Australian Government
Grape and Wine Research and Development Corporation

Ecology and Management of the Common Starling (*Sturnus vulgaris)* in the McLaren Vale Region



FINAL REPORT to GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

Project Number: UA 01/05

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Date: **August 19, 2005**

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Title page

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1. Abstract

Current management techniques are relatively ineffective at controlling Common Starling (*Sturnus vulgaris*) damage to winegrapes. Ecological data collected on starling breeding, foraging, roosting and movement behaviours in the McLaren Vale district have been used to suggest alternative management regimes. Individual birds moved up to 12km indicating the need for a regional scale management plan. Economic estimates of grape losses to starlings across the McLaren Vale region indicate relatively little damage, although some individual growers may suffer significant losses. The most cost effective management of starlings in grape growing districts is better met by implementing a regional cull of breeding pairs.

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2. Executive summary

The Common Starling (*Sturnus vulgaris*) is a well-known pest to viticulture. This report provides data on starling ecology and behaviour in the McLaren Vale grape-growing district of South Australia with practical implications to improve management and to limit grape losses.

2.1. Practical implications

Summaries of the research findings and their practical implications are given under five headings relating to the behaviour of the birds. These findings also demonstrate the benefit of doing a detailed ecological study before implementation of controls and should be used as a guide for other pest bird species.

2.1.1. Individual Movements

Common Starlings trapped in the McLaren Vale area largely remained within the region. Most individuals roamed over distances ranging from a few up to twelve kilometres during the grape season. During the spring breeding season adults rarely moved more than a kilometre from their nests. Data collected did not show large-scale movements of birds out of the region.

This has two implications for management. First, birds are moving over the region and not localized to a single property during the grape season. Therefore management of starlings to reduce grape losses needs to operate at a regional scale rather than an individual property scale. Second, starlings stay close to their nesting hollows during the breeding season, so culling efforts may be easier to implement while bird movements are restricted.

2.1.2. Flock Composition & Dynamics

Flock sizes vary seasonally and diurnally. Individuals also join and leave foraging flocks on a regular basis. On average, at least one starling arrives or departs a foraging flock per minute, so the composition of a flock is fluid. During the grape season, flocks consist of both adult birds and their offspring, and both contribute to grape losses. Juvenile starlings account for around 72% of birds in a flock.

If 72% of individuals in a flock are juvenile birds, then controlling breeding in spring may be more effective at reducing subsequent grape losses than attempting to shoot birds in flocks that are wary during the grape season. High turnover of individuals within flocks may also lessen the effectiveness of various deterrents (e.g. scaring devices or shooting at large flocks) during the grape season.

2.1.3. Diet

Common Starlings are primarily insectivorous (based on diversity not on volume) but also consume a wide range of plant material, including agricultural crops such as fruits and seeds. Gut contents from birds showed a varied diet over the grape season, with over 30 different food items noted in addition to grapes.

In aviary feeding trials, water deprived birds lost significantly more weight than their counterparts on a grape-only feeding trial. This provides evidence that grapes do not act as an alternate water source for starlings; therefore the provision of free water will not reduce the amount of grapes eaten. This also suggests that starlings cannot live on a diet of grapes alone. Consequently, providing starlings with alternative foods during summer may actually increase their chance of survival and subsequently damaging grapes.

Control by baiting or providing alternative foods during summer is not currently considered a feasible option, with grapes being an unlimited food source throughout the region. However, limiting other abundant food sources like feral olives may reduce starling fitness and nestling success during winter and spring. This can be done by removing feral and roadside olives altogether and ensuring that any planted olives (often used as windbreaks) are harvested so that starlings cannot exploit this high caloric food source.

2.1.4. Roosts

Night-time roosts were found in reed beds, conifers, palms and trees with dense canopies, thickets, hedges, bamboo stands within the region, as well as off-shore islands around 40km away. These roosts were used repeatedly year after year. Thousands of birds often aggregated in major roosts, but sizes of these roosts varied temporally. Autumn and winter roosts were often large and consisted of both adults and immature birds. Both males and females attended roosts. Individuals showed poor fidelity to a roost site, with some birds visiting another nearby roost (ca 2-3 km away) or roosting individually away from communal roosts. This lack of site constancy to a major roost means that removing the roost site vegetation (often introduced

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plants like boxthorn) would simply be countered by a shift of birds to a different roost site. Culling birds at roosts may still be possible, but any management program would have to be implemented during autumn and winter over a number of weeks or months and over a number of sites to ensure all birds were removed.

2.1.5. Nesting Biology

Starlings nested in a variety of habitats, from roofs and buildings to nest boxes, fenceposts and tree hollows between September and December. Within the McLaren Vale region, starlings used only 18-28% of available hollows in remnant vegetation and both adults and young returned to the previous year's breeding areas. On average 5 eggs were laid per clutch, fledging 3 young per nesting attempt and pairs typically had two broods per season. Thus starling populations in the McLaren Vale region increase 3-4 fold during the breeding season and population densities were highest immediately prior to the grape season. Hence, there is some site fidelity between seasons and hollows are not limiting breeding potential, so removal of breeding birds one year should reduce breeding populations in subsequent years.

Nesting hollows are easily identifiable in the breeding season with breeding birds typically returning to active nests at intervals of 5-10 minutes, so little effort is needed to detect breeding pairs of starlings on properties. Hollows in man-made structures can be eliminated with minor modifications (e.g. to roofs, fenceposts and other crevices). Within McLaren Vale, a high proportion of nest hollows occur in remnant vegetation. These tree hollows cannot be modified or removed, but control efforts can be focussed on culling breeding birds within a few hectares of remnant scrub that remain in the region. This strategy also has the effect of reducing the population size quickly compared to grape season culling and is drastically more cost efficient than any other current control methods.

2.1.6. Economics of Starling Damage

There have not been any previous attempts to estimate the dollar loss attributable to starlings, to growers, or the wine industry, in the McLaren Vale grape-growing district. Economically, regional efforts to control starling flocks during the grape season are more than 20 times as costly per hectare as a full-time cull implemented during the breeding season. The current costly control techniques are ineffectual at reducing the starling population on a regional level, but may aid in deterring other bird pests on individual properties during the grape season.

2.2. Industry Benefits

Implementation of controls outside of the grape season, save time and money now spent on other, often ineffective and expensive, control methods during the busy grape season. Implementing controls in the spring would also reduce the overall costs of current management regimes for starlings. The resulting smaller summer flocks would benefit growers by lowering subsequent crop losses to starlings.

2.3. Future Research

The major emphasis should now be on implementing a breeding season control program across the region and monitoring the benefits. Additional research recommendations include: conducting a comprehensive cost/benefit assessment of starling activity across the region; exploring structural variations among vineyards, like the influence of inter-row crop management on flock sizes/damage; watering trials in adjacent paddocks/lawns to determine if this is an effective way to draw starlings away from grapes; conducting more aviary feeding preference trials may provide insight to the limiting factor which makes starlings switch on to grapes; and conducting similar ecological studies on other pest birds in the region.

2.4. Dissemination Strategies

The results of this research will be disseminated through publication of scientific papers, a PhD thesis and presentation of these results at professional meetings.

2.5. Financial Support

Additional financial support for the student stipend and tuition was from the National Science Foundation Predoctoral Fellowship (Bentz 2000), University of Chicago's Unendowed fund (1999-2004), and the Illinois Minority Graduate Incentive Program Fellowship (Bentz 1999). Additional project funds were received from Onkaparinga Council, the Animal and Plant Control Group of the Department of Water, Land and Biodiversity Conservation, and the South Australian Farmer's Federation.

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3. Background

Common Starlings (*Sturnus vulgaris*) have spread throughout the world and are a serious pest in the viticulture industry. Damage is through loss of entire fruits, rather than damage to grape flesh which usually results in subsequent fungal or bacterial contamination (Somers and Morris 2002). The success of the starling in grape growing areas can be attributed to the ecology of this species, including communal roosting, flock feeding, a variable diet, and flock movements. Most research on this species is from North America and Eurasia. Knowledge of the diets, breeding, flocking and roosting behaviour as well as Common Starling movements within Australia are needed to develop more effective strategies for managing the species. This study describes the ecology of Common Starlings in the McLaren Vale grape-growing region.

3.1. Introduction

Common Starlings were introduced to Australia from their native European range in the late 1800s. They spread and established from subsequent introductions and now cover approximately 30% of Australia (Forde 1989). For example, in 1881 South Australia's Acclimatisation Society intentionally released 89 birds at Black Hill and Torrens Park; this was followed by rapid expansion and establishment on Eyre Peninsula and Kangaroo Island by 1900 (Long 1981). Little quantitative data are available on the economics of this damage but one estimate in the Sunraysia table grape and sultana industry put losses at a cost of $1.58 per bird per season (Doyle 1997).

The level of damage experienced in individual vineyards varies dramatically both spatially and temporally, with grape variety, proximity to suitable perches (powerlines, large trees), the extent of leaf cover over bunches and the age of the vine all influencing the extent of damage (Graham 1996; Somers and Morris 2002). Management of these fruit losses to birds in Australia primarily relies on deterrents (particularly gas guns and other noise generating scaring devices) with and without shooting. These methods are largely ineffective (Weber 1979; Bomford 1990; Bomford and O'Brien 1990; Crossfield 2000; Sinclair and Bomford 2002), and even if effective at reducing damage at a local vineyard scale, are likely to shift birds to a nearby vineyard than alleviate the problem on a regional scale. The use of audible deterrents also irritates neighbours, while culling birds has animal welfare implications if not done humanely. Both of these actions draw public criticism and reflect badly on the industry, locally, nationally and internationally. Covering vines with netting, however, greatly reduces damage caused by all types of birds but is not always economically practical and may encourage insect pests that would otherwise be removed (Doyle 1997; Sinclair and Bomford 2002). Similarly removing suitable perches and 'launch' sites

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such as powerlines and large trees near vineyards is not often feasible. Therefore, practical alternatives to economically limit grape loss to Common Starlings are needed.

The improvement of current techniques to minimize damage and develop effective management plans is difficult without adequate knowledge of the behaviour and population biology of the pest species (Weber 1979; Feare 1984; Feare 1989). Examining the Common Starling's use of the agricultural landscape by integrating the spatial scale of damage with the distribution of the species across the region and documenting their behaviour would be useful in determining alternative control methods. Hence, a more thorough understanding of the introduced Common Starling's biology and ecology within agricultural regions of Australia is essential for developing new approaches for managing this pest species.

