property of the Crown or any person. It includes possession, quarantine, restricted areas, disinfection, destruction, seizure and compensation.

Agency	Relevant legislation and strategies	Role
Game Council of NSW	*Game and Feral Animal Control Act 2002*	To provide for the effective management of introduced species of game animals and to promote responsible and orderly hunting of those game animals on public and private land and of certain pest animals on public land. A person must not release a game animal into the wild for the purpose of hunting the animal or its descendants. 'Game animal' is any of the following that is living in the wild: deer, California quail, pheasant, partridge, peafowl, turkey. Any of the following animals that is living in the wild is also a 'game animal' for the purposes of this Act: pig, dog (other than dingo), cat, goat, rabbit, hare and fox.
NSW Police	*Inclosed Lands Protection Act 1901*	To consolidate the enactments relating to the protection of inclosed lands from intrusion and trespass. This Act includes unlawful entry and offensive conduct.
Department of Environment and Climate Change (NSW)	*National Parks and Wildlife Act 1974*	To consolidate and amend the law relating to the establishment, preservation and management of national parks, historic sites and certain other areas and the protection of certain fauna, native plants and Aboriginal objects. Also governs the issue of permits for the destruction of native species that are causing damage to agriculture. A person shall not harm any animal that is within a national park or historic site, or discharge a prohibited weapon in a national park or historic site. A person shall not use any substance, animal, firearm, explosive, net, trap, hunting device or instrument or means whatever for the purpose of harming any such fauna.
Department of Infrastructure, Planning and Natural Resources	*Native Vegetation Conservation Act 1997*	Relating to the conservation and sustainable management of native vegetation and the clearing of land. Its role is, in part, to prevent the inappropriate clearing of vegetation.
Environment Protection Authority	*Pesticides Act 1999*	To promote the protection of human health, the environment, property and trade in relation to the use of pesticides, having regard to the principles of ecologically sustainable development within the meaning of the *Protection of the Environment Administration Act 1991*; and to minimise risks to human health, the environment, property and trade. A person must not use a pesticide in a manner that harms any non-target animal or non-target plant, or (if there is no approved label or permit for the pesticide) harms any animal or plant.
RSPCA	*Prevention of Cruelty to Animals Act 1979*	To prevent cruelty to animals; to promote the welfare of animals by requiring a person in charge of an animal to provide care for the animal; to treat the animal in a humane manner; and to ensure the welfare of the animal. This includes not inflicting pain, not abandoning animals, and providing adequate food/water/shelter.

Agency	Relevant legislation and strategies	Role
Department of Environment and Climate Change	*Protection of the Environment Operations Act 1997*	In part, to protect, restore and enhance the quality of the environment in New South Wales, having regard to the need to maintain ecologically sustainable development; and also to reduce risks to human health and prevent degradation of the environment. It covers waste and pollution, including noise pollution.
Rural Lands Protection Boards	*Rural Lands Protection Act 1989*	Responsibilities for vertebrate pest management. Declared pests do not currently include birds. Restrictions on removal or destruction of timber.
Queensland		
Department of Primary Industries and Fisheries	*Land Protection (Pest and Stock Route Management) Act 2002*	Management of particular pests on land and for other purposes. Pest animal management includes exotic mammals, reptiles and amphibians. Bird species are not included at present, but local governments have power to declare pests under local law.
Department of Natural Resources and Water	*Land Protection (Pest and Stock Route Management)*	Management of stock route network aspect of the legislation.
Environment Protection Agency and Queensland Parks and Wildlife Service	*Nature Conservation Act 1992*	Research and management of protected areas, protecting native wildlife and its habitat. Protects biological diversity, cultural resources and values, and the conservation values of land. In particular, defines 11 classes of protected area ranging from national parks (scientific), World Heritage management and international agreement areas to national parks (Aboriginal land) and nature refuges and co-ordinated conservation areas involving private property. This Act also covers trespass: a person must not take wildlife on any land, or enter, or be on, any land for the purpose of taking wildlife and the keeping or selling of birds.
Environment Protection Agency	*Environment Protection Act 1994*	For the protection of Queensland's environment. Covers research, and development of policies. Implements and integrates environmental strategies into matters such as land-use planning and managing natural resources, ensuring actions to protect environmental values from environmental harm, monitoring contaminants in the environment, and requiring those causing environmental harm to pay costs and penalties. Includes environmental nuisance by noise.
Department of Primary Industries and Fisheries	*Animal Care and Protection Act 2001*	Stipulates that a person must not be cruel to an animal. This includes areas such as inhumane practices, caging without sufficient food or water, transportation that causes harm, neglect to provide shelter, and more. Also mentions the killing of pest animals but provides an exemption if the act causes as little pain as is reasonable.

Agency	Relevant legislation and strategies	Role
Department of Natural Resources and Water	*Land Act 1994*	Covers destruction of trees on holdings, etc., permits, tree management plans and destruction of noxious weeds.
ACT		
Department of the Territory and Municipal Services	*Nature Conservation Act 1980*	Provides for the protection and conservation of native animals and native plants, and for the reservation of areas for those purposes. Includes keeping, selling, killing, exporting/importing native animals, as well as interference with nests of native animals. Contains legislation on clearing causing substantial loss or harm to a reserve area. A person shall not interfere with a nest of a native animal, or with anything in the immediate environment of such a nest.
Department of the Territory and Municipal Services	*Environment Protection Act 1997*	Provide for the protection of the environment and for related purposes, including noise control.
Department of Land Planning and Environment	*Pastoral Lands Act 2000*	To make provision for the conservation and granting of title to pastoral land and the administration, management and conservation of pastoral land, and for related purposes.
Parks and Wildlife Commission	*Parks and Wildlife Commission Act 2000*	To establish a Commission to establish and manage, or assist in the management of, Parks, Reserves, Sanctuaries and other land; to encourage protection, conservation and sustainable use of wildlife; to establish a land-holding corporation in connection with these purposes; and for related purposes.
Animal Welfare Advisory Committee	*Animal Welfare Act 1992*	To prevent neglect of, and cruelty to, animals, to ensure the welfare of animals. A person must not lay a poison in any place with the intention of killing or injuring a domestic or native animal. A person shall not, knowingly, use spurs with sharpened or fixed rowels on an animal. A person shall not, without reasonable excuse, administer an electric shock to an animal, except in a manner authorised under a law of the Territory. A person shall not, without reasonable excuse, convey or contain an animal in circumstances under which the animal is subjected to unnecessary injury, pain or suffering.
Department of the Territory and Municipal Services	*Enclosed Lands Protection Act 1943*	Relating to protection of enclosed lands from intrusion and trespass. This act includes penalties for trespass on enclosed lands, and for leaving gates open.

