# Table of Contents

List of Figures ....................................................................................................................... iii
List of Tables ........................................................................................................................ iv

Part A: Project Outline ........................................................................................................... 1

1. Project Information ......................................................................................................... 1
   1.1 Project Name............................................................................................................ 1
   1.2 Personnel ................................................................................................................ 1
   1.3 Period of Project ...................................................................................................... 1
   1.4 Project Objectives ...................................................................................................... 1

2. Project Description .......................................................................................................... 2
   2.1 Project Background .................................................................................................... 2
   2.2 Starlings .................................................................................................................. 2
   2.3 Macquarie Street, Dubbo ........................................................................................... 2

Part B: Review of Starling Natural History & Behaviour ......................................................... 5

1. Taxonomy .................................................................................................................... 5
   1.1 Scientific Name ......................................................................................................... 5
   1.2 Common Name ......................................................................................................... 5

2. Natural History .............................................................................................................. 5
   2.1 Identification ............................................................................................................ 5
   2.2 Diet ....................................................................................................................... 6
   2.3 Breeding Ecology ....................................................................................................... 8
   2.4 History in Australia ..................................................................................................... 9
   2.5 The Problem with Starlings ........................................................................................ 9
   2.6 Roosting Behaviour .................................................................................................... 10

Part C: Investigations into Starling Roost Preference, Macquarie Street ................................... 11

1. Introduction ................................................................................................................. 11

2. Methods ...................................................................................................................... 11
   2.1 Study Area .............................................................................................................. 11
   2.2 Data Loggers ........................................................................................................... 11

3. Results ........................................................................................................................ 12

4. Discussion .................................................................................................................... 14

Part D: Review of Starling Control Options .......................................................................... 15

1. Previous Management & Control Options Used in Dubbo ................................................ 15

2. Management & Control Options Used Elsewhere .......................................................... 15
2.1 Poisoning and Bait Stations ................................................................. 15
2.2 Scaring ............................................................................................... 15
2.3 Falconry .............................................................................................. 15
2.4 Habitat modification (revegetation) ....................................................... 15
2.5 Reduce water availability ................................................................. 16
2.6 Removal of roost sites ...................................................................... 16
2.7 Long-term Trapping and Euthanasia ................................................... 16
2.8 Repellents .......................................................................................... 16

3. Novel Control Options ........................................................................ 16
   3.1 Remote-controlled model aircraft in the shape of birds of prey ........ 16
   3.2 Microclimate Alteration (Temperature) .......................................... 16
   3.3 Fogging With Repellents ................................................................. 17
   3.4 Predator Relocation ....................................................................... 17
   3.5 Control insects at feeding sites ......................................................... 17

Part E: Recommendations for the Control of Starlings in Dubbo .................. 18
   1. Manage Common Starlings at their roosting sites .......................... 18
   2. Manage Common Starlings at their staging sites ............................ 18
   3. Control Common Starling populations at their feeding sites ........... 18
   4. Control Common Starling populations within the region ................ 18

Part F: References ................................................................................... 20
List of Figures

Figure 1 Typical *Celtis* street trees on Macquarie Street, Dubbo. ................................................................. 3

Figure 2 Map of trees on Macquarie Street, Dubbo. ......................................................................................... 4

Figure 3 Adult male Common Starling in breeding plumage ............................................................................. 5

Figure 4 Female Common Starling, non-breeding winter plumage ............................................................... 5

Figure 5 Adult starling feeding fledgling ........................................................................................................... 6

Figure 6 Male (l) and female (r) adult breeding Common Starlings sexed by eye colour, hackle length and bill colour (base). ............................................................................................................. 6

Figure 7 Common Starling nest with five eggs. Note grass cup construction decorated with fresh foliage, feathers and rubbish. ................................................................................................................. 8

Figure 8 Distribution map of the Common Starling in Australia ....................................................................... 9

Figure 9 Riverdale Shopping Centre on Macquarie Street, Dubbo. Note signage tower over the entrance which is a major staging area for Common Starlings before night time urban roosting. .................................................. 10

Figure 10 Retrieval of data loggers from Macquarie Street trees using Dubbo City Council cherry picker, August, 2013 ......................................................................................................................................................... 12