3.2. Project Aims

There is broad interest in limiting agricultural damage by pest species. The aim of this study was to gain a better understanding of the ecology of the Common Starling in the grape growing region of McLaren Vale to improve their current management strategies and limit grape damage. After understanding more about the biology and behavioural strategies of this species, alternative management options can be tailored to specific times of year or specific locations when and where starling populations are most vulnerable to interference. These findings may be relevant to improve management of the species nationally, or even globally.

Specifically, the goals of this project were to determine the:

1) seasonal patterns in the diet of starlings;
2) age structure, size and movement patterns of flocks causing damage to grapes;
3) locations of the most used habitats within and around vineyards including damage hotspots and roosts;
4) breeding population densities, site fidelity and reproductive outputs; and
5) alternatives to current management strategies to manage starling populations and reduce losses caused by their consumption of grapes.

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4. Project Aims and Performance Targets

4.1. Outputs

1) Document age compositions and map movements of flocks of starlings in the McLaren Vale region.
2) Map locations and sizes of nocturnal roosts used during and outside of grape season.
3) Identify food sources used by starlings in the McLaren Vale region.
4) Map distribution, abundance, nest sites and nest success of Common Starlings in the region and compare between years.
5) Assess the potential for alternative management options for Common Starlings in the McLaren Vale region.
6) Implement and test the efficacy of alternative management actions for Common Starlings in the McLaren Vale region.
7) Provide training opportunities for McLaren Vale growers to estimate levels of damage and to assist in the research program.
8) Production of a PhD thesis and submission of research papers to refereed journals for publication.

4.2. Performance targets

1) Map major concentrations and flight paths of Common Starlings during the grape season in a ca 100km^2 area of the McLaren Vale region by 30 June 2002 and outside the grape season by 31 Dec 2002. Repeat mapping in subsequent year, reporting in June 2003 and December 2003.
2) Map nocturnal roosts used and show seasonal changes in numbers using roosts during grape season by 30 June 2002 and outside the grape season by 31 December 2002. Confirm these patterns in the subsequent year.
3) Describe and report on foods and feeding habitats used by Common Starlings in the McLaren Vale area by 30 June 2002. Confirm these patterns in the subsequent year.
4) Provide nesting report by 31 December 2001 and repeat the survey in the following year and provide comparative report by December 2002.
5) Provide a discussion paper by 30 April 2003. Establish industry review committee and decide on alternative management options by 30 June 2003.
6) Report on findings of trial management programs and disseminate material to the McLaren Vale growers and to the industry as a whole by 30 June 2004.
7) Two meetings with McLaren Vale growers in each year of the project.
8) Production of a PhD thesis by 30 June 2005.

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5. Methodology

This study was conducted in the McLaren Vale grape-growing District of South Australia, Australia. According to the Phylloxera and Grape Industry Board of South Australia, the total area of vines planted in the McLaren Vale region in 2005 was 6,758 hectares.

The study area was divided into a grid of 100 x 1km^2 blocks, bordered on the north by the Onkaparinga River, a main highway (Main South Road) on the west, the foothills of the Mount Lofty ranges on the east and a local road (Colville Road) on the south.

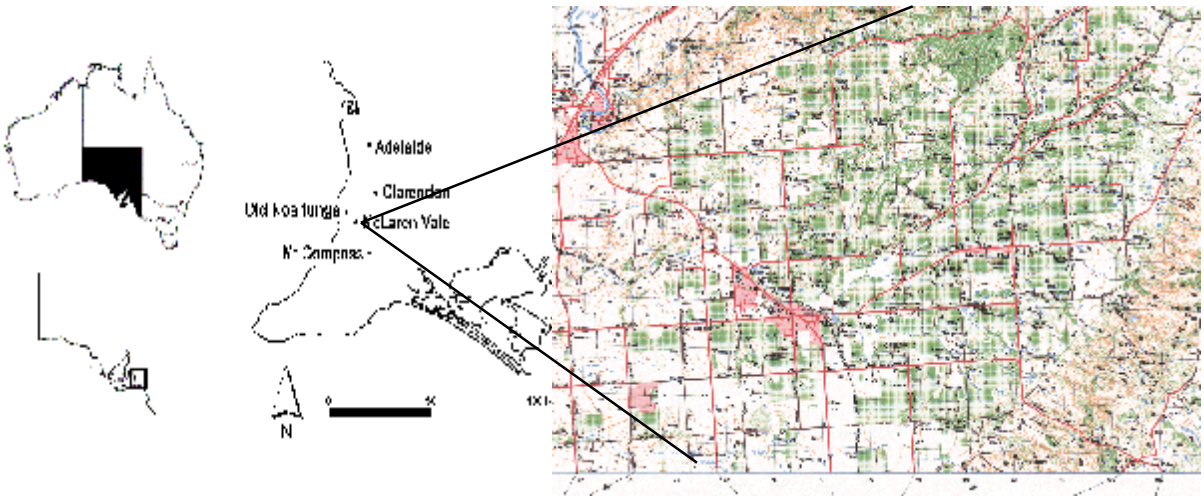


Figure 1. Location of the study area in the McLaren Vale grape-growing district of South Australia, Australia.

A sub-sample of these cells was systematically searched for starlings on a regular basis. For each cell, the numbers of starlings seen were counted (or estimated when in large flocks), the positions of the birds mapped using a Garmin GPS 12 CX, and their behaviour recorded (e.g. perching, singing, flying, foraging). A range of habitat types was sampled within of these cells, including urban areas, native scrubland, remnant scrub patches near or within vineyards and vineyards both near and away from creeklines as well as paddocks and reedbeds. Once the entire study area was surveyed, smaller study sites for behavioural research were chosen accordingly.

This study included mark and release methods consisting of mist-netting or manual capture of Common Starlings and leg banding of the captured individuals. Once animals were captured, body measurements and other demographic data were compiled.

5.1. Diet & Feeding Ecology

Samples of birds were collected from owners of properties where culling starlings was used as a control method during and outside of the grape season. Gizzard contents of

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each bird were examined to determine food items eaten and to determine seasonal shifts in food items consumed. The percent volume of animal, vegetable and grape matter was visually estimated, since dry weights are biased to indigestible matter.

Spatial patterns and density of birds foraging in different environments were also investigated to determine the scale of management efforts needed across the region. When the birds were found feeding, the substrate (e.g. irrigated pasture, fallow paddock, vine) and a GPS location were recorded. Once a flock was located, observations of foraging flock activities were taken in 2-minute intervals for as long as the flock was present. The percent of individuals involved in particular activities (e.g. foraging, perching on trellis poles/vine wires, flying) was estimated. Movements of individual birds into and out of the foraging flock were also noted.

5.2. Movements

To quantify levels of site fidelity, a number of birds were captured, leg-banded with a uniquely numbered ring and coloured bands in a coded system, and then released at the original capture site. When individuals were subsequently seen they were identified by their colour bands, and the time, GPS position, structure in use and the activity of the bird were noted. These data were compared to initial capture locations to determine the distance of their movements. Young birds captured on the nest were also banded if old enough (>10 days, eyes open and legs thick enough so that bands would not slip off) to help determine their post-fledging movements and survival rates.

Individual birds were also captured and fitted with radio transmitters. Home ranges were determined by regularly locating these birds using a RX5 transceiver and directional aerial during the day and night. A GPS was then used to map these positions in the landscape. Transmitters lasted for up to 3 months, and individuals were followed until the transmitters fell off or the signal was lost. A minimum convex polygon of 100% on the Ranges 6 version 1.08 program (Kenward *et al.* 2003) was used to estimate the greatest area used by an individual bird. Areas of the 80 and 100% isopleths were determined using Kernel Analyses, Arcview 3.2 to create best-fit ellipses of individual starling home ranges (ESRI 1999).

Capture, tagging, and radiotelemetry techniques were approved by University of Adelaide Animal Ethics Committee (Approval Numbers S-16-2002, S-52-2003 and S-60-2003).

5.3. Flocks

Foraging site selection by birds is assumed to be related to foraging efficiency, food availability and abundance, as well as predation risk (Elchuck and Wiebe 2002). To

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determine flock sizes and their movements within the region, groups of starlings were located and followed for as long as possible. The numbers of birds in the flock were counted and the positions of the flock in the landscape were documented using a Garmin GPS at regular intervals.

Flocks were also noted while systematically searching the entire 100km^2 using a series of transects established along a network of roads within the region. This transect sampling was completed at least once per month while grapes were on the vines (February, March and April) and flock positions were noted in the landscape. GPS locations were mapped to determine Common Starling hotspots and habitat variables recorded to enable their descriptions. Preferences in structural or physical characteristics found at starling hotspots were determined after exploring and characterizing a random sample of points within the region.

5.4. Roosting Behaviour

Once roosts were located, the total numbers of birds arriving at dusk or leaving the roost at dawn were counted to determine fluctuations in roost sizes. The individual sizes of each flock arriving or departing roosts were also noted. The time each flock moved and the direction of flight were noted to determine flock dynamics.

Birds were also captured at two major roosts outside McLaren Vale at Enterprise Road, Mt Compass and Wright Island, Victor Harbor. They were banded to determine if there was any movement of birds between them and the McLaren Vale area. Radio-tracking of several of these roosting individuals was also conducted to determine roost site fidelity and comparative movement data.

5.5. Breeding Ecology

Systematic searches for suitable hollows and evidence of breeding were made in some of the 100 - 1km^2 cells during spring (September to December) to map distribution, abundance, nest sites and nest success of starlings. Nests of starlings were easily identified when the birds were feeding young in the nest, with parents moving regularly to and from the hollow. The intention was to estimate the number of nesting pairs within the study area and to identify opportunities to restrict nesting (e.g. elimination of roof access, hollow modification, or nesting habitat modification). Again, mist-netting and live trapping were used to capture and individually band breeding pairs for subsequent identification. All nestlings determined old enough were also colour banded for later identification and to determine natal dispersal. Radio-transmitters were fitted to a few fledglings and adults to determine breeding season home ranges and dispersal dynamics.

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The d'Arenberg winery (Osborn Road, McLaren Vale) and Tatachilla Lutheran College (Tatachilla x California Roads, McLaren Vale) were chosen as the main nesting study sites because of the presence of remnant scrub with suitable hollows. The d'Arenberg Winery consists of patches of remnant scrub interspersed throughout the vineyard and associated buildings, while the Tatachilla hollows are interspersed with man-made structures. These patches were surveyed over 2002 and 2003 to determine hollow densities, number of breeding birds, site fidelity, and reproductive outputs in and around vineyards. Active hollows or other nest sites were mapped with a GPS and the distribution and abundance per patch of scrub were noted. Nesting densities and active hollows were determined from searches conducted in the patches of remnant vegetation and counting active starling pairs. Hollow availability and extent of use at each site was also recorded.