Agency	Relevant legislation and strategies	Role
South Australia		
Department of Primary Industries and Resources of South Australia (PIRSA) Rural Chemicals Program	*Agriculture and Veterinary Products (Control of Use) Act 2002*	Relating to the use of agricultural chemical products, fertilisers and veterinary products, and for other purposes.
Environment Protection Agency	*Environmental Protection Act 1993*	To provide for the protection of the environment; to establish the Environment Protection Authority and define its functions and powers, and for other purposes. Provides for the protection of the environment, and for related purposes. Includes noise pollution, especially through enforceable Codes of Practice such as Guidelines for the Use of Audible Bird Scaring Devices.
National Parks and Wildlife South Australia	*National Parks and Wildlife Act 1972*	To provide for the establishment and management of reserves for public benefit and enjoyment; to provide for the conservation of wildlife in a natural environment; and for other purposes. A person must not take an animal, or the eggs of an animal, or a native plant within certain areas (e.g. sanctuaries, reserves). Hunting is discussed. The Minister may grant to any person a permit to take protected animals or the eggs of protected animals, if satisfied that it is desirable to grant the permit: to facilitate scientific research; or to enable the person to place bands, marks or tags upon such animals and then to release them; or to permit the destruction or removal of animals that are causing, or are likely to cause, damage to the environment or to crops, stock or other property; or for any other purpose (other than for sale). A plan of management must not provide for the culling of protected animals from a reserve unless the Minister is of the opinion that the culling of those animals is the only practicable option for controlling an overpopulation of animals of that species in the reserve. The Minister may also approve permits for the harvesting of protected animals. It is a defence to a charge of an offence involving molestation or harassment of a protected species if it can be proven that the defendant acted reasonably to frighten the animal in order to protect himself or herself or another person or to protect property comprising plants cultivated for commercial or other purposes or animals or property of any other kind.
Department of Water, Land and Biodiversity Conservation	*Native Vegetation Act 1991*	To provide incentives and help to landowners in relation to the preservation and enhancement of native vegetation; to control the clearance of native vegetation; and for other purposes. This includes its significance as a habitat for wildlife, or if plants are of a rare, vulnerable or endangered species. Amendments prohibit broadacre clearance of intact native vegetation but allow clearance in accordance with exemptions in the regulations to the *Native Vegetation Act 1991*.

Agency	Relevant legislation and strategies	Role
Natural Resources Management (NRM) council and boards; Animal and Plant Control Group, Department of Water, Land and Biodiversity Conservation	*Natural Resources and Management Act 2004*	To promote sustainable and integrated management of the State's natural resources; to make provision for the protection of the State's natural resources, and for other purposes. This includes possession, movement, release, quarantine, sale and control of pest and native species.
Department of Water, Land and Biodiversity Conservation	*Pastoral Land Management and Conservation Act 1989*	To make provision for the management and conservation of pastoral land; and for other purposes. Includes trespassing and rights to travel across land. Includes restrictions on hunting/shooting on pastoral land, damage or interference with pastoral land, cutting down, lopping of branches from, or otherwise damaging, any living tree or bush on pastoral land.
Animal Welfare Advisory Committee	*Prevention of Cruelty to Animals Act 1985*	To discourage cruelty to animals; and for other purposes. Includes ill-treatment of animals (e.g. failure to supply adequate food and water, inhumane transport, and other causes of unnecessary pain), electrical devices for control, and medical and surgical procedures.
Northern Territory		
Department of Primary Industry, Fisheries and Mines	*Agricultural and Veterinary Chemicals (Northern Territory) Act 1994*	To apply certain laws of the Commonwealth relating to agricultural and veterinary chemical products as laws of the Northern Territory, and for other purposes. Regulates agricultural chemical products and veterinary chemical products.
Department of Primary Industry, Fisheries and Mines	*Agricultural and Veterinary Chemicals (Control of Use) Act 2004*	To control the use of agricultural and veterinary chemicals and the manufacture, sale and use of fertilisers and stockfoods, to manage land and agricultural produce contaminated by chemicals, and for related purposes.
Department of Local Government, Housing and Sport	*Animal Welfare Act 1999*	To provide for the welfare of animals, prevent cruelty to animals, and for related purposes. Includes neglect; cruelty; abandonment; provision of food, drink and shelter; prohibited procedures; confinement; and transportation. Also includes regulations on poison, traps, electrical devices and spurs.
Department of Primary Industry, Fisheries and Mines	*Biological Control Act 1986*	To make provision for the biological control of pests in the Northern Territory, and for related purposes.
Department of Primary Industry, Fisheries and Mines	*Exotic Diseases (Animals) Compensation Act 1990*	To provide compensation for certain losses occasioned by exotic diseases of animals. 'Exotic disease' means a disease, parasite or pest prescribed in the Schedule.

Agency	Relevant legislation and strategies	Role
Pastoral Land Board	*Pastoral Lands Act 1998*	To make provision for the conversion and granting of title to pastoral land and the administration, management and conservation of pastoral land, and for related purposes. Includes, in part, the prevention or minimisation of degradation of, or other damage to, the land and its indigenous plant and animal life. The Board may, by notice in writing, direct a pastoral lessee to control declared feral animals on his or her pastoral land by culling, fencing or other means directed by the Board, and the pastoral lessee shall comply with the reasonable directions of the Board. Also includes public access and closures of pastoral lands.
Department of Health and Community Services	*Public Health Act 1985*	Relating to Public Health. This act includes measures for the control or destruction of noxious vermin and insects, the disposal of dead animals, and the testing, examination, isolation and destruction of animals and the payment of compensation for the destruction of animals that are found to be diseased.
Department of Primary Industry, Fisheries and Mines	*Stock Diseases Act 2003*	Relating to the control of diseases in stock and for other purposes. The objects of this Act are, in part, to provide for the detection, prevention, control and eradication of diseases that affect stock. Includes quarantine and movement of stock.
Department of Primary Industry, Fisheries and Mines	*Stock Routes and Travelling Stock Act 1996*	To provide for the maintenance and control of stock reserves and stock routes, for the construction, maintenance and control of watering places and dips for stock, for the control of travelling stock, and for other purposes.
Department of Justice	*Summary Offences Act 2001*	To provide for the control of certain criminal offences. Includes noise that constitutes undue noise.
Department of Natural Resources, Environment and The Arts	*Territory Parks and Wildlife Conservation Act 2005*	To make provision for, and in relation to, the establishment of Territory Parks and other Parks and Reserves and the study, protection, conservation and sustainable utilisation of wildlife. Firearms and traps are prohibited in sanctuaries. A person shall not, in a sanctuary, take, capture, kill or have in his other possession any animal. This Act includes the survival of wildlife in its natural habitat; the management of identified areas of habitat, vegetation, ecosystem or landscape to ensure the survival of populations of wildlife within those areas; and the control or prohibition of the introduction or release of prohibited entrants into the Territory. Also, feral animals are to be managed in a manner that reduces their population and the extent of their distribution within the Territory and controls any detrimental effect they have on wildlife and the land.
Department of Justice	*Trespass Act 2000*	To amend the law relating to trespass. Includes trespass on premises, on prohibited land, after direction to leave, and after warning to stay off.