Figure 11 Daily maximum and minimum temperature readings of ten trees on Macquarie Street, Dubbo from 28 March, 2013 to 19 July, 2013 ........................................................................................................ 13

Figure 12 Average daily maximum and minimum humidity readings of ten trees on Macquarie Street, Dubbo from 28 March, 2013 to 19 July, 2013 ........................................................................................................... 14
List of Tables

Table 1 Timeline for Starling control research project................................................................. 1

Table 2 List of plant items eaten by Common Starlings in Australia ............................................... 7

Table 3 List of animal items eaten by Common Starlings in Australia ............................................. 7

Table 4 Characteristics of trees used in data logger study, Macquarie Street, Dubbo ......................... 11

Table 5 Climactic summary statistics data for Dubbo (BOM, Dubbo Airport) 1993–2013. For each row, the intensity of the colour reflects the intensity of the reading................................................................. 13

Table 6 Statistical analyses of average daily minimum and maximum temperatures and %humidity between roost trees (n=5) and non-roost trees (combined non-roost (n=3) and occasional roost (n=2)) of the Common Starling in Dubbo, NSW from 01 April to 31 June, 2013................................. 14
Part A: Project Outline

1. Project Information

1.1 Project Name
Starling Control and Management in Macquarie Street, Dubbo

1.2 Personnel
Dr. Maggie J. Watson
Institute for Land, Water & Society (ILWS)
Charles Sturt University,
Albury 2640
mawatson@csu.edu.au
(w) 0260519893; (m) 0427654085

Associate Professor Gary Luck
ILWS
Charles Sturt University,
Albury 2640
galuck@csu.edu.au
(w) 0260519945

1.3 Period of Project
The project will be conducted between November 2012 and November 2014 using the following timeline:

Table 1 Timeline for Starling control research project

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 2012</td>
<td>Report on tree selection for Macquarie Street</td>
</tr>
<tr>
<td>March 2013–July 2013</td>
<td>Data collection on roosting site variables</td>
</tr>
<tr>
<td>August 2013–November 2013</td>
<td>Analysis of data and report on possible control options for Starlings in Dubbo</td>
</tr>
<tr>
<td>March 2014–June 2014</td>
<td>Trials of roosting deterrents on Macquarie Street</td>
</tr>
<tr>
<td>July 2014–November 2014</td>
<td>Analysis of data and submission of final report</td>
</tr>
</tbody>
</table>

1.4 Project Objectives
1. To consider the appropriateness of current tree species on Macquarie Street.
2. To gain an understanding of the factors that may attract Common Starlings to specific trees on Macquarie Street.
3. To determine bird deterrent methods that may be appropriate to trial on Macquarie Street against the Common Starling.
4. To trial those deterrent methods, and
5. To suggest long-term control measures for Dubbo City Council to use against their feral population of Common Starlings.
2. Project Description

2.1 Project Background
Dubbo City Council has employed Dr. Maggie J. Watson, author of this report, as a consultant to determine the best course of action for managing and controlling the feral Common Starling *Sturnus vulgaris* population currently causing damage to Macquarie Street, Dubbo. For at least ten years, Council has tried to disrupt starling roosts on Macquarie Street, but with little to no long-term success (Manager Landcare Services, pers. comm.). The aim of this project is threefold (a) to assess the trees on Macquarie Street and determine the factors that make these trees attractive to the starlings; (b) to propose methods for deterring and reducing the population of Common Starlings present in Dubbo; and, (c) to test the effectiveness of some of these methods so as to improve the final recommendations for Common Starling control in Dubbo.

2.2 Starlings
The Common Starling is a small to medium frugivorous and insectivorous bird which is a noted pest species in Australia. Starlings cause damage to fruit and sprouting crops as well as exhibiting nuisance behaviour (noise and mess) when roosting. They usurp nest hollows of native species and spread environmental weeds (Pell & Tidemann, 1997; NSW DPI, 2007). Additionally, they have been implicated in the transmission of salmonella, *Cryptococcus*, Newcastle disease, transmissible gastroenteritis, eastern encephalitis and foot-and-mouth disease (NSW DPI, 2007). Starlings in Dubbo are known to nest in River Red Gum *Eucalyptus camaldulensis* hollows as well in urban and peri-urban roof cavities causing the displacement of native bird and mammal species (Manager Landcare Services, pers. comm.). The population size of Common Starlings in Dubbo is unknown, but estimates of up to 500,000 birds using autumn/winter roosts on Macquarie Street have been suggested (Manager Landcare Services, pers. comm.).