In addition to inspecting hollows (aided with a borescope), hollows were watched to record the frequency with which starling parents returned to nests with chicks. During the breeding season, feeding rate observations were taken for one-hour intervals between 06:00hr and 18:00hr. Sex of the parents (if unbanded) and food items were noted using binoculars during observations. Feeding rates for nesting pairs were recorded to determine amount of time spent outside versus time inside the hollow feeding young. This information was then used to recommend an adequate time needed for a census to determine if starlings are breeding on individual properties, and to identify food items important to nestlings, and possibly limit these food items to hinder successful broods.

Manual capture was conducted at nesting hollows and was used to band breeding pairs while incubating and subsequently to band young. Data on site fidelity was accumulated using colour bands to identify individuals nesting in the same areas over multiple years. Banded individuals that were breeding in the area were noted along with a GPS of the nest tree and hollow locations.

An estimate of the overall productivity of the nesting population was made to see if that alone could account for the apparent influx of starlings into vineyards in the following summer. Number of eggs and/or young were noted for each active hollow found within patches of remnant scrub on the d'Arenberg and Tatachilla properties.

In the final laying season (September 2004 to December 2004) removal of breeding pairs was made in one of the scrub sections to determine rates of hollow recolonisation and subsequent hollow use in the following year (2005).

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6. Results and Discussion

6.1. Demography

There were 728 Common Starlings captured from May 2002 to May 2004. Of these, 467 were captured in the McLaren Vale region and 261 birds were captured at two major roosts outside of the study area. These latter birds were banded to study roosting dynamics and provide comparative data on movements. Within the McLaren Vale region, 60 birds (12.8%) were resighted at least once within the area after initial capture (includes radio-tracked birds). Of these resightings, there were 10% of banded nestlings that returned to their natal areas to nest as adults in the subsequent year. There were also 30% of banded adult birds, both male and female that returned to their previous year's nesting areas.

There were 252 birds collected from properties that used culling as a control method throughout the year (147 January to April and 105 June to November). Fifty-seven percent of the starlings shot and collected during the grape season were juveniles. Outside of the grape season, the sex ratio of collected adults was 50/50 (49M:48F).

6.2. Diet & Feeding Ecology

Data from gut contents revealed that in addition to taking red and white grapes at least 30 other types of food, including snails, beetles, weevils, wasps, ants, isopods, millipedes and worms, were taken. These items will be subsequently identified by museum experts and compared to the items in Barker and Vestjens (1990) list.

Common Starlings also need to drink free water daily (Feare 1984). With drying summer soils and dams, starlings flock to any ephemeral water source, especially going into the vineyards when drippers are leaking (Bentz, pers obs). Watering adjacent paddocks or lawn may provide alternative sources of water and keep insect numbers up during summer and attract starlings to these non-grape areas, though this has not been tested.

Aviary trials were conducted in 2005 to determine if starlings were using grapes as an alternative water source (Table 1). Starlings consumed individual grapes plucked from bunches. Adult starlings ate from 20 to 55 grams of wine grapes during a 12-hour period (31 g average 2004, 39 g average 2005) during aviary feeding trials. Data collected show that though there was no significant difference in grape consumption between water treatments or between age classes ($F = 1.2$, $p=.28$, $df = 1$; $F=.99$, $p=.33$, $df = 1$, respectively). However, there was a significant difference in the final amount of weight loss of birds in the two water treatments, with water restricted birds losing more than those provided water ad libitum ($F=6.1$, $p=.02$, $df = 1$).

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Table 1. Mean temperature, grape consumption and weight loss over an 11-hour period for adult and juvenile Common starlings fed grapes with and without ad libitum water

TRIAL	MEAN MAX °C	MEAN MIN °C	MEAN (g) Grapes Eaten	BIRD (g) LOSS
ALL	28.4	13.6	39.30	**7.25**
Free H2O	28.4	13.6	42.50	**5.20**
Restricted H2O	28.4	13.6	36.10	**9.30**
ADULT	28.4	14.3	35.75	**8.25**
JUV	28.4	13.2	41.67	**6.58**

This provides evidence that grapes do not act as an alternate water source for starlings; therefore the provision of free water will not reduce the amount of grapes eaten. This is markedly shown during the two hottest days (32°C & 35°C) where restricted water treatment birds ate less than half the amount of grapes that the free water starlings ate (mean 15.25g:38.50g, respectively), and lost more than twice the weight (mean 14.75g:4.50g). This also suggests that starlings cannot live on a diet of grapes alone. Consequently, providing starlings with alternative foods may actually increase their chance of survival.

6.3. Movements

The Australian Bird and Bat Banding Scheme Database (2005) cites the average distance travelled by Common Starlings in Australia is 2 km, while the maximum distance of a recaptured starling is 987 km. Elapsed time since recaptures is also noted, with an average time of 1 year 6.7 months and maximum of 14 years 1.7 months (ABBBS 2005). During the study period, juvenile birds were resighted at greater distances from their original banding sites than adult birds in the McLaren Vale area (Table 2). Adult starlings were also relocated within the region up to two years from initial capture. Five banded nestlings were relocated as juvenile birds over 2.5km from their natal areas, with one located over 12km from its initial capture site in McLaren Vale.

Table 2. Age, sex and number of relocated marked Common Starlings with the ranges of time since initial capture and distances travelled between sightings

Stage & Sex	Range of Longest Time Since Last Resighting	Range of Distances From Original Banding Sites (m)
Adult Females (n= 16)	1 month to 2 years	0 -1,240
Adult Males (n= 14)	1 week to 1 year 5 months	1 -1,498
Juveniles (n= 17)	1 month to 23 months	0 -12,617

Table 3 below shows that adult birds used areas of under 500 hectares (ha) during the tracking periods. Minimum convex polygons (MCP) were constructed using the Ranges6 v1.08 program (Kenward *et al.* 2003). Radio-tracked juvenile bird 100%

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MCPs ranged from 76 to 2053 ha. Only one adult female was successfully tracked during the breeding season and she was restricted to an area of 1 ha. Other attempts were made, however putting a radio transmitter on 2 other breeding females caused them to abandon their nests. Males did have restricted movements during incubation, but once young hatched, they no longer roosted in the hollow and increased their ranges.

Table 3. Common Starling radio-tracking data movement summary: 100% Minimum Convex Polygon (MCP) home ranges determined using Ranges6

Bird ID#, Age, Sex	**Dates** (Season)	**Location** (# fixes)	**MCP 100% Home range (ha)**
	Sept – December 2002		
404, Adult Female	Breeding 2002	McLaren Vale (18)	1
302, Adult Male	Breeding 2002	McLaren Vale (32)	38
402, Adult Male	Breeding 2002	McLaren Vale (59)	84
405, Adult Male	Breeding 2002	McLaren Vale (16)	122
403, Adult Male	Breeding 2002	McLaren Vale (32)	160
	February – April 2003		
381, Juvenile	Post-fledging 2003	McLaren Vale/Aldinga (16)	582
	June – August 2003		
517, Adult Male	Pre-breeding 2003	Victor Harbor (28)	130
507, Adult Male	Pre-breeding 2003	Victor Harbor (63)	147
511, Adult Female	Pre-breeding 2003	Victor Harbor (9)	263
515, Adult Male	Pre-breeding 2003	Victor Harbor (35)	394
516, Adult Female	Pre-breeding 2003	Victor Harbor (30)	469
	February – April 2004		
711, Juvenile	Post-fledging 2004	McLaren Vale (54)	76
714, Juvenile	Post-fledging 2004	Willunga (55)	352
708, Juvenile	Post-fledging 2004	Willunga (46)	2053
	December- March 2005		
763, Adult Female	Post-fledging 2005	McLaren Vale (28)	31
760, Juvenile	Post-fledging 2005	McLaren Vale (46)	179
761, Juvenile	Post-fledging 2005	McLaren Vale (50)	253
762, Juvenile	Post-fledging 2005	McLaren Vale (48)	393

Home range data were analysed with Kernel Analyses (Arcview 3.2) and are presented with 100% isopleths and concentric circles shaded at 20% intervals. The outermost and darkest isopleths represent the 90-100% probability that you will locate the bird within that area (and those contained within it). This trend follows for 70-80%, 50-60%, 30-40% and the lightest isopleth represents only a 10-20% chance of locating the bird within the core.

When breeding, home ranges were reduced by as much as 10 times the pre-breeding home ranges (Figure 2). The literature suggests that home ranges of 2-4 hectares are common during the breeding season (Tinbergen 1981; Bautista *et al.* 1998). The data on the lone female is more representative of this than the males studied. This is most likely due to her constraints of tending the nest, incubating eggs and feeding nestlings.

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Bird ID: 302 Adult Male

80% Isopleth (Area): 14.57 ha

100% Isopleth (Area): 43.36 ha



Bird ID: 402 Adult Male

80% Isopleth (Area): 2.10 ha

100% Isopleth (Area): 58.51 ha



Bird ID: 403 Adult Male

80% Isopleth (Area): 55.03 ha

100% Isopleth (Area): 253.13 ha



Bird ID 405 Adult Male

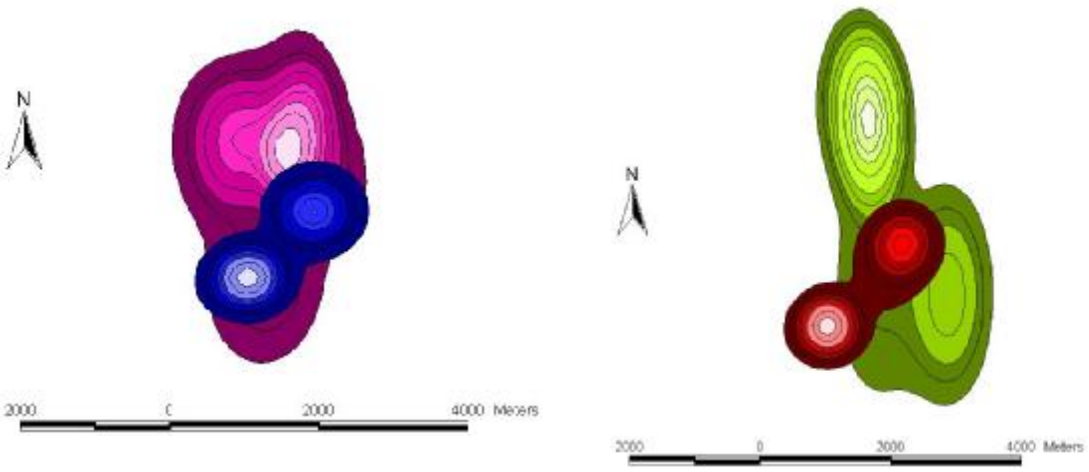
80% Isopleth (Area): 214.34 ha

100% Isopleth (Area): 304.84 ha

Figure 2. September – December 2002 breeding season home ranges of adult male Common Starlings in McLaren Vale with 100% Kernel Analyses best-fit ellipses overlaid onto regional street map.