Agency	Relevant legislation and strategies	Role
Department of Planning and Infrastructure	*Valuation of Land Act 1994*	Relating to the valuation of Land. 'Improvements' within this act include pest and weed management.
Tasmania		
Department of Primary Industries, Water and the Environment	*Vermin Control Act 2000*	To provide for the control of vermin. Mostly in regards to rabbits, yet the Minister may declare any animal or bird vermin. This Act includes destruction of vermin, entry of inspectors to land to destroy vermin if the owner does not comply (but does incur costs); and laying of poison by inspectors. A person must not destroy, injure or remove any trap, snare, poison or other thing that is intended to capture or destroy vermin. A person may not set at large any vermin and must not destroy/damage, or leave open vermin-proof fences.
Department of Primary Industries, Water and the Environment	*Agriculture and Veterinary Chemical (Control of Use) Act 1995*	To control the use and application of agricultural chemical products and veterinary chemical products, to provide for related matters and to repeal certain Acts.
Department of Primary Industries, Water and the Environment	*Animal Health Act 1995*	To provide for the prevention, detection and control of animal diseases, to provide for the maintenance and improvement of animal health, and for related purposes. Discusses quarantine, importing and movement of animals. Also sale, possession and disposal of infected animals.
Department of Primary Industries, Water and the Environment	*Animal Welfare Act 1993*	To prevent neglect of, and cruelty to, animals, to ensure the welfare of animals, and for related purposes. Includes storage, transport, unnecessary pain, humane treatment and so on.
Department of Primary Industries, Water and the Environment	*Environmental Management and Pollution Control Act 1994*	To provide for the management of the environment and the control of pollution in the State. Covers general pollution, including the nuisance of noise.
National Parks and Wildlife Service, Tasmania	*National Parks and Reserve Management Act 2002*	To provide for the management of national parks and other reserved land. A person must not cut down a tree, or damage or otherwise destroy a tree or a fallen tree, that is on reserved land without the approval of the managing authority. This Act involves the preservation and protection of fauna and flora; seizure, destruction or killing in reserved land; and also exclusion or ejection of persons from the area.

Agency	Relevant legislation and strategies	Role
Parks and Wildlife Service Tasmania	*Nature Conservation Act 2002*	To make provision with respect to the conservation and protection of the fauna, flora and geological diversity of the State, to provide for the declaration of national parks and other reserved land and for related purposes. The Minister may enter into any agreement relating to the use and management of any private land if to do so would, in the opinion of the Minister, tend to promote conservation purposes in relation to that land, or the purposes for which a private nature reserve or private sanctuary has been set aside under this Act. It contains regulations on the prohibitions or control of taking, keeping, buying/selling, export and disposal of wildlife or wildlife products. Also possession or use of hunting equipment or animals for this purpose.
Victoria		
Parks Victoria	*Agriculture and Veterinary Chemicals (Control and Use) Act 1992*	To impose controls in relation to the use, application and sale of agricultural and veterinary chemical products, fertilisers and stock foods and the manufacture of fertilisers and stock foods. This includes protecting the environment and protecting the health and welfare of animals.
Department of Sustainability and Environment	*Catchment and Land Protection Act 1994*	Sets up a framework for the integrated management and protection of catchments. In part, its aim is to encourage community participation in the management of land and water resources and also to set up a system of controls on noxious weeds and pest animals. It states that the landowner has to prevent the spread of, and as far as possible eradicate, established pest animals (including on roadsides and Crown land held under lease).
Environment Protection and Heritage Council	*Environment Protection Act 1970*	To create a legislative framework for protection of the environment in Victoria, having regard to the principles of environmental protection. Focuses on pollution and waste, including noise pollution.
Department of Sustainability and Environment	*Flora and Fauna Guarantee Act 1988*	To establish a legal and administrative structure to enable and promote the conservation of Victoria's native flora and fauna and to provide for a choice of procedures that can be used for the conservation, management or control of flora and fauna and the management of potentially threatening processes.
Victorian Land Titles Office	*Land Act 1958*	Involves lands from urban, agricultural, non-agricultural lands. Includes trespass onto lands. Some conditions may be applied to leases in regards to felling/clearing of vegetation. Leases may contain conditions on the destruction and control of vermin and noxious weeds, and also the destruction, removal, or use of forest produce.

Agency	Relevant legislation and strategies	Role
Department of Sustainability and Environment	*National Parks Act 1975*	The preservation and protection of the natural environment, including wilderness areas and remote and natural areas in those parks; and the protection and preservation of indigenous flora and fauna and of features of scenic or archaeological, ecological, geological, historic or other scientific interest in those parks. Non-indigenous animals may not be used in any parks. The Act includes special provisions for a number of Parks (e.g. protection of life occupancies in Alpine National Park). There is to be no hunting, although guns and other weapons may be used to hunt feral animals. Exotic fauna are to be exterminated in National and State parks.
Department of Primary Industries	*Prevention of Cruelty to Animals Act 1986*	To prevent cruelty to animals, to encourage the considerate treatment of animals, and to improve the level of community awareness about the prevention of cruelty to animals.
Department of Sustainability and Environment	*Wildlife Act 1975*	To establish procedures in order to promote the protection and conservation of wildlife, the prevention of taxa of wildlife from becoming extinct, and the sustainable use of, and access to, wildlife; and to prohibit and regulate the conduct of persons engaged in activities concerning or related to wildlife. The Minister may authorize the use of prohibited equipment for certain purposes (e.g. to capture wildlife for study). A person must not buy, sell, acquire, receive, dispose of, keep, possess, control, breed, process, display, take samples from, or experiment on, wildlife without writing from the Minister. The use of any snare, trap, net, gun, or substance prohibited is an offence. Any person who kills, destroys, takes or injures wildlife by any bait impregnated with poison or any substance, whether liquid, solid, or gaseous, which is prescribed to be a poison for the purposes of this section or lays any such poison or substance with intent to kill, destroy, take, or injure wildlife shall be guilty of an offence. A person cannot use any glue, adhesive material, bird-lime or any similar viscid substance for taking or restraining of wildlife. A person must not interfere with, harass, hinder or obstruct a person who is engaged in hunting or taking game.
Western Australia		
Department of Agriculture and Food, WA	*Agriculture and Related Resources Protection Act 1976*	Protects primary industries and the resources related to primary industries. Is involved with prohibiting or regulating measures for the control of declared plants and animals. This includes chemicals, appliances, trapping, experiments, disposal and permits. Also contains regulations on storage, use and transport of prescribed chemicals.
Department of Agriculture and Food, WA	*Soil and Land Conservation Act 1945*	To provide for the prevention of land degradation and land restoration. Contains legislation in regards to clearing or damaging trees, shrubs, grass or any other plants on any land.

Agency	Relevant legislation and strategies	Role
Department of Environment and Climate Change	*Wildlife Conservation Act 1950*	Concerned with the conservation of protected flora and fauna. This Act discusses restrictions placed on possessing, taking or disposal of fauna. Also, a person may not take duck, goose or quail for the purposes of sport or recreation. Also discusses keeping, importing/exporting to/from the State, breeding and so on, whether the animal is protected or not. Contains information on storage and/or use of illegal means or devices for taking fauna on lands of which that person is the occupier.
Environmental Protection Authority	*Environment Protection Act 1986*	To provide for the protection of the environment and for related purposes, including noise.
Conservation Commission of Western Australia, Marine Parks and Reserves Authority, and Marine Parks and Reserves Scientific Advisory Committee; Department of Environment and Conservation (DEC)	*Conservation and Land Management Act 1984*	A person shall not, without lawful authority, fell, cut, injure, destroy, obtain, or remove any forest produce in, on, or from any land to which this section applies. A person shall not, except under a permit, licence, or lease under this Act, or a grant, lease, licence, or other authority from the Crown, hunt, shoot, or destroy or set snares for the purpose of capturing any indigenous fauna on land to which this Act applies, or occupy, clear, or break up for cultivation, or any other purpose, land to which this Act applies.
Department for Planning and Infrastructure	*Land Administration Act 1997*	Pastoral land is not to be used other than for pastoral purposes without a permit. Pastoral lessee must not remove trees or otherwise clear land under the lease or disturb or affect its soil.
Department of Local Government and Regional Development; in partnership with the RSPCA, local governments, Department of Agriculture and Food, Department of Environment and Conservation and Fisheries WA	*Animal Welfare Act 2002*	Stipulates that a person must not be cruel to an animal. This includes areas such as inhumane practices, caging without sufficient food or water, transportation that causes harm, failure to provide shelter, and more. Also mentions the killing of pests.
Department of Agriculture and Food, WA	*Agriculture and Related Resources Protection Act 1976*	Application of provisions relating to the control of certain pests or diseases may be made to commercial and non-commercial producers.
Police and Emergency Services	*Police Act 1892*	To provide for the management of WA Police. This act deals with trespass, including land that is fenced or enclosed by natural structures such as creeks. Persons will be fined if they were not invited onto the land.