2.3 Macquarie Street, Dubbo

2.3.1 History
As part of a beautification development in Dubbo, two exotic tree species (European Hackberry *Celtis australis* and Northern Hackberry *C. occidentalis*) were planted on both sides of Macquarie Street between 1991 and 1997 (Director Parks & Landcare Services, 2013). A long-term introduced pest species in the area, the Common Starling, began using these trees as their late summer to early winter roosts starting about 2002. Between 2002 and 2011, Council observed that Common Starling numbers during the late summer to early winter roosting period on Macquarie Street were so large as to cause damage to infrastructure, pose a health risk due to accumulation of faeces and cause noise and odour pollution. For at least ten years, Council has tried to disrupt starling roosts on Macquarie Street, but with little to no long-term success (Director Parks & Landcare Services, 2013; see section D). Council resolved in 2012 to engage the Institute of Land Water and Society (Charles Sturt University) to investigate the relationship between tree species and starling roosting, undertake a study on starling behaviour and to assess deterrent and control measures for Macquarie Street.
2.3.2 Trees

*Celtis australis* (European hackberry, European nettle tree, Mediterranean hackberry or Honeyberry)

There are 39 *Celtis australis* located on Macquarie Street and the adjacent Church Street plaza (Fig. 1, Fig. 2 yellow numbers). This tree is the favoured species of the Common Starling, and is mostly clustered at the northern end of Macquarie Street. This species is notable for its dense canopy with a high number of small branches.

*C. occidentalis* (Northern Hackberry, Common Hackberry, Nettletree, Beaverwood, American Hackberry)

There are 51 *C. occidentalis* located on Macquarie Street and the adjacent Church Street plaza (Fig. 1, Fig. 2 blue numbers). This tree is less-favoured for roosting by the Common Starling, and is the main tree present between Church Street and Bultje Street. This tree is noticeably larger at maturity than *C. australis* and has a more diffuse canopy. This tree also loses its leaves earlier in the autumn than *C. australis*.

---

*Figure 1 Typical Celtis street trees on Macquarie Street, Dubbo. The tree on the left is *C. australis* (tree e11 from Fig. 2) and the tree on the right is *C. occidentalis* (tree w20 from Fig. 2). Note that the photo was taken in March, 2013 and the *C. occidentalis* tree is already losing its leaves. Photos: M Watson*
Figure 2 Map of trees on Macquarie Street, Dubbo. Prefix indicates position on the street—’w’ for west, ‘e’ for east, ‘c’ for centre and ‘p’ for plaza. Trees are numbered sequentially from north to south, with a white ‘x’ indicating missing trees (removed). Colour indicates tree species—blue for *Celtis occidentalis* and yellow for *C. australis*. Trees with data loggers were—w9, c6, e4, e8, e16 (Common Starling roost trees), w3, c2 (occasional roost trees) and p1, e15, e19 (not roost trees). Photo: NSW Region Centres High Resolution, LPMA, 2010
Part B: Review of Starling Natural History & Behaviour

1. Taxonomy
Common Starlings belong to the Sturnidae family which include the mynas and the starlings.

1.1 Scientific Name
_Sturnus vulgaris_ Linnaeus 1758

1.2 Common Name
Common Starling, European Starling, Purple-winged Starling

2. Natural History

2.1 Identification
Identification information from ‘Starlings and Mynas’ (Feare and Craig, 1998) unless otherwise stated.

Length: 20–22cm
Mass: 58–101g

Adults are blackish with pale tips to the body feathers after the post-nuptial moult (Fig. 4), but these tips are abraded over time, leaving adults in the breeding season black with an iridescent green and purple sheen (Fig. 3, Fig. 5). The wings and tail are dark brown. The bill is straight, pointed and yellow with a steel blue base in males and a pink base in females during the breeding season. The bill is brownish-black at other times of the year. The legs are a deep pink during the breeding season and brownish during the rest of the year. In flight, the pointed wings and short tail are diagnostic.