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As well as monitoring roost dynamics, home ranges of Common Starlings captured and radio-tracked around a major off-shore island roost near Victor Harbor were determined from movements. Observations showed that areas of core use centred around powerlines (launch sites), olives, and stock grazing paddocks. Some individual birds also used more than 10 different roost sites during the 3-month tracking period (Figure 3).



Bird IDs

516: Adult Female, Pink

517: Adult Male, Blue

80% Isopleths (Area): 150.96 ha, 24.14 ha

100% Isopleths (Area): 445.72 ha, 336.89 ha

Bird IDs

507: Adult Male, Red

515: Adult Male, Green

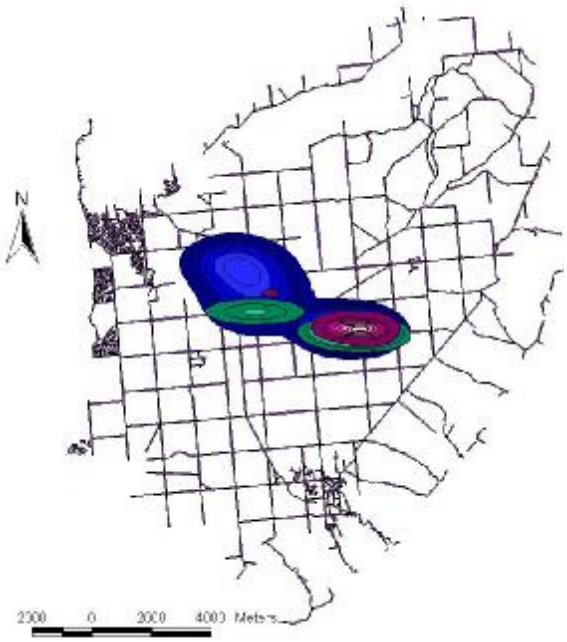
80% Isopleths (Area): 38.55 ha, 66.72 ha

100% Isopleths (Area): 432.94 ha, 464.56 ha

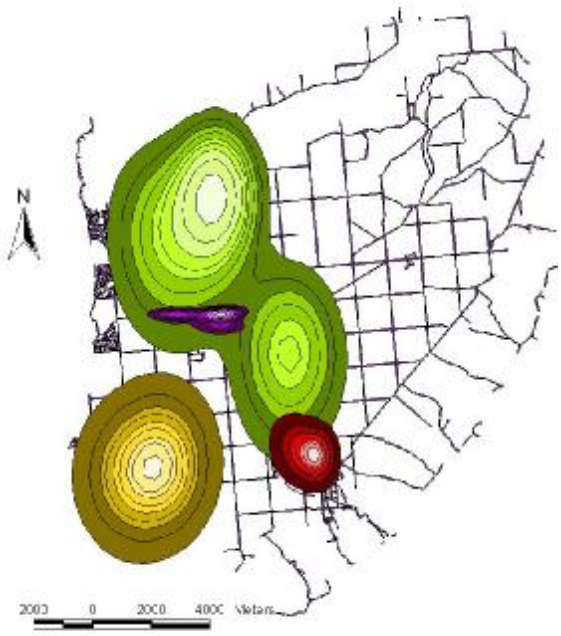
Figure 3. June - August 2003 pre-breeding season home ranges of adult Common Starlings, Victor Harbor, 100% Kernel Analyses best-fit ellipses.

Data collected from radio-tracking juvenile starlings showed overlapping and wide-ranging home range areas in the McLaren Vale district (Figure 4). They also were not faithful to any one roost on more than a few consecutive nights. These data indicate that juveniles are dispersing across the region and their movements make management of these wide-ranging individuals a difficult task.

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Bird IDs: 760, 761, 762
Colours: Purple, Green, Blue
80% Isopleths (ha):
112.57, 49.24, 383.34
100% Isopleths (ha):
543.67, 394.90, 622.92



Bird IDs: 381, 708, 711, 714
Colours: Brown, Green, Purple, Red
80% Isopleths (ha):
142.16, 1305.43, 156.07, 104.05
100% Isopleths (ha):
1681.34, 4232.53, 209.06, 481.43

Figure 4. Post-fledging juvenile Common Starling home range areas from 100% Kernel Analyses (February – April 2003 & 2004 right, December 2004 – March 2005 left).

In summary, radio-tracked starlings ranged over areas from 1 to over 2,000 ha throughout the year and individual birds moved up to 12km from their original capture sites. This suggests that management efforts must be undertaken on a regional scale. Juvenile birds are dispersing across the landscape, making management efforts difficult once these young fledge. These data presented also show that adult birds are restricted in their movements and tied to nesting sites during the breeding season and therefore may be amenable to focussed management efforts during spring.

6.4. Flock Distributions, Composition & Abundances

The literature suggests estimates of Common Starling densities in any particular area at around 3 starlings per hectare, between 1.5 to 2 resident birds and the odd displaced juvenile or migrant. For the McLaren Vale region study area, this could suggest a maximum population size of 30,000 Common Starlings, but experience in the field would not support such a high estimate.

6.4.1. Flock Distribution

Regular transects conducting surveys along existing roadways throughout the 100km^2 study area estimated where flock hotspots occur and the regional population size of Common Starlings (Figure 5). However, due to the scale of these transects, they are

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likely to be an unreliable indicator of how many birds are actually present in the region. The behaviour of Common Starlings in relation to inclement weather is to retreat into dense foliage, where hundreds to thousands of birds quietly perch without being noticed. Thousands of starlings descending into grape vines are also difficult to detect when feeding on the ground between the vines since only handfuls of sentinels perch on the trellis poles.

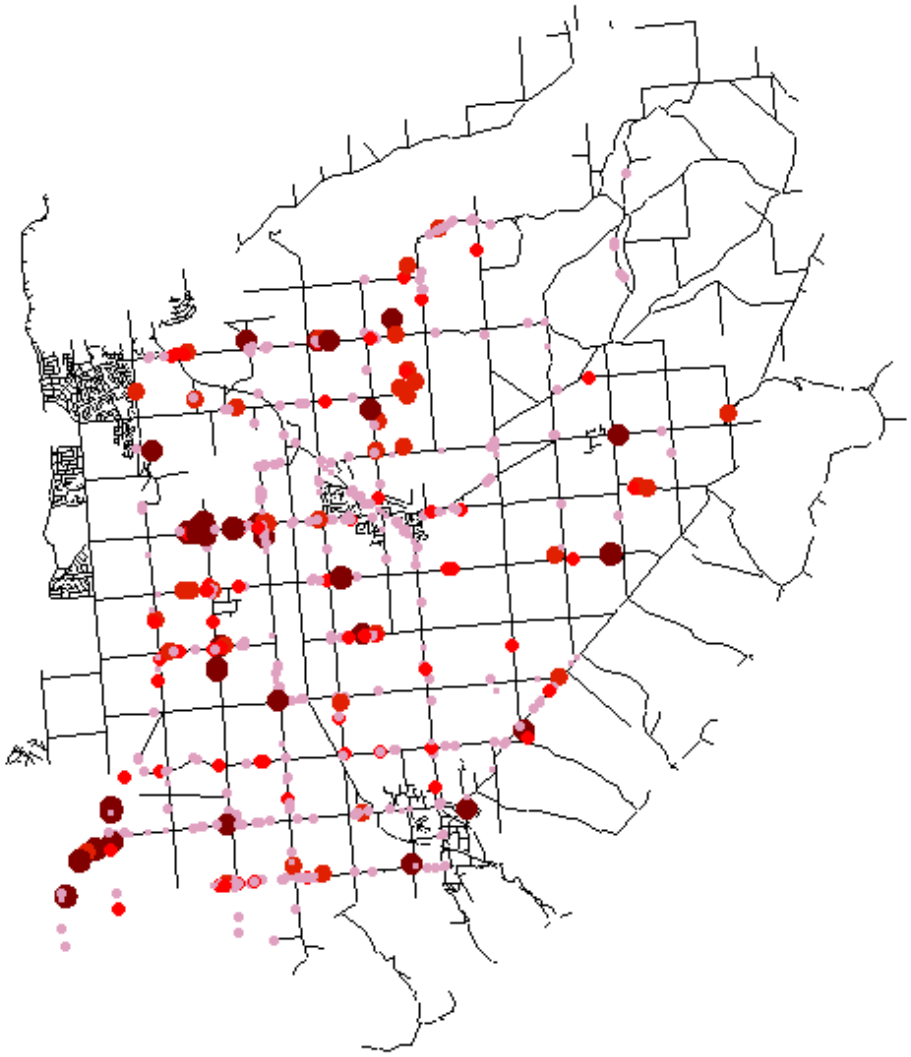


Figure 5. Patterns to the locations of flocks of Common Starlings detected during survey transects in the McLaren Vale region, 2003-2005. The increasing sizes and shades of the dots represent increasing flock sizes (small pink 1-30; medium red 31-100; and large dark red 1010-1200 birds)

6.4.2. Flock composition

Composition of flocks by age can be determined from January to April, when post-fledging flocks consist of both adult plumaged and juvenile plumaged birds. Transect data demonstrated that post-fledging, grape-damaging flocks consisted, on average, of 72% juvenile birds (SE ± 3%). Opportunistic data on flocks provides a similar figure of

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66% juveniles (SE ± 8%). This gives more weight to the argument for management by reductions in the population during the breeding season.

6.4.3. Flock Abundances

Repeated counts performed on the property where breeding season surveys were conducted and show a peak in individual numbers following fledging (Figure 6). This pattern follows the cycle shown in the model (Figure 11): A spring influx of juveniles coming into the system results in peak summer numbers of starlings. Subsequent first year deaths (0.48 annual survival rate) during the harsh summer decrease the population to an autumn-winter trough. A final influx of a few new breeding birds into the system during late winter boosts the resident breeding population for the subsequent spring.

The ratio of adult to juvenile starlings on d'Arenberg's property was 43:7. This suggests a resident population of adults, which is further supported by regular sightings of colour-banded birds, and data obtained from radio-tracked birds.