Appendix E: Legislation and conditions relating to the destruction of native birds

Jurisdiction	Species locally unprotected[1]	Permits for destruction of native birds	Conditions	Agency	Relevant legislation
ACT	None	Not available	No permits are issued for native birds, even if they are considered to be causing damage to agriculture or the environment	Department of the Territory and Municipal Services	*Nature Conservation Act 1980*
NSW	Sulphur-crested cockatoo, galah, crows and ravens and the purple swamp hen	Available. Sections 120 and 121 of the Act	Issued where birds are causing or likely to cause environmental or agricultural damage. The number and species of birds and the time period are specified on the permit.	Department of Environment and Climate Change	*National Parks and Wildlife Act 1974*
NT	None	Available. Section 55 of the Act	Issued where birds are causing or likely to cause environmental or agricultural damage. The number and species of birds and the time period are specified on the permit.	Parks and Wildlife Service of the Northern Territory	*Territory Parks and Wildlife Conservation Act 2005*
QLD	None	Available	Issued where birds are causing or likely to cause environmental or agricultural damage. The number and species of birds and the time period are specified on the permit.	Environment Protection Agency and Queensland Parks and Wildlife Service	*Nature Conservation Act 1992*
SA	Red wattlebird, galah, silvereye, budgerigar, zebra finch, little corella, crows and ravens	Available. Section 53 of the Act	Issued where birds are causing or likely to cause environmental or agricultural damage. The number and species of birds and the time period are specified on the permit.	Department for Environment and Heritage	*National Parks and Wildlife Act 1972*
TAS	Long-billed corella[2]	Available	Issued where birds are causing or likely to cause environmental or agricultural damage. If < 25 then a 'shoot to scare' permit may be issued for one month. If > 25 then a 'shoot to kill' permit may be issued. Five birds a day may be shot, with a maximum of 25 birds over a one-month period.	Tasmanian Parks and Wildlife Service	*National Parks and Wildlife Act 1970*

Jurisdiction	Species locally unprotected[1]	Permits for destruction of native birds	Conditions	Agency	Relevant legislation
WA	Sulphur-crested cockatoo[2], rainbow lorikeet[2], galah	Not available	Open seasons are declared in defined regions for particular species known to cause agricultural or environmental damage or those considered dangerous. For these species no permit is required and there is no limit on the number of birds that can be destroyed.	Department of Environment and Conservation; Department of Agriculture and Food, WA	*Wildlife Conservation Act 1950*; *Agriculture and Related Resources Protection Act 1976*
VIC	Sulphur-crested cockatoo, galah and long-billed corella	Available. Section 7A, 28A of the Act (Commercial Wildlife (Wildlife Controller Licence)) under r.34 of the Wildlife Regulations	S28A permits are issued where birds are causing environmental or agricultural damage. The number and species of birds, methods of destruction and the time period are specified on the permit. S7A Governor in Council declaration as [the listed species being] unprotected only where serious damage is being done to trees, vineyards, orchards, recreational reserves or commercial crops, and [the listed species] may be destroyed by (a) landowners and occupiers, their employees and members of their families; or (b) in the case of recreational reserves, members of committees of management. r.34 A Commercial Wildlife Controller may take (the listed species) for the purpose of removing danger to persons or property from that wildlife.	Department of Sustainability and Environment	*Wildlife Act 1975, Wildlife Regulations 2002*

Jurisdiction	Species locally unprotected[1]	Permits for destruction of native birds	Conditions	Agency	Relevant legislation
Common-wealth	None	Not available	In addition to regulating native species in Commonwealth parks and reserves, the EPBC Act requires permits for: • activities outside Commonwealth parks or reserves that may affect protected species[3] in Christmas Island, Cocos (Keeling) Islands or Coral Sea Islands territories. • activities that occur in a Commonwealth area that may affect a member of a listed threatened species or ecological communities, a member of a listed migratory species, or a member of a listed marine species.	Department of the Environment and Water Resources	*Environment Protection and Biodiversity Conservation Act 1999*

1 Permits are not required for these species within designated regions (Figure 6.1).

2 Considered introduced pests

3 For a definition of 'protected species' see Regulation 9 of the *Environment Protection and Biodiversity Conservation Regulations 2000* (Regulations) and the definition of the term in the dictionary at the end of the Regulations.

Appendix F: Chemicals available for bird control by registration or under permit

Active ingredient	ACT	NSW	NT	QLD	SA	TAS	WA	VIC	Product Names	Supplier	Conditions
Lethal poisons											
Alphachloralose							Y		Alphachloralose	Agriculture Protection Board Of Western Australia	For use by licensed pest control operators, Agriculture Protection Board officers and other authorised persons only on commercial areas. For use on pigeons, starlings, sparrows and sulphur-crested cockatoos (below 20 degrees south). Not to be used on other native species without permission from DEC WA.
					Y	Y			Rentokil Alphachloralose Bird Control Agent	Rentokil Initial Pty Ltd	For introduced species, only in and around buildings. For use by licensed pest control operators or persons authorised by the Registrar of Pesticides.
		Y							Rentokil Alphachloralose Bird Control Agent	Rentokil Initial Pty Ltd	Site permit required from NPWS. For some native and introduced species, only in and around buildings. To be used by licensed pest control operators or appropriately trained NSW Agriculture and Rural Lands Protection Board Staff.
Fenthion									Fenthion (Status A)	Bayer Cropscience Pty Ltd	For the control of pigeons, starlings, mynas and sparrows. This product is to be supplied only to, and used only by, a licensed pest control operator and the user must have in their possession a copy of standard operating procedures (e.g. *AAA Bird Control Services Standard Operating Procedures (SOP) for the Application of Avigrease Pest Bird Eradication Compound*).
			Y			Y		Y	Control-A-Bird Agent	Control-A-Bird Pty Ltd	
			Y			Y		Y	Avigrease Pest Bird Eradication Compound	Australian Pest Bird Management Pty Ltd	
			Y			Y		Y	Avigel Pest Bird Control Agent	Greg Cowan Trading As ANC Bird Control	