Adult male spring: glossy black, elongated throat feathers, limited spotting especially on back and vent, yellow bill with bluish base, dark eye (Fig. 3).

Adult female spring: similar to male, but more and larger spotting, pinkish base to yellow bill, pale eye ring on iris

First year birds: generally less glossy than older birds

Juvenile: sandy brown, whitish throat, usually dark streaking on underparts (Fig. 5)

Figure 3 Adult male Common Starling in breeding plumage

Figure 4 Female Common Starling, non-breeding winter plumage. Photo: P Lomax, 2006
Common Starlings can be accurately (97%) sexed by the colour of the irises, rich to chocolate brown in males and mouse-brown or grey in females. The accuracy can increase to 100% if the length of throat feathers is considered—males exhibit much longer throat feathers than females (Fig. 6) (Smith et al., 2005).

Song: males are highly vocal and sing in most months, only silent during the early stages of moult. When singing, the elongated throat feathers of males are easily visible. Starlings sing during both day and night. Song is most prominent after arrival at the evening roost and just before departure. It is thought that this song serves to synchronise the departure of groups of birds (Feare 1984).

2.2 Diet
Common Starlings are primarily insectivorous but also consume a wide variety of plant material. In a study in the McLaren Vale Region of Australia, gut content analysis revealed that snails, beetles, weevils, wasps, ants,
isopods, millipedes and worms were some of the invertebrate prey taken, while the main vegetative part of the diet consisted of grapes (Paton et al., 2005). A comprehensive list of food items found in Common Starlings from Australia is provided in Tables 2 and 3.

Table 2 List of plant items eaten by Common Starlings in Australia

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marsileaceae</td>
<td>aquatic ferns</td>
<td>McKeown, 1934</td>
</tr>
<tr>
<td>Arecaeeae</td>
<td>palm tree fruit</td>
<td>Thomas, 1957</td>
</tr>
<tr>
<td>Poaceae</td>
<td>oat seeds</td>
<td>Barker &amp; Vestjens, 1990; Thomas, 1957; Vestjens, 1977; McKeown, 1934</td>
</tr>
<tr>
<td>Amaranthaceae</td>
<td>amaranth seeds</td>
<td>Vestjens, 1977</td>
</tr>
<tr>
<td>Cactaceae</td>
<td>cactus spines</td>
<td>Thomas, 1957</td>
</tr>
<tr>
<td>Chenopodiaceae</td>
<td>saltbush seed</td>
<td>Thomas, 1957</td>
</tr>
<tr>
<td>Cactaceae</td>
<td>cactus spines</td>
<td>Thomas, 1957</td>
</tr>
<tr>
<td>Fabaceae</td>
<td>clover leaves and seed</td>
<td>Thomas, 1957; Vestjens 1977</td>
</tr>
<tr>
<td>Moraceae</td>
<td>fig fruit and mulberries</td>
<td>Thomas, 1957</td>
</tr>
<tr>
<td>Oleaceae</td>
<td>olive fruit</td>
<td>Thomas, 1957</td>
</tr>
<tr>
<td>Polygonaceae</td>
<td>dock seed</td>
<td>Thomas, 1957</td>
</tr>
<tr>
<td>Rosaceae</td>
<td>plum fruit, hawthorn berries</td>
<td>McKeown, 1934</td>
</tr>
<tr>
<td>Solanaceae</td>
<td>boxthorn berries, tomatoes</td>
<td>Thomas, 1957</td>
</tr>
<tr>
<td>Vitaceae</td>
<td>grapes</td>
<td>Barker &amp; Vestjens, 1990; McKeown, 1934; Thomas, 1957</td>
</tr>
</tbody>
</table>