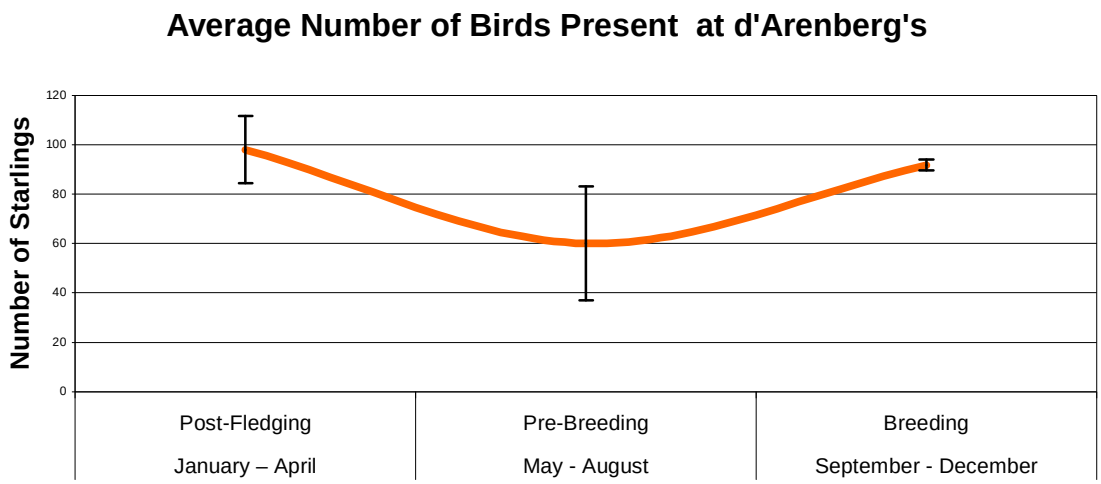


Figure 6. 2003-2005 Seasonal transect summary for Common Starling flock sizes at d'Arenberg's Winery, McLaren Vale. Data are mean flock sizes ± standard error.

Transect data across the 100km^2 study site detected variation in flock sizes ranging from 143 to 3383 starlings (mean = 1313 ± 214 SE). These transects do not show peaks in post-fledging flock sizes and subsequent reduction in numbers (Figure 7), nor do they accurately estimate the McLaren Vale region's Starling population size. The pattern seen in Figure 7 could be due to the breaking up of flocks in spring to procure nest sites, as well as summer post-fledging flock detection being low due to the birds being hidden while foraging in the vines. This demonstrates the inconsistency of this sampling method and suggests that subsequent transects be conducted at smaller scales to increase accuracy of population size estimates.

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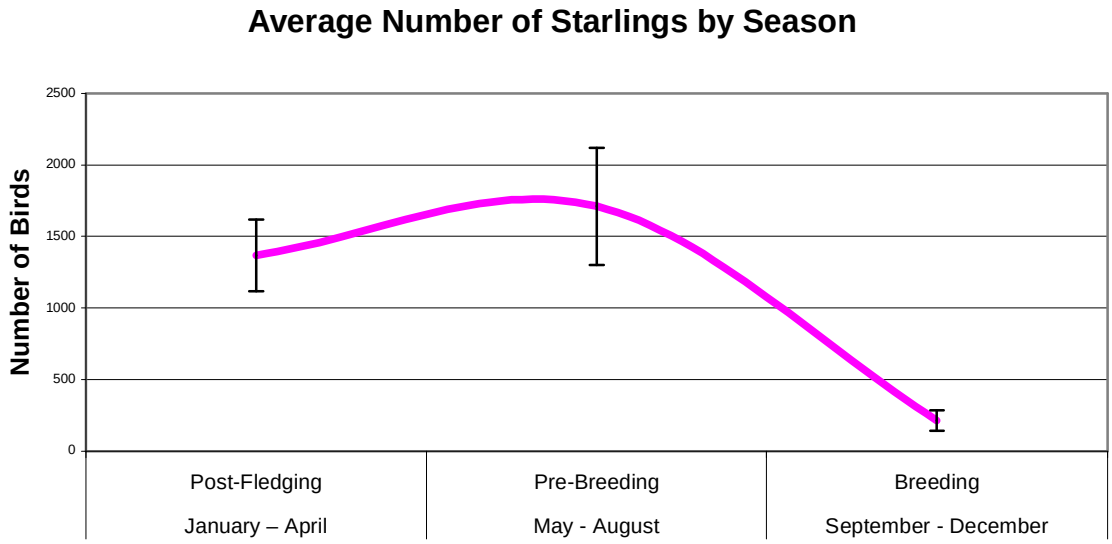


Figure 7. 2003-2005 Seasonal transect summary for Common Starling flock sizes recorded on surveys throughout the McLaren Vale district. Data are mean flock sizes ± standard error.

6.5. Roosting Behaviour

No major nocturnal roosts were found in the McLaren Vale district, but small numbers of starlings (<500) roosted communally in a variety of dense shrubs, trees, hedges or building roofs throughout the district (Figure 8). Communal roosts were ephemeral and seasonal, and the birds tended to roost singly in nest hollows during breeding season. A pine hedge was used as a creche-like roost immediately following fledging and minimally throughout the rest of the year. However, major roosts (>1000 birds) do exist in surrounding areas, for example: pines near Aldinga Oval, a *Phragmites spp*. reed bed in Mt. Compass and an off-shore island roost with boxthorns near Victor Harbor.

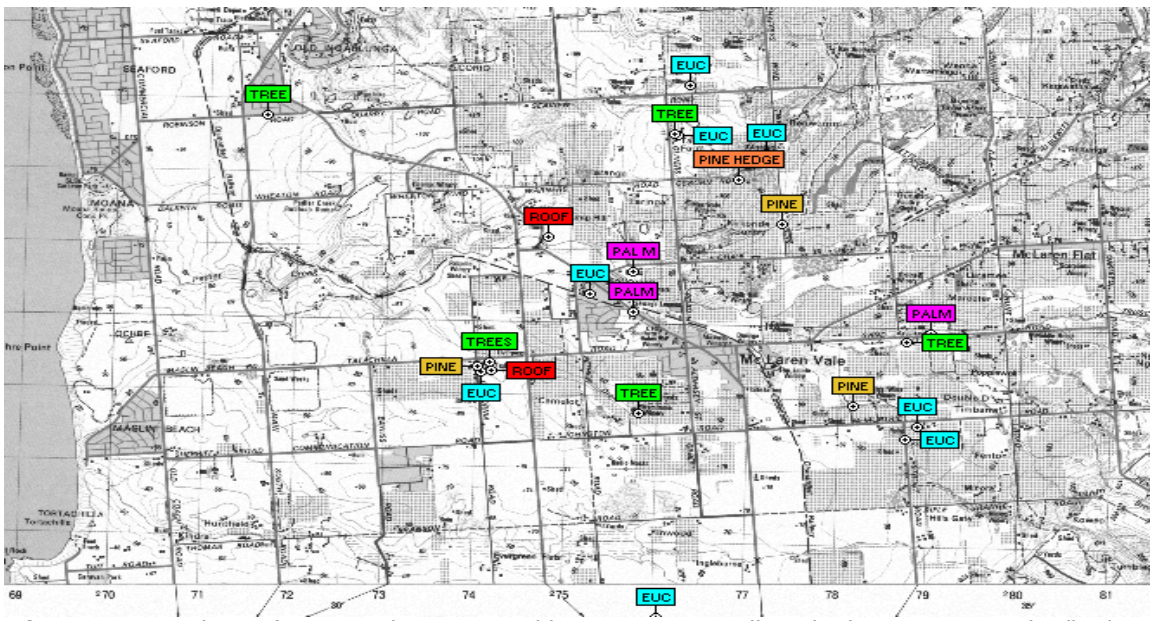


Figure 8. Locations of nocturnal roosts used by Common Starlings in the McLaren Vale district.

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The number of starlings roosting in boxthorns on Wright Island ranged from 95 to 1461 (mean = 860 ±125 SE, Table 4). Starlings roosting in the *Phragmites spp*. reed bed at Mt Compass ranged from 0 to 3500 birds (mean = 1634 ± 411 SE); and those roosting in pine trees around Aldinga Oval ranged from 0 to 3992 individuals (mean = 1338 ± 510 SE, Table 4). Morning counts of bird departure groups could not be conducted at Mt Compass due to the mass exodus of birds shortly after sunrise. Flocks departing from Aldinga Oval ranged from 1 to 1000 starlings (mean = 52 ± 8 SE, Table 4). Numbers of birds in departure flocks also varied greatly and ranged from 1 to 400 throughout the Wright Island observation period (mean = 47 ± 4 SE, Table 4).

Table 4. Mean and Range in Roost Departure Groups Wright Island, Victor Harbor

Date	Location	Total # Birds	Average Flock Size	Standard Error	Range in Flock Size	# Flocks
21/06/2003	Wright Island	1055	117	41	5 - 400	9
22/06/2003	Wright Island	1461	47	6	6 - 128	31
23/06/2004	Wright Island	1234	56	14	4 - 310	22
24/06/2003	Wright Island	797	35	7	2 - 100	23
25/06/2003	Wright Island	1325	55	10	8 - 250	26
26/06/2003	Wright Island	803	38	10	3 -180	21
27/06/2003	Wright Island	802	57	14	7 - 180	14
21/07/2003	Wright Island	429	36	10	4 - 124	12
19/07/2003	Wright Island	95	24	11	1 - 46	8
20/07/2003	Wright Island	223	45	15	14 - 96	5
4/09/2003	Wright Island	900	50	11	4 - 180	18
5/09/2003	Wright Island	1190	60	12	10 – 238	20
29/01/2003	Aldinga Oval	3992	235	75	20-1000	17
4/02/2003	Aldinga Oval	1612	85	26	3-500	19
5/02/2003	Aldinga Oval	2812	47	12	1-300	30
10/02/2003	Aldinga Oval	1496	33	5	1-250	86
18/02/2003	Aldinga Oval	267	38	21	1-150	7
21/03/2003	Aldinga Oval	205	12	3	1-50	17
25/03/2003	Aldinga Oval	319	12	3	1-55	27

By tracking birds captured on an island roost, we were able to confirm that birds did not remain faithful to one major nocturnal roost, but over-nighted in 12 different areas on different nights and may or may not subsequently return to the island (Figure 9). One bird reused an *Acacia* sp. roost on 5 consecutive nights as well as using the island, ornamental trees and a tree (*Eucalyptus* sp.). However, other concurrently radio-tracked starlings used a combination of 3-4 different roosts, on non-consecutive nights.