Active ingredient	ACT	NSW	NT	QLD	SA	TAS	WA	VIC	Product Names	Supplier	Conditions
4-aminopyridine	Y	Y	Y	Y		Y		Y	Scatterbird	Sterling Pest Control Pty Ltd	License must be obtained from NSW NPWS. In NT, use requires written approval from the Department of Natural Resources, Environment and the Arts. To be used by licensed pest control operators only. Used only around buildings. For exotic birds e.g. pigeons, starlings, sparrows and mynas.
Chemical deterrents											
Aluminium ammonium sulfate	Y	Y	Y	Y	Y	Y	Y	Y	D-Ter Animal and Bird Repellent	Lorac Australia Pty Ltd	
	Y	Y	Y	Y	Y	Y	Y	Y	Multicrop Scat Bird and Animal Repellent	Multicrop (Aust) Pty Ltd	For garden areas.
		Y							Rudducks Bird and Animal Repellent	Rudducks Pty Ltd	For garden areas.
Polybutene		Y				Y		Y	Cyndan Bird Ban Bird Repellent	Loremo Pty Ltd trading as Cyndan Manufacturing	Do not contaminate waterways. Do not apply to wet surfaces, ice, snow. Use on ledges, sills, railings, i.e. roosts. For exotic birds, e.g. pigeons, starlings, sparrows.
	Y	Y	Y	Y		Y	Y	Y	Scarecrow Bird Repellent	Garrards Pty Ltd	Do not contaminate waterways. Do not apply to wet surfaces, ice, snow. Use on ledges, sills, railings, i.e. roosts. For exotic birds, e.g. pigeons, starlings, sparrows.
		Y							Garrard's Bird Repellent	Garrards Pty Ltd	

Source: Australian Pesticides and Veterinary Medicines Authority

Note: This information does not replace product labels, or legislation. Conditions, status and the availability of registered chemicals may have changed. For the latest information check the APVMA's registry database PUBCRIS, which is available on-line at www.apvma.gov.au , or contact the department of agriculture in each State or Territory (Appendix A).

Appendix G: Scientific names of pest and other bird species mentioned in the text

Native Australian species

Adelaide rosella *Platycercus elegans adelaidae*

Australian brush turkey *Alectura lathami*

Australian king parrot *Alisterus scapularis*

Australian raven *Corvus coronoides*

Australian ringneck *Barnardius zonarius*

Australian shelduck (mountain duck) *Tadorna tadornoides*

Australian wood duck (maned duck) *Chenonetta jubata*

Barn owl *Tyto alba*

Bassian thrush (White's thrush) *Zoothera lunulata*

Baudin's black cockatoo *Calyptorhynchus baudinii*

Black duck (Pacific black duck) *Anas superciliosa*

Black currawong *Strepera fuliginosa*

Black-eared miner *Manorina melanotis*

Black-faced cuckoo-shrike *Coracina novaehollandiae*

Black swan *Cygnus atratus*

Blue bonnet *Northiella haematogaster*

Blue-faced honeyeater *Entomyzon cyanotis*

Brown falcon *Falco berigora*

Budgerigar *Melopsittacus undulatus*

Butcherbirds *Cracticus* spp.

Cape barren goose *Cereopsis novaehollandiae*

Chestnut teal *Anas castanea*

Common koel *Eudynamys scolopacea*

Cormorants *Phalacrocorax* spp.

Coxen's double-eyed fig parrot *Cyclopsitta diophthalma coxeni*

Crimson rosella *Platycercus elegans elegans* (*P. elegans nigrescens* in north-east coastal Queensland)

Cuckoos — family Cuculidae

Eastern rosella *Platycercus eximius*

Emu *Dromaius novaehollandiae*

Figbird *Sphecotheres viridis*

Flesh-footed shearwater *Puffinus carneipes*

Forest raven *Corvus tasmanicus*

Galah *Elophus* [*Cacatua*] *roseicapilla*

Gang-gang cockatoo *Callochephalon fimbriatum*

Glossy black-cockatoo *Calyptorhynchus lathami*

Goshawks *Erythrotriorchis radiatus* and *Accipiter* spp.

Great bowerbird *Chlamydera nuchalis*

Green rosella *Platycercus caledonicus*

Grey currawong *Strepera versicolor*

Grey shrike-thrush *Colluricincla harmonica*

Grey teal *Anas gracilis*

Gulls *Larus* spp.

Hardhead (white-eyed duck or widgeon) *Aythya australis*

Honeyeaters — family Meliphagidae

Hooded plover *Thinornis rubricollis*

Ibis — family Threskiornithidae

Kookaburra *Dacelo novaeguineae*

Lewin's honeyeater *Meliphaga lewinii*

Little corella *Cacatua sanguinea*

Little crow *Corvus bennetti*

Little eagle *Hieraaetus morphnoides*

Little lorikeet *Glossopsitta pusilla*

Little raven *Corvus mellori*

Little tern *Sterna albifrons*

Long-billed corella *Cacatua tenuirostris*

Lorikeets *Glossopsitta* spp

Magpie *Gymnorhina tibicen*

Magpie goose *Anseranas semipalmata*

Magpie-lark *Grallina cyanoleuca*

Major Mitchell's cockatoo *Cacatua leadbeateri*

Mallee ringneck *Barnardius zonarius barnardi*

Maned duck (Australian wood duck) *Chenonetta jubata*

Masked lapwing (spur-winged plover) *Vanellus miles*

Metallic starling *Aplonis metallica*

Mistletoe bird *Diaceum hirundinaceum*

Musk lorikeet *Glossopsitta concinna*

New Holland honeyeater *Phylidonyris novaehollandiae*

Noisy friarbird *Philemon corniculatus*

Noisy miner *Manorina melanocephala*

Olive-backed oriole *Oriolus sagittatus*

Pale-headed rosella *Platycercus adscitus*

Parrots *Platycercus* spp. and *Polytelis* spp.

Peaceful dove *Geopelia striata*

Peregrine falcon *Falco peregrinus*

Pied currawong *Strepera graculina*

Pink-eared duck *Malacorhynchus membranaceus*

Purple-crowned lorikeet *Glossopsitta porphyrocephala*

Purple swamphen *Porphyrio porphyrio*

Rainbow lorikeet *Trichoglossus haematodus*

Red-capped parrot *Purpureicephalus spurius*

Red-rumped parrot *Psephotus haematonotus*

Red-tailed black-cockatoo *Calyptorhynchus banksii*

Red wattlebird *Anthochaera carunculate*

Red winged parrot *Aprosmictus erythropterus*

Regent bowerbird *Chlamydera nuchalis*

Regent parrot *Polytelis anthopeplus*

Ringneck *Barnardius zonarius*

Rosella *Platycercus* spp.

Satin bowerbird *Ptilonorhynchus violaceus*

Scaly-breasted lorikeet *Trichoglossus chlorolepidotus*

Short-billed black-cockatoo *Calyptorhynchus latirostris*

Silver gull *Larus novaehollandiae*

Silvereye *Zosterops lateralis*

Sooty tern *Sterna fuscata*

Spiny-cheeked honeyeater *Acanthagenys rufogularis*

Spotted bowerbird *Chlamydera maculata*

Sulphur-crested cockatoo *Cacatua galerita*

Superb parrot *Polytelis swainsonii*

Swans *Cygnus* spp.