Table 3 List of animal items eaten by Common Starlings in Australia

<table>
<thead>
<tr>
<th>Scientific Names</th>
<th>Common Names</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nematoda</td>
<td>roundworms</td>
<td>Thomas, 1957</td>
</tr>
<tr>
<td>Bivalvia</td>
<td>freshwater mussels</td>
<td>Thomas, 1957</td>
</tr>
<tr>
<td>Gastropoda</td>
<td>snails and slugs</td>
<td>Barker &amp; Vestjens, 1990; Thomas, 1957</td>
</tr>
<tr>
<td>Annelida</td>
<td>earthworms</td>
<td>Thomas, 1957</td>
</tr>
<tr>
<td>Arthropoda-Diplopoda</td>
<td>millipedes</td>
<td>Barker &amp; Vestjens, 1990; Cleland et al., 1918; Green, 1966</td>
</tr>
<tr>
<td>Arthropoda-Chilopoda</td>
<td>centipedes</td>
<td>Thomas, 1957</td>
</tr>
<tr>
<td>Arthropoda-Insecta</td>
<td>silverfish, damselflies, dragonflies, cockroaches, termites, earwigs, grasshoppers, crickets, mole crickets, cicadas, assassin bugs, water striders, water boatmen, beetles and larvae, flies and maggots, mosquitoes, moths, caterpillars, wasps, bees, ants</td>
<td>Barker &amp; Vestjens, 1990; Cleland et al., 1918; Green, 1966; McKeown, 1934; Vestjens, 1977</td>
</tr>
<tr>
<td>Crustacea</td>
<td>slaters</td>
<td>Barker &amp; Vestjens, 1990; Thomas, 1957</td>
</tr>
<tr>
<td>Arachnida</td>
<td>scorpions, spiders, ticks</td>
<td>Barker &amp; Vestjens, 1990; Green, 1966; Thomas, 1957</td>
</tr>
<tr>
<td>Reptilia</td>
<td>lizards and skinks</td>
<td>Barker &amp; Vestjens, 1990; Thomas, 1957</td>
</tr>
</tbody>
</table>
2.3 Breeding Ecology

Common Starlings form breeding pairs in early spring (August to September) and nest in tree hollows, holes in the ground or in cliffs, between shrubs and buildings, in very dense foliage of shrubs, and in crevices in buildings (Feare, 1984). Holes or hollows are selected for their height (Verheyen, 1969) and small entrance diameter (Moeed & Dawson, 1979). During the territory formation and pairing up period, males are especially antagonistic and will attack other birds or evict them from hollows. Female Common Starlings are aggressive, too, but generally only towards other female Common Starlings. Once paired with a male, the female lays between 4 and 8 light blue eggs in a cup-shaped grass nest decorated, by the male, with fresh foliage, feathers and rubbish (Fig. 7).

Common Starlings may have up to three broods a year (Feare, 1984) starting generally in late October. The exact timing of the first brood is dependent upon temperature (Evans, 1980; Meijer et al., 1999) and are highly synchronous with all other Common Starlings in the area (almost all eggs are laid with 7 days of each other) (Flux & Flux, 1981). The brooding period (time from egg laying to hatching) is 12 days. Chicks are altricial—born blind and featherless—and weigh between 4.36 and 6.07g (Ricklefs, 1979). Chicks fledge about 21 days after hatching. Second broods occur between November and December with final broods starting in January. Generally, the third brood is less successful than earlier broods and may be dependent upon water or food availability. Seventy to ninety percent of first broods produce fledged young, while 40 to 80 percent of second broods produce fledglings (Feare, 1984).

High-protein foods such as insects are the main food source for chicks until they fledge (Table 3) (Moeed, 1980); the fledgling diet then turns to plant items, usually fruit (Tracey & Saunders, 2003). Fledglings follow adults around to learn where feeding sites are located. Fledglings suffer greater mortality than adults, usually due to starvation. The average life-span of the Common Starling in Australia is 1.6 years with a maximum of 14.2 years (ABBBS, 2007). Females will breed in their first year, while males may wait until 2 years to breed.

Figure 7 Common Starling nest with five eggs. Note grass cup construction decorated with fresh foliage, feathers and rubbish. Photo: MR 2006.
2.4 History in Australia

The Starling was introduced into Australia in the mid-1850s (Long 1981) by acclimatisation societies (who admired the songs of this native European bird) and by farmers wishing to control insect pests. Availability of water appears to be the most important factor to determining their successful colonisation, hence those areas that have the highest rainfall, irrigated areas and swampy areas support the highest densities in Australia (NSW DPI, 2007). There are no accurate estimates of the population size of the Common Starling in Australia. The worldwide population has been estimated at 310 million (Rich et al., 2004).