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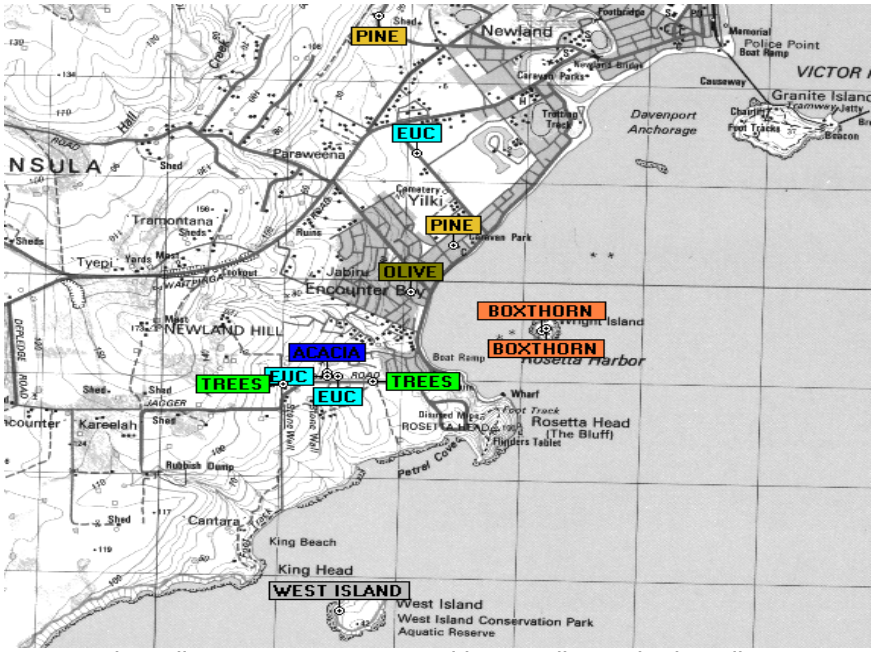


Figure 9. 2003 Pre-breeding season roosts used by 4 radio-tracked starlings over a one-month period (late June - late July), Victor Harbor.

Lack of roost site fidelity is further demonstrated by the flux in numbers in roosting individuals over time. Elapsed departure time (first to last bird/flock leaving roost) ranged from 19 to 106 minutes from the island. The deviations to the mean departure times can be explained by cold and windy weather conditions (July 19 & 20) as well as a response to the presence of predators (Peregrine Falcons, June 25-27).

It is interesting to note that McLaren Vale does have similar reed beds to those in Mt Compass, but they were not used during the study period. However, anecdotal reports from local growers noted previous use by large numbers of starlings. Nevertheless, this lack of major roost sites around the McLaren Vale district would make roost control efforts labour intensive and this control strategy is not recommended.

6.6. Breeding Ecology

Common Starlings nested in a variety of available hollows in the McLaren Vale area, mostly close to humans and in small, patches of remnant scrub (Figure 10). There were 248 breeding pairs detected on a breeding bird survey transect throughout the 100km^2 study area in 2004. This suggests that there are around 2.48 breeding pairs (or 4.96 birds) per square kilometre (± 0.38 SE). However, the urban birds within the towns of McLaren Vale and Willunga were difficult to detect because views were obscured by obstacles such as high fences, so this is undoubtedly an underestimate. Only 1 pair was found within native remnant scrub (Aldinga Conservation Scrub) during an extensive search of the area in 2003 (and this was in an old eucalypt located on the edge of the park, close to the track and caravan park). However this may be due to the

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vegetation type not having many hollows. These findings further support the Common Starling's close association with humans and degraded natural habitats.

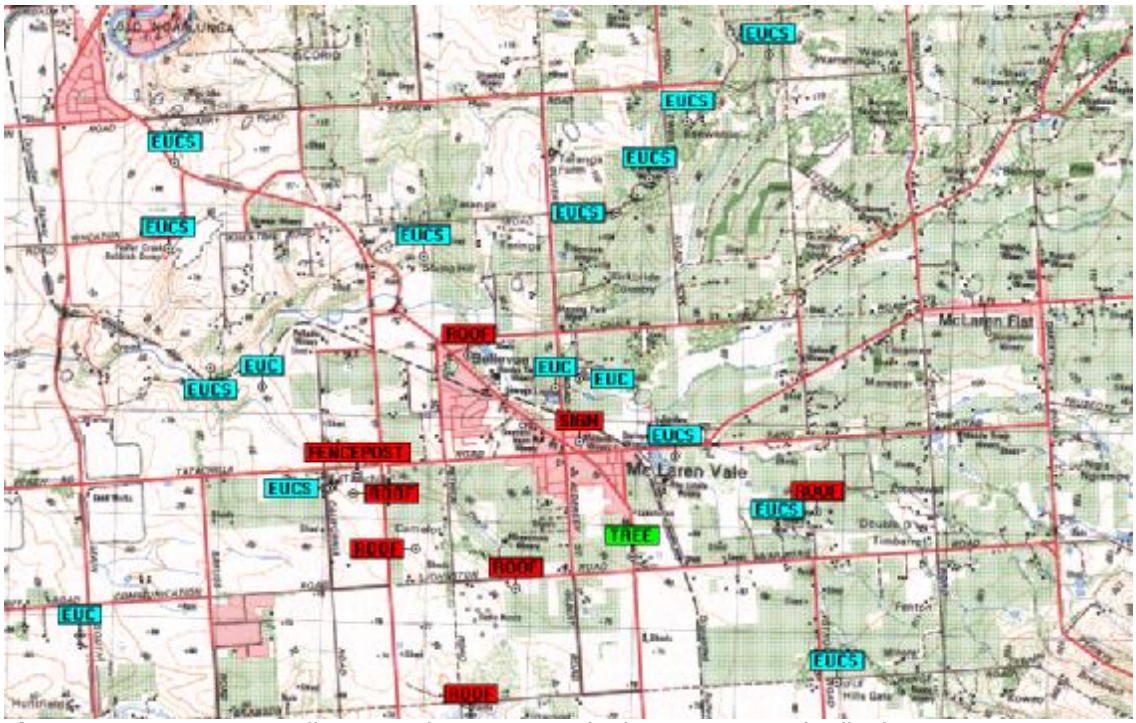


Figure 10. Common Starling nest site structures in the McLaren Vale district.

Nest site fidelity is supported with previously banded adult and juvenile birds re-nesting in the same areas in following years. Nestlings banded in hollows also returned to breed at their natal areas, with some of the first-year females starting to breed at only 10 months of age.

Common Starlings in the McLaren Vale area produced around 3 young per brood and two broods per breeding season (Table 5). With around 20 nests per hectare, remnant woodlands were a significant source of young starlings for the following grape season.

Table 5. Mean Number of Young per Brood (averaged for 1st & 2nd broods)

Year	Mean # Young/ Breeding Attempt	Standard Error
2002	2.8 (n =158)	0.22
2003	3.2 (n =148)	0.16

Starling parents spent around 5 minutes away from the hollow between returning to feed nestlings, presumably foraging (Table 6). Starling parents also averaged 12.5 feeding events per hour (n = 49, se $\pm$ .8). This demonstrates the close tie that breeding pairs have to the nesting hollows when dependent young are present in the nest.

Common Starlings only used from 18 to 27% of available hollows for nesting in remnant scrub (Table 6). Although some hollows are used by other species (e.g. bats

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and parrots), a high proportion of potential hollows (>60%) were unused in the 2002 and 2003 breeding seasons. This also suggests that hollows are not limited. Therefore, there is some site fidelity between seasons and hollows are not limiting breeding potential, so removal of breeding birds in one year should reduce breeding populations in subsequent years.

Table 6. Breeding starling hollow dynamics over 2 years

Year	Available Hollows	Percent Occupied by Starlings	Percent Occupied by Other Species	Percent of Unused Hollows	Feeding Rates-Time In (seconds ± se)	Feeding Rates-Time out (min:sec ± se)
2002	257	18.2	13.6	68.2	13 ± 2	5:16 ± 0:44
2003	257	27.6	11.3	61.2	14 ± 1	4:31 ± 0.66

Using the field data gathered from the nesting dynamics study, a theoretical population model was created (Figure 11). The model suggests that removal of 50% of the breeding pairs early in the nesting season should significantly reduce the size of the starling population that subsequently attacks grape crops and would also be more effective than a comparable cull during the grape season.

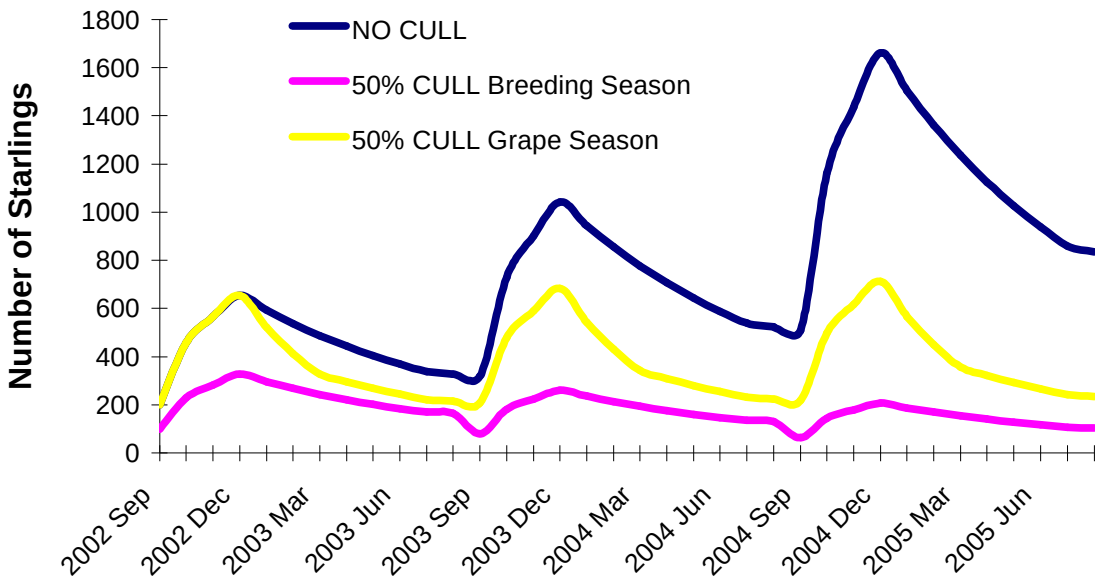


Figure 11. Population model showing number of starlings over a 3-year period with no cull, and a 50% cull of pre-breeding pairs versus a 50% cull during the grape season.