Swift parrot *Lathamus discolor*

Torresian crow *Corvus orru*

Turquoise parrot *Neophema pulchella*

Twenty-eight parrot *Barnadius zonadius semitorquatus*

Wedge-tailed eagle *Aquila audax*

Welcome swallow *Hirundo neoxena*

Western rosella *Platycercus icterotis*

Western corella *Cacatua pastinator*

Whistling kite *Milvus sphenurus*

White-plumed honeyeater *Lichenostomus penicillatus*

White-naped honeyeater *Melithreptus lunatus*

White tern *Gygis alba*

White's thrush (Bassian thrush) *Zoothera lunulata*

Yellow-faced honeyeater *Lichenostomus chrysops*

Yellow rosella *Platycercus elegans flaveolus*

Yellow-tailed black-cockatoo *Calyptorhynchus funereus*

Yellow-throated miner *Manorina flavigula*

Yellow oriole *Oriolus flavocinctus*

Zebra finch *Taeniopygia guttata*

Introduced (exotic) species

Blackbird (European) *Turdus merula*

Chicken *Gallus gallus*

Goldfinch (European) *Carduelis carduelis*

Greenfinch (European) *Carduelis chloris*

House sparrow *Passer domesticus*

Myna (common or Indian) *Acridotheres tristis*

Pigeon feral or wild or rock dove *Columba livia*

Skylark *Alauda arvensis*

Song thrush *Turdus philomelos*

Starling (common or European) *Sturnus vulgaris*

Tree sparrow *Passer montanus*

Overseas species not found in Australia

American blackbirds

This is an inclusive term that refers to any bird of the family Icteridae (Passeriformes), whose male is black or predominantly black. This family has 96 species of New World orioles, blackbirds, cowbirds and allies. In this document this term mainly refers to red-winged blackbirds (*Agelaius phoeniceus*), common grackles (*Quiscalus quiscala*) and brown-headed cowbirds (*Molothrus ater*). Common starlings (Family Sturnidae) have also been included in this group on occasion. This term has been used in the text only if the individual species have not been more accurately identified.

American crow *Corvus brachyrhynchos*

American goldfinch *Carduelis tristis*

American robin *Turdus migratorius*

Brown-headed cowbird *Molothrus ater*

Canada goose *Branta canadensis*

Cape sparrow *Passer melanurus*

Cedar waxwing *Bombycilla cedrorum*

Common grackle *Quiscalus quiscula*

Dickcissel *Spiza americana*

Grackle *Quiscalus quiscula*, *Cassidix mexicanus*

Grey catbird *Dumetella carolinensis*

Herring gull *Larus argentatus*

Horned lark *Eremophila alpestris*

House (Columbo) crow *Corvus splendens*

House finch *Carpodacus mexicanus*

Japanese quail *Coturnix coturnix*

Jungle crow *Corvus macrorhynchos*

Mockingbird *Mimus polyglottos*

Mourning dove *Zenaida macroura*

Quelea *Quelea quelea*

Red-billed gull *Larus delawarensis*

Red-winged blackbird *Agelaius phoeniceus*

Rook *Corvus frugilegus*

Rufous turtle dove *Streptopelia orientalis*

Wild Pigeon *Columba livia*

Wood-pigeon *Columba palumbus*

GLOSSARY

Accuracy: a measure of how close an estimate is to the true value. This can be measured by bias ([Estimate – Known]/Known) or mean squared error (sample variance + $[bias]^2$). If an estimate equals the actual value it is unbiased. By this definition the accuracy of an estimate can be measured only when the true value is known. Some estimates of bias can be achieved by investigating factors that consistently cause a value to be over- or under-estimated. In most cases, estimates are assumed accurate and unbiased and only precision is estimated.

Acoustic: see *Deterrents, acoustic*.

Adaptive management: use of different management options, implemented so that treatments and their effectiveness can be monitored, evaluated and compared and the knowledge gained can be used to improve future management. Also called 'adaptive experimental management' or 'learning by doing'.

Alarm call: loud call given by bird when it senses danger; to alert other birds. Not all birds have alarm calls. Usually causes birds to take flight immediately. Usually species specific.

Ambient temperature: the air temperature surrounding the animal.

Annual migrant: see *migratory.*

Arthropod: invertebrate (animal without a backbone but with an external skeleton, and jointed legs). This group includes:

- insects
- myriapods (including centipedes and millipedes)
- arachnids (including spiders, mites and scorpions)
- crustaceans (including slaters, prawns and crabs).

Avicide: poison specifically used for killing birds.

Barbiturate: any of a group of barbituric acid derivatives that act on the central nervous system. Used in humans to treat insomnia, seizure and convulsions and to relieve anxiety and tension, and in animals to sedate.

Benefit–cost ratio: a ratio that identifies the relationship between the benefits and costs of a proposed project**.** Specifically, it is the ratio of discounted benefits to discounted costs, indicating the potential return per $1 invested over the period. Profitable control options will have a benefit–cost ratio greater than one.

Bioacoustic sounds: see *Biosonic sounds*

Biocontrol: see *Biological control.*

Biological control: the control of pests using other living organisms, usually infectious diseases, but also includes the use of predators. Also called *biocontrol*.

Biosonic sounds: broadcasts of recorded calls used in animal communication — usually alarm, distress or predator calls, or electronic mimics of such calls. The calls are recorded, sometimes digitised and modified, amplified, and broadcast through speakers to keep birds away from vulnerable crops.

Bird of prey: meat-eating bird. Day-hunting birds of prey (Order Falconiformes) are kites, hawks, eagles (Accipitridae) and falcons (Falconidae). Night-hunting birds of prey (Order Stringiformes) are owls. Birds of prey are also called raptors.

Brassica crops: vegetables and oilseeds from the Family Brassicaceae, including broccoli, cabbage, brussels sprouts, cauliflower, turnips, mustard and canola.

Brix°: a scale used for the measure of soluble sugar content (SSC). Expressed in degrees.

Cambium: the layer of tissue (one to several cells thick) between the bark and the wood of a woody plant. The cells increase by division and form new wood (phloem) cells and bark (xylem) cells. See *phloem* and *xylem*.

Cannon net: a rocket-propelled, large net that may catch large numbers (up to 500) birds at one time. Usually the target birds need to be pre-fed where the net has been set up. The net operator observes from a hidden location and activates the explosive propellent with an electrical charge to 'fire' the net over the top of the feeding birds.

Chemical repellents: aversive substances that are usually sprayed onto crops because their taste, smell, colour or physiological effects make the treated fruit unattractive to birds. Also called chemical deterrents. See also *Primary repellents* and *Secondary repellents.*

Clutch: the complete set of eggs or chicks produced at any one time.

Communication jamming: sounds with a similar frequency range to birds' communication calls are broadcast in an attempt to disrupt communication between flock birds. Trialled as a pest bird control technique but has unproven effectiveness.

Compensatory crop production: recovery growth in plants that occurs following damage and may reduce the economic losses resulting from the damage. For example, new shoots may grow from the site of the damage, or remaining fruit may grow larger.

Corvids: the family grouping of birds that includes ravens and crows. Five native species are recognised that are of a similar size and appearance and are difficult to distinguish: little crow (*Corvus bennetti*), Torresian crow (*C. orru*), Australian raven (*C. coronoides*), forest raven (*C. tasmanicus*) and little raven (*C. mellori*). An introduced species, the house or Columbo crow (*C. splendens*), has also been observed in Fremantle (Western Australia) and near the Melbourne Zoo in Victoria.

Cost–benefit analysis: an analysis that compares benefits and costs at a particular level of activity. (see *Benefit-cost ratio*).

Cost-effectiveness analysis: a type of analysis that is used to compare the cost-effectiveness of different management strategies.

Crisis management: control applied reactively with no forward planning.