Figure 8 Distribution map of the Common Starling in Australia (NSW DPI, 2007)

2.5 The Problem with Starlings

In urban environments, the roosting of large numbers of Starlings causes damage to property (e.g. faeces corrosion of buildings and paintwork, tree damage and tree death) and poses potential health risks (e.g. faeces contamination of water supplies, fungal pathogens such as histoplasmosis and respiratory mycosis) as well as being unsightly and loud. Day roosts are generally small, and therefore, not as noticeable as the winter roosts (Feare, 1984). In Australia, the larger night roosts are occupied between late summer and winter, possibly a reflection of the less seasonal nature of Australia compared to the native range of the Common Starling.

In addition to these impacts on the urban human environment, Common Starlings pose serious problems to peri-urban and rural human communities as well as native flora and fauna. In areas that house and feed livestock, Common Starlings have been implicated in the transmission of disease (Linz et al., 2007). Common Starlings are also known dispersers of weed seeds (Bridal Veil Creeper Asparagus asparagoides, Olives Olea europaea and Blackberries Rubus sp.) (Forde, 1986) as well as causing significant damage to fruit crops (especially grapes and cherries) (Paton et al. 2005). Their aggressive behaviour and breeding system causes the Common Starling to come into contact with native Australian wildlife resulting in competition for limited breeding hollows (Green, 1983). In fact, Common Starlings have been implicated in the reduction of breeding success of some native species (Pell & Tidemann, 1996). It should be noted that these same studies indicate that the Indian Myna Acridotheres tristis has an even greater effect on the breeding success of native species than the Common Starling (Pell & Tidemann, 1996, Parsons et al. 2006).
2.6 Roosting Behaviour
Roosting behaviour has four stages, as described by Feare (1984) and modified to include specific information from observations on Macquarie Street, Dubbo:

1. Assembly: Birds converge from feeding areas (parks, gardens and sports fields) to pre-roost assembly sites or staging areas, generally in a direct line of flight. Major staging areas in Dubbo are the Riverdale Shopping Centre tower (Fig. 9) and aerial structures on the roof of Oliver House, Church Street.

2. Entry: Birds enter in two flight patterns, either mass aerial manoeuvres (swirling cloud-like formations) with a quick decent into the chosen roost tree, or mass direct flight from the staging area. Both of these entries are usually silent, with calling only occurring on the staging area and within the roost tree. Birds that are late at arriving at the roost are often more noisy.

3. Roosting: Birds are very active during roosting with much singing, fighting and flying between roost trees. It has been suggested that healthy and older individuals arrive first and are in the centre of the roosts while edge individuals are either unhealthy or juvenile (Summers et al. 1987).

4. Dispersal: Morning activity commences with singing. This singing reaches a crescendo and then cuts to silence. This occurs several times, and at one of the sudden silences, birds begin to disperse to feeding grounds. Those leaving the roost form small flocks and travel *en masse* to their chosen feeding ground.

It is unclear what function or purpose these large roosts hold for the Starling. It has been suggested that Starlings use these roosts to save energy (maintaining internal temperature) by escaping extremes of temperature or wind (Kelty & Lustick, 1977), to protect themselves from predators, as a method to gather information (by following other birds) on better feeding sites (information centre hypothesis) (Caccamise, 1990). Unfortunately there is little information on this behaviour, either from the Common Starling’s native range nor Australia, so few inferences for methods of control can be made from these hypotheses.

Figure 9 Riverdale Shopping Centre on Macquarie Street, Dubbo. Note signage tower over the entrance which is a major staging area for Common Starlings before night time urban roosting. A. McDonald, 2013.
Part C: Investigations into Starling Roost Preference, Macquarie Street

1. Introduction

The Common Starling’s night-time communal roosting area in Dubbo is on the northern end of Macquarie Street. The most conspicuous roosting behaviour generally occurs during the cooler months between March and July, before the deciduous trees lose their leaves for the winter. Common