Population sizes of Common Starlings were at least twice the size of the spring breeding population when 50% were culled across the 3 month grape season and there was no effect on (i.e. reduction of) the subsequent year's breeding population. However, the culling of breeding pairs in spring led to much lower numbers of starlings during the grape season, and also had the potential to reduce the size of the breeding population from one year to the next (Table 7).

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Table 7. Comparison of the relative number of starlings that need to be culled in consecutive years based on a 50% culling effort (starting with 100 breeding pairs)

	Season of Cull	
	Breeding Season	**Grape Season**
Year 1	100	251
Year 2	85	262
Year 3	67	274

Reducing breeding outputs outside of the grape season may have significant advantages over current management efforts. Note that the effort to achieve population reduction also diminishes over time with a breeding season cull, but not with the grape season activity.

6.7. Economics of Common Starling Damage & Control Methods

There have not been any previous attempts to estimate the dollar loss attributable to starlings, to growers, or the wine industry, in the McLaren Vale grape-growing district. Below are several different scenarios, based on caged birds fed on a grape only diet. These seem to indicate that the damage caused by starlings might be less than $100,000 per year for the McLaren Vale district based on a captive bird study.

6.7.1. Economics of Common Starling Damage

The total area of vines planted in the McLaren Vale region in 2005 was 6,758 hectares (Hathaway 2005). According to the Phylloxera and Grape Industry Board SA (2004) the McLaren Vale district produced 51,903 tonnes of grapes, with an average value per tonnage of around $1,300 giving a total crop value of $64.4M. If a tonne of grapes produces 1,000 bottles of wine and this retails for an average of $12 per bottle, then the gross value of the local industry could be around $600M. Of course, these values are based on grape production after bird damage (all species), more specifically the primary and secondary damage caused by them (i.e. reduced returns due to lower quality from bird damage or disease).

- Using the estimate of average daily consumption of 31g of grapes per bird per day (see 6.1), an average of 90 grape damage days per season and 5,000 - 10,000 birds as an estimate of the McLaren Vale starling population, the loss to growers would range from $18,150 - $36,300 per year at $1,300 per tonne lost.
- Even with the maximum daily intake of 55g of grapes per bird and overestimate of 30,000 birds in the region (see 6.1), the estimated loss would be $193,050 per year in grape tonnage.

These estimates are based on grape consumption figures (without access to alternative foods) and are most likely overestimates. Gizzard samples from birds shot

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in vineyards contained a mixture of grapes and other food items and starlings also cannot survive on grapes alone for any longer than a few days. Another problem with these estimates is that starling damage is not spread evenly across growers or regionally.

However, these cost estimates do not take into account the potential benefits of starlings foraging on crop pests, larvae and seeds amongst the vines earlier in the season. It should also be taken into account that Common Starlings only pluck entire fruits, so do not have added indirect effects on grape quality, resulting in a 1:1 loss of grapes rather than a 1 to bunch loss through punctures and subsequent bunch damage from disease. Therefore other pest bird species are potentially a bigger problem due to the secondary damage they cause.

6.7.2. Economics of Common Starling Control Methods

Estimates of dollar value of grapes lost to Common Starlings across the McLaren Vale region range from $18,150 to $193,050 per year (based on a population of 10,000 or 30,0000 and grape consumption figures obtained from captive bird trials, section 6.7.1). Estimates of the costs to implement various methods of bird control across the region are given in Table 8, assuming 6,758 hectares of planted vines, and suggest that the costs to growers are substantial. However, bird control methods are not evenly spread across the district, nor are grape losses to starlings and other pest birds. Most of the current methods used for bird control only benefit individual growers and are only performed during the grape season. A cull of breeding starlings in spring would, however, benefit the region as a whole but only affect the starling population.

Table 8. Annual costs per hectare of control methods applied across the McLaren Vale region

Control Method	Cost/ha	Additional Comments	Regional Cost per annum (cost/ha*6758ha)
Netting	**$1,300**	all costs: nets, caps, staples, & labour (Replace every 5 years)	$8,785,400
Bird Detecting Radar & Screamer	**$875**	1 radar unit & 2 audio units per 20 ha	$5,913,250
Computer Controlled Gas Gun	**$187.50**	1 unit + stand per 10ha	$1,267,125
Bird Kites	**$240** without poles	1 per ha recommended + cost of 6,758 poles	$ 1,621,920 (+ cost of poles)
Hired Shooter, Grape Season	**$1235.50***	Average overall 2004-2005 grape season was $500 per acre including shooters, person on bike and materials.	$8,349,509
50% Culls in Breeding Season**	**$6.22**	**$15,000 (cartridges, transport and depreciation) plus 90 days (August – October) x $300 labour per day**	**$42,000**

*Rates as quoted from contractor, **5000 birds = 50% population estimate for McLaren Vale

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The values in the above table are likely to be overestimates because they assume starlings eat a grape only diet for 90 days and they cannot realistically survive for more than a few days on grapes alone. The population sizes used in the calculations are also likely to be overestimated based on data from transect surveys in the McLaren Vale region (section 6.4.3). However, there have been no previous attempts to quantify grape losses to starlings and the costs associated with grape loss to growers or the industry. The above sections present estimates and is meant only as a possible framework for further detailed analyses.

Starling damage does not seem to be a large problem in the McLaren Vale area because flock sizes appear to be in decline (Sinclair, pers. comm.). Except for individual growers who get large numbers of birds damaging grapes in isolated places, economic estimates do not warrant expensive control methods like netting entire vineyards. A spring cull of breeding starlings would decrease the population more effectively than the current management options and would be more cost effective. However, the current control methods may also alleviate other pest bird damage that may be of more concern to growers than starling damage.

6.8. Management Implications

6.8.1. Diet

Common Starlings are primarily insectivorous but a wide range of plant material, including agricultural crops such as fruits and seeds, are also consumed. Gut content analyses from culled birds show a varied diet over the grape season, with over 30 different food items noted in addition to grapes. So, birds are not solely taking grapes when foraging within vineyards. Olives were observed to be an important food source for both adults and nestlings during winter and throughout the breeding season. Figs and other stone fruit were also taken seasonally as noted from captured birds. Given this diverse diet, reducing grape damage by providing starlings with alternative food sources may prove difficult. It may also increase survival of starlings since they are unable to live on grapes alone. However, limiting abundant food sources like feral and roadside olives may reduce starling fitness and nestling success. This can be done by removing feral olives altogether, or ensuring that any planted olives (often used as windbreaks) are harvested so that starlings cannot exploit this food source. In the future, growers should refrain from planting olives as windbreaks as well.

Common Starlings also need to consume water daily, especially in summer, and therefore are dependent on some free water source. Watering a nearby paddock or lawn (to provide an alternative water source to grapes and drippers in the summer, as well as promoting insect levels) may be a management alternative, but this has not

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been tested or costed. Aviary trials, however, have shown that providing more water may actually increase the numbers of grapes the starlings are able to eat by diluting the indigestible sugars.

6.8.2. Movements

Based on adult and juvenile movements, Common Starlings remain within the region and operate at scales of 0-12km. At present no data show any larger scale movements (e.g. migration). Management therefore needs to be implemented at a regional scale and not at an individual property scale.

Movements of breeding birds in spring are restricted up to ten-fold compared to movements in the pre-and post-breeding seasons. This has two implications for management. Starlings are restricted to the immediate vicinity of nest hollows during the breeding season and these nest areas are easily locatable. Culling birds is not only more easily implemented but also has a greater impact on reducing the population during the breeding season than at other times of the year.

6.8.3. Flocking

Current control methods attempt to limit grape damage by increasing a bird's perceived predation risks at the time when grapes are ripening. These control methods include visual, aural and physical deterrents, and have been found to be ineffective ((Weber 1979; Bomford 1990; Bomford and O'Brien 1990; Crossfield 2000). Weber (1979) has even gone so far as to say that balloons and colourful ribbons are best left with children to play with.

Flock sizes of birds have also been shown to increase in response to the presence of a predator (Caraco 1979). To this end, flocking may afford the anti-predator protection necessary for birds to use risky foraging behaviours and habitats. Therefore, the use of current harassment methods and shooting may counterintuitively increase flock sizes visiting a property where bird control is actively promoted. The properties that appear to have the greatest predation risk (i.e. where gas guns and shooting occur) also have the largest flocks of starlings visiting them (Bentz, pers. obs).

The highly variable sizes of flocks and their presence throughout the region suggest that grape damage is spread unevenly across the region. The mobility and fluid composition of foraging flocks would make control efforts during the grape season ineffectual at reducing the population as a whole.

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6.8.4. Roosting

Nocturnal roost site constancy is also poor. This is one reason why control efforts at any one roost may not be effective in controlling the starling population. Departure dynamics also differed dramatically between major roosts with Mount Compass birds departing in several large flocks (hundreds to thousands of birds) just minutes after sunrise versus many smaller flocks departing the Wright Island and Aldinga Oval roosts. This further indicates that roost dynamics are complicated and without proper knowledge of individual roosting behaviour, control efforts focusing on major roost sites would not be recommended.

Control at nocturnal roosts may still be an option, but the lack of site constancy to a major roost means that removing the roost site vegetation (often introduced plants like boxthorn) would simply be countered by a shift of birds to a different nearby roost site. Any program to control birds at nocturnal roosts, however, would have to be implemented over a number of days or weeks to ensure a high proportion of birds were culled.

6.8.5. Breeding

Nesting hollows are easily identifiable in the breeding season with breeding birds typically returning to active nests at intervals of 5-10 minutes, so little effort is needed to detect breeding pairs of starlings on properties. Hollows in man-made structures can be eliminated with minor modifications that block entrances to cavities (e.g. to roofs, fenceposts and other crevices). Within McLaren Vale, a high proportion of nest hollows occur in remnant vegetation. These tree hollows cannot be modified or removed because many of the trees are protected by the Native Vegetation Clearance Act, but control efforts can be focussed on culling breeding birds within a few hectares of remnant scrub that remain in the region. This strategy also has the effect of reducing the population size quickly compared to culling during the grape season and is drastically more cost efficient than any other current control methods.

Feral olives can also be removed from roadsides throughout the region to remove important food sources for breeding birds and their young. Efforts should also be made to harvest existing olives planted as windbreaks and to instead plant native vegetation as windbreaks in the future. Vignerons can benefit from implementing these less demanding management strategies instead of exerting intensive and largely ineffective and expensive efforts during the periods when grapes are present on the vines, as the starling breeding season does not coincide with the busy grape season.