Cryptic: appearance that conceals or disguises an animal's shape or behaviour — often in birds through dull-coloured plumage or when birds keep themselves hidden from view by inhabiting dense vegetation such as heavy grapevine canopies.

Decoy crop: a crop grown specifically to attract birds. Ideally, it should be attractive just before nearby commercial crops become vulnerable to bird attack, and remain more attractive to the birds than the commercial crop(s) throughout the period when the commercial crops would otherwise be attacked.

Decoy feeding: providing attractive food to birds to lure them away from attacking commercial crops. Decoy food must be highly palatable and at least as nutritious as the commercial crop, otherwise there is little reason for birds to be attracted to it.

Descriptive models: models that help users to understand economic relationships. For example, they may help users to estimate the level of bird control that has the maximum economic benefit. Descriptive models require accurate measurements of a range of factors, including damage and management costs, benefits of applying control, and the relationships between bird density and the damage they cause. A descriptive model can also support process management and improvement, helping to identify potential problems before they occur. Examples include economic threshold models, marginal analysis and cost-effectiveness analysis (Chapter 5).

Destruction permit: a permit issued by a State or Territory government to allow a grower to kill or harass a specified number of specified birds by specified means, often over a specified period of time, to reduce crop damage.

Deterrents, acoustic: sound-producing devices intended to scare pest birds. Outputs may include audible, ultrasonic (above human-hearing range) or infrasonic (below human-hearing range) sounds, or combinations of these. Includes electronic devices, gas guns, firecrackers, shotgun reports, bangers (crackershells) and biosonic sounds. Also called auditory devices.

Deterrents, visual: devices whose appearance is intended to scare pest birds. Includes scarecrows, predator models, kites, artificial eyes, balloons, and flashing and fluttering objects.

Diatomaceous earth: a light, porous rock or soil derived from fossilised microscopic unicellular algae called diatoms. The sharp fragments can irritate mucous membranes or eyes.

Discount rate: the rate used to calculate the present value of future benefits or costs. It is calculated by using the reverse equation to that used to calculate interest rates on invested money.

Dispersal: the permanent emigration of individual birds from a population or from their normal home range. This is most often associated with juveniles or young adults dispersing from their natal home range or place of birth, but can also be used to describe adults permanently vacating their home range for other reasons (e.g. permament changes in food, water or shelter). This behaviour can occur within migratory, nomadic or sedentary populations. See also *migratory*, *nomadic*, *sedentary*.

Distress call: loud 'squawk' given by a bird held captive usually by a predator. Often attracts other birds to mob the predator.

Dockage: penalty applied by wholesalers for blemishes, impurities, or reduced quality of fruit as a direct or indirect consequence of bird damage.

Drape-over netting: increasingly common form of temporary exclusion bird netting used to protect commercial horticulture crops, particularly high-value grape and berry crops, over the ripening season. Drape-over nets can be lightweight, relatively inexpensive nets that can cover a single row. Alternatively, they can be two-, four- or six-row nets or a 'lock-out' system, where nets are draped over orchard trees or vines and then joined together to create a complete cover. Some growers use poles to create low-cost support structures for drape-over nets. Well cared-for drape netting can last between five and eight years. Also called *throw-over netting*.

Dynamic programming: an optimisation procedure that is particularly applicable to problems requiring a sequence of interrelated decisions. Each decision transforms the current situation into a new situation. A sequence of decisions, which in turn yields a sequence of situations, is sought that maximises (or minimises) some measure of value or effectiveness. Consider a simplified example: comparing starling control strategies that vary with the season. If a decision is made to impose a level of control during the breeding season, then the situation changes and will affect subsequent decisions. For example, this decision is likely to influence the rate of population change and the population density, and hence the efficacy of subsequent control decisions made during the ripening season. Dynamic programming attempts to take account of changes to the situation and provides a guide to selecting the optimal solution.

Economic threshold model: indicates the density of a bird population where the benefit of management just exceeds its cost (Stern et al. 1959; Mumford and Norton 1984). This break-even point can be used to decide the bird density at which a particular management strategy should be initiated.

Eradication: permanently eliminating the entire population of a bird species in a defined area by a defined date.

Exclusion netting: use of nets to physically prevent birds from gaining access to crops — usually economic only when high levels of bird damage occur in a high value crop. See also *Permanent netting*, *Drape-over netting*.

Exotic species: non-native species. Also called introduced or alien species.

Externality: an effect of production that is not taken into account by the producer and that affects the utility or costs of other producers.

Falconry: traditional art of training falcons to hunt game.

Fertility control: technique used to reduce the fertility of animals—contraception.

Fledging: the stage of chick development when the flight feathers are developing or developed and the chick is ready to fly.

Free-feeding: placement of unpoisoned bait for several days before a poisoning campaign to improve efficiency, reduce the impacts on non-target species and limit bait shyness.

Gravid: a female carrying eggs or embryos.

Habituation: process by which a bird's response to a fear stimulus is reduced over time following repeated exposure. If the bird learns through repeated exposure to the stimulus that it presents no real danger, the bird will eventually ignore the stimulus.

Horticultural crops: cultivated fruits, nuts, berries, vegetables, flowers and ornamental plants.

Inflorescence: a cluster of flowers on one stalk.

IRR [internal rate of return]: the *discount rate* that equates discounted benefits and costs over time: that is, the discount rate at which net present value = 0. Essentially, this is the return that a grower would earn if he/she expanded production or invested back into the property, rather than investing that money elsewhere. Profitable bird control options will have an IRR greater than the discount rate.

Internode: a section of stem between two nodes (plant stem where a leaf is or has been attached).

Linear programming: A linear programming problem has a linear objective function (for example, to maximise whole-farm gross margins from fruit production) and a set of linear constraints (for example, the numbers of pest birds present, fruit varieties grown, labour and capital resources), arranged in an array.

Marginal analysis: an analysis of the relative shift in cost and benefit values that occurs as incremental changes are made in the level of pest control effort.

Marginal benefit: the shift in benefit values that occurs as incremental changes are made in the factor(s) that affect the level of costs (for example, changes to fruit damage losses that occur as bird scaring activity is increased).

Marginal cost: the shift in cost values that occurs as incremental changes are made in the factor(s) that affect the level of costs (for example, changes that occur in the cost of deploying additional scaring devices around an orchard as pest bird activity increases).

Migratory: regular movements of a species usually within season over long distances, often collectively and in large numbers. Species can be described as: *annual migrants*, where all or most individuals move between breeding and non-breeding ranges (for example shorebirds); *partial migrants*, where some individuals in the population are migratory, while others are sedentary (for example Tasmanian silvereyes display innate migratory behaviour moving from Tasmania as far north as Queensland every year, while many silvereyes of northern populations do not migrate); or as *regional migrants*, where regular movements occur over short distances with season. See also *dispersal*, *nomadic*, *sedentary*.

Mist net: fine, almost invisible nets used for catching birds for research or monitoring purposes only. Mist nets are not available to growers as a damage reduction tool.

Monofilament lines: nylon 'fishing' lines strung over crops. These have been claimed to repel birds. It has been speculated that because monofilament line seems to appear and disappear, birds are repelled by the uncertainty of whether a barrier exists or not. Perhaps the fear of becoming entangled is part of the deterrent. Effectiveness in reducing bird damage to horticultural crops is unproven.

Net present value: the future stream of benefits and costs converted into equivalent values today. This is done by assigning monetary values to benefits and costs, discounting future benefits and costs using an appropriate discount rate, and subtracting the sum total of discounted costs from the sum total of discounted benefits.