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6.8.6. Economics

Economically, regional efforts to control starling flocks during grape season are more than 20 times as costly per hectare as a full-time cull during the breeding season. The money currently being spent on control methods might be better spent organising a regional cull of breeding pairs in the McLaren Vale area. The current costly control techniques are ineffectual at reducing the starling population on a regional level, but may aid in deterring other bird pests during the grape season. The projected regional losses of grapes to Common Starlings are also not covering the costs of current controls implemented over the busy grape season (without taking other bird pests into account). Starling breeding habitat is somewhat limited throughout the region and once identified would allow a strategic and concentrated effort to be applied to culling breeding pairs during spring. By shifting and consolidating control efforts to a regional breeding season cull, the population size will experience a quicker reduction and this approach will be more cost effective than current efforts.

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7. Outcomes and Conclusions

7.1. Performance Outcomes

7.1.1. Achievement of Objectives

There is a broad interest in limiting agricultural damage by pest species. This study contributes to our understanding of starling behaviour and ecology, and thus contributes to the development of methods to achieve cost effective control of pest species in agriculture.

7.1.2. Justification

Due to some required leaves of absences to return to Chicago (3-6 months per year from 2002-2004, enforced by the University of Chicago) and a subsequent transfer to University of Adelaide, the thesis and scientific papers will be delayed in production until December 2005.

7.2. Practical Implications

- Movement data of starlings suggest that management efforts need to be conducted at a regional scale and not at an individual property scale. Efforts should be made to coordinate a best practice management regime for starling control across the McLaren Vale region.
- Adult breeding pairs can produce an average of 3-5 young per year, so the regional population can more than double prior to the grape season. Therefore culling breeding pairs will reduce population increases over spring and prior to the grape season.
- Grape season flocks are not cohesive and consist of over 70% juvenile birds. Therefore, culling breeding pairs would not only limit the number of young birds being produced, and so impact on the overall population size later in the year.
- The use of current harassment methods are considered to be ineffectual and may counterintuitively lead to increased sizes of starling flocks throughout the region. However, they may be effective controls for other pest bird species.
- Control by baiting or providing alternative foods is not currently considered a feasible option, with grapes being an unlimited food source throughout the region during summer (and olives during winter). Since starlings cannot live on grapes alone, providing additional foods may increase survival and lead to a larger breeding population in the following spring.
- Reducing the availability of important food sources like feral olives may reduce starling fitness before breeding and also reduce nestling success during spring.

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This can be done by removing feral olives altogether and ensuring that any planted olives (often used as windbreaks) are harvested so that starlings cannot exploit this high caloric food source. It would also be beneficial to plant native vegetation for windbreaks instead of olives.

- Management at roost sites throughout the McLaren Vale district would be difficult due to the lack of roost site constancy and fluctuations in the numbers of roosting starlings at any one site. Culling birds at major nocturnal roost sites may still be possible, but any management program would have to be implemented during autumn and winter over a number of weeks or months to ensure a major proportion of the birds were culled. Modification of suitable roost sites (e.g. pruning dense foliage of the roost trees and shrubs) may also lead to higher concentrations of birds at other major roosts and facilitate possible management efforts.
- Little effort is needed to detect nest sites and breeding pairs of starlings on properties during spring and considerable potential exists to reduce grape damage by reducing the starling population before summer. Breeding habitat is also clumped throughout the region so that control efforts can be focused on a few key locations.
- A model was constructed to compare the effectiveness of a 50% grape season cull versus a 50% breeding season cull. Shifting the timing of management efforts to spring results in a quicker reduction of the overall population, decreases subsequent efforts, and also does not interfere with vineyard management activities during the busy grape season.
- The Native Vegetation Clearance Act prohibits elimination of natural hollows to preserve this rare resource for native fauna. However, efforts can be made to restrict man-made hollows in roofs and other suitable crevices in man-made structures.

7.3. Benefits

7.3.1. Economic Benefits

- Cost estimates of control methods per annum compared to annual grape loss estimates indicate average controls applied regionally (without suggested breeding season cull) costs over $5million, while maximum losses of grapes to starlings is only $193,050 (section 6.7.1).
- If controls are to be used, implementation of controls outside of the grape season saves time and money now spent on other, often ineffective and expensive control methods during the busy grape season.
- By eliminating breeding starlings at the hollows, subsequent flocks of Common Starlings in grape growing districts will be smaller. This would result in money

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saved from subsequent crop losses and reduce overall costs of current management (cheaper to implement controls in spring).

- By implementing a regional breeding season cull, the cost per hectare of starling control to growers could be as little as $6.22!

7.3.2. Environmental Benefits

- Starlings compete with native fauna for hollow nest sites therefore removing breeding pairs may allow recolonisation by hollow-nesting native birds and bats.
- If numbers of starlings are controlled throughout the region, and feral olives eliminated, the spread of woody weeds (e.g. feral olives, boxthorn) throughout remnant scrub and roadsides would be reduced.

7.3.3. Community Benefits

- Reduced impact for other industries that suffer from starling damage.
- Reduced cost to the community through reduced need for weed control.
- Reduced reliance on noise generating scaring devices and therefore improved amenity for neighbours.

However, there is also the potential for a possible negative impact through removal of an effective pasture/crop insectivore.

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8. Recommendations

8.1. Future Research

Tina Bentz conducted one additional year (2004-2005) of fieldwork to conclude her PhD research without GWRDC support. This involved:

- An extensive removal experiment to determine the effects of removing breeding pairs of Common Starlings on recolonisation of nest hollows and their subsequent local population size.
- Aviary trials to suggest reasons why starlings are eating a poor food source like grapes.
- Assessment of vegetation and habitat features coinciding with flock hotspots from transects to determine if certain structures or food sources are generating the patterns of flock locations across the McLaren Vale landscape.
- Extensive survey of the entire 100km^2 study area to plot nesting sites across the region.

Other research recommendations include:

- Develop suitable techniques for estimating population size within the region.
- Develop suitable techniques for estimating grape damage caused by starlings.
- Investigate effectiveness of using irrigation to encourage alternative foods (i.e. Insects).
- Similar ecological studies of other bird pest species in McLaren Vale.
- Similar studies of Common Starlings in other grape-growing regions. The generality of findings here suggest potential for similar controls in other districts, however patterns of starling ecology need to be confirmed in other districts before extrapolation and implementation.

8.2. Research Outcomes & Industry Practices

Outcomes from this research suggest that current industry practices are ineffective and a more adequate approach to controlling the starling population in the region would come from implementation of a region-wide cull of breeding pairs during spring (August to November). This study also illustrates the value of research on pest species before implementing controls as being an important first step to cost effective management.

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8.3. Research Priorities

8.3.1. Further Research & Development

Further research priorities would be to:

- Conduct a comprehensive cost/benefit assessment of starling activity across the region, including possible benefits of starlings in reducing pasture pests.
- Explore structural variations among vineyards, such as the influence of inter-row crop management or launch sites on flock sizes and grape damage.
- Conduct watering trials in adjacent paddocks/lawns.
- Identify and map breeding habitats, and develop methods to humanely remove breeding birds.
- Conduct ecological and behavioural studies other pest bird species.

8.3.2. Extension

- Provide a management plan to growers in the McLaren Vale district.
- Additional workshops on identification of starling breeding habitat and birds.
- Additional articles, both scientific and popular, in suitable journals for further dissemination of research results and management recommendations.

8.3.3. Policy

- Coordinate a regional cull of breeding pairs during spring.

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9. Appendix 1: Communication

9.1. DISSEMINATION

While no formal publications have resulted from the work, production of a PhD thesis and submission of chapter papers to scientific journals are an endpoint for this project. However, dissemination thus far has taken the form of:

- An interview for a magazine article in Australian Viticulture (2003)
- A poster and information booth at Grower's Day (June 2003)
- Presentation of work in progress to growers during a SAFF meeting (June 2003)
- Presentation of a talk on the Common Starling and its general ecology at Birds SA (formerly, South Australian Ornithological Association), Speaker (July 25, 2003)
- Presentation of a poster paper on the Common Starling and the theoretical aspects of management through breeding behaviour research at the International Wildlife Management and Conservation Conference, Christchurch, NZ (December 2003)
- Newsletter articles in The Growers' Voice (2003, 2004, 2005)
- Grape damage identification and assessment workshop (March 2004)
- A talk and poster given at the McLaren Vale Grower's Day (June 2004)
- A nest and bird identification workshop following the 2004 Grower's Day
- Presentation of a talk on the Common Starling and its general ecology as well as some research findings and implications for management to the West Coast Integrated Pest Management Program (WCIPMP) in Ceduna (August 25, 2004)
- Article in the National Grapegrowers Magazine (interviewed by Taryn Waters 27 August 2004)
- Magazine article The Australian & New Zealand Grapegrower & Winemaker (September 2004)
- Interviewed for an article in the Biosecurity in Agriculture Newsletter, Department of Agriculture, WA (December 2004)
- Presentation of a talk on the Common Starling and its ecology at the Ecological Society of Australia Conference in Adelaide, South Australia (December 2004)
- Article in the National Grapegrowers Magazine (interviewed by Shay Bayly June 2005)
- Upcoming article in the bird control feature of the October edition of National GrapeGrowers (2005)

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9.2. PUBLICATIONS

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9.3. FURTHER COMMUNICATION

Additional research and workshops would be aimed at facilitating ease of implementation and efficacy of possible control methods (e.g. nestboxes installed to aid in locating and removing breeding pairs). A PhD thesis and submission of chapter papers to scientific journals are an endpoint for this project.

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10. Appendix 2: Intellectual Property

- Identify the intellectual property and/or valuable information arising from the research.

This is pure research into the ecology and behaviour of a bird pest species. Therefore, there are no immediate intellectual properties of commercial value.

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11. Appendix 3: References

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12. Appendix 4: Staff

Colin Bailey & Brydie Hill were the only paid staff members during the project.

However, a very special thanks to volunteers during the project:

Ronald Bentz
Piers Brissenden
Emma Crossfield
Craig Gillespie
Kath Gillespie
Paul Koch
Dragos Moise
Janet Newell
David Paton
Daniel Rogers
Trisha Rogers
Jill Sparkes
Matthew Ward
Duncan Watt
Nigel Willoughby
Mark Ziembicki

EMR III Students 2002 & 2003

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13. Appendix 5: Relevant Materials

Please find copies of the following articles relating to this project attached electronically as separate pdfs. Photocopied pages of the articles will be included in the bound copies submitted to GWRDC.

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14. Appendix 6: Budget Reconciliation

No funds were given by GWRDC for this project during 2004-2005. A final budget report will be provided to GWRDC by University of Adelaide's ARI if required.

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