Nomadic: irregular movements of a species over long distances in response to temporary resources (especially the availability of food, water or shelter) apparently randomly, or through no affiliation with a normal home range. For example, movements of Australian ducks over long distances in response to available surface water (unlike migratory ducks in the northern hemisphere that move seasonally between breeding and non-breeding areas); or movements of lorikeets and many honeyeaters in response to available nectar. Note there is often insufficient information to distinguish between movement classifications; in many cases behavioural traits overlap. Caughley (1977) considered nomadism as a form of dispersal that is difficult to differentiate from local movements, but by definition this implies the absence of a home range. This text differs from Caughley's (1977) definition in relation to the scale of movements, to allow us to differentiate movements in a local area (sedentary) which have a spatial component (less than 50 kilometres), from irregular movements over thousands of kilometres. In this text we have avoided the term 'dispersive', an apparent synonym for nomadic, due to possible confusion with 'dispersal'. See also *dispersal*, *migratory*, *sedentary*.

Odometer: instrument that indicates distance travelled by a vehicle.

Operational monitoring: monitoring that aims to evaluate the efficiency of a control programme. Labour, materials, transport and any other control costs need to be included in estimating the total costs of a programme, so that the relative costs of alternative approaches can be compared.

Opportunity cost: the cost of using a resource on the basis of what it could have earned if used for the next best alternative — for example, the opportunity cost of farming the land by growing a less profitable type of crop than the one that could have been grown if pest birds were not present.

Partial migrant: see *migratory*.

Passerines: order of birds that comprises the perching songbirds.

Pay-off matrix: table listing management strategies and their costs and benefits.

Performance indicators: these define the desired level of achievement against the management objectives — that is, they describe the outcomes that will be achieved in measurable terms and the timeline for achieving them.

Performance monitoring: aims to determine how well the implemented management plan performs in meeting the objectives, as defined by the performance criteria.

Permanent netting: use of long-life, ultraviolet radiation-stabilised, strong plastic netting supported over the top and sides of a crop with a pole and wire or cable structure to exclude birds from crops. Nets may last over ten years before needing to be replaced and supporting structures last much longer. Can be applied to a wide range of horticultural crops.

Phloem: the layer of cells just inside the bark of woody plants that conducts food from the leaves to the stem and roots. On the outside edge of the cambium, which separates the phloem from the xylem. See *xylem* and *cambium*.

Phytotoxic: toxic to plants and at sufficient concentrations will cause plant damage or death.

Pome fruit: apples (*Malus* spp.), pears (*Pyrus* spp.), nashis (*Pyrus pyrifolia*), quinces (*Cydonia oblonga*) and related fleshy fruit. Also called pipfruit.

Pre-baiting: see *Free-feeding.*

Precision: a measure of how close estimates are to each other, or how close they are to an expected value based on repeated samples, and measured by a variance. A measure of precision can be obtained by replicating sampling units. In general, the larger the number of sampling units the more precise the estimate.

Pre-feeding: see *Free-feeding.*

Prescriptive models: models that incorporate value judgements and compare different management strategies using specific, subjective criteria. An example in economics is 'decision theory', where risks, costs and benefits are considered subjectively to aid decision-making (Section 5.5).

Primary repellents: chemical repellents that produce an immediate avoidance response by birds because of their unpleasant smell or taste, or because they cause irritation or pain.

Propane exploder: a noise-generating device that looks vaguely like a cannon or gas gun and in which propane or LP gas is exploded to produce loud impulsive bangs as a technique for scaring pest birds.

Psittacine: birds that belong to the order Psittaciformes — that is, the parrots and cockatoos. Common psittacines include cockatiels, lorikeets, cockatoos and rosellas.

Psyllids and coccids: sap-sucking insects similar to scale insects (Sternorryncha).

Ramsar: The Ramsar Convention on Wetlands is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. It was adopted in the Iranian city of Ramsar in 1971 and came into force in 1975. The Convention's member countries cover all geographic regions of the planet see http://www.ramsar.org/ for more information.

Raptor: see *Bird of prey.*

Regional migrant: see *migratory*.

Repellents: see chemical repellents.

Resident: see *sedentary*.

Secondary losses: fruit spoilage by moulds, yeasts, bacteria and insect damage following bird damage.

Secondary plant compound: defence chemicals, occurring in plants that have evolved to inhibit feeding by herbivores.

Secondary repellents: chemical repellents that make birds feel ill after ingestion. The birds subsequently develop a conditioned aversion to the food on which the repellent has been applied.

Sedentary: movements of a species within a given area or home range normally of less than 50 kilometres. In this text we use sedentary as a synonym for 'resident' and vice versa. See also *dispersal*, *migratory*, *nomadic*.

Sensitivity analysis: analysis of how sensitive outcomes are to changes in the assumptions used in a model.

Soluble sugar content: an indication of the potential alcohol percentage and residual sugars (sweetness) of wine.

Soporific: a substance that induces unconsciousness.

Standard deviation (*s.d.*): an estimate of the variability of a sample calculated from the square root of the variance (s^2):

$$s.d. = \sqrt{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2 / (n-1)}$$

where x_i = value of each measurement from $1–i$; $\bar{x}$ = sample mean; and n = sample size.

Standard error (s.e.): a measure of the variability of measurements around the mean.

$$s.e._{(\bar{x})} = \mathrm{s.d.}/\sqrt{n}$$

where $s.d.$ = standard deviation; $\bar{x}$ = sample mean; and n = sample size.

The interval $\bar{x} \pm 2s.e$ will contain the true mean in 95% of large random samples. This interval thus constitutes the 95% confidence limits.

Stone fruit: fleshy soft fruit with large seed (*Prunus* spp.), including nectarines (*Prunus persica* var. *nucipersica*), peaches (*Prunus persica*), plums (*Prunus* spp.) and apricots (*Prunus armeniaca*).

Strategic one-off control: implementation of a single management action that has a long-term effect.

Strategic sustained control: a management strategy that requires a sustained effort over an extended period of time to reduce crop damage.

Strategic targeted control: control implemented only when conditions indicate that it is desirable.

Stratifying: where a site to be sampled is divided into sub-units (strata) based on the homogeneity of some feature within each sub-unit. For example, damage is to be estimated in a vineyard block where bird damage is concentrated in the last four panels of vines of each row closest to an area of native vegetation. The block can be divided into high and low damage strata along the line between the fourth and fifth panel, and this would be the demarcation line for sampling effort.

Sub-population: a well-defined set of interacting individuals that compose a proportion of a larger, interbreeding metapopulation.

Tactile repellents: chemicals that are applied to perches and irritate birds' feet on contact. Most are non-toxic, sticky or oily substances.

Throw-over netting: see *Drape-over netting*

Ultrasound: very high frequency sound above the range of human hearing (greater than or equal to 20 kilohertz). Most bird species cannot hear ultrasound at all or hear only the lower frequencies.

Ventriculus: part of a bird's digestive system, being the thick-walled muscular pouch below the proventriculus (similar to the stomach in other animals) and crop in many birds, used for grinding food. Also called a gizzard.

Veraison: ripening period when grapes begin to colour and their sugar content increases.

Xylem: the layer of tissue just inside the bark of woody plants that transports minerals and water from the roots to the stems and leaves.

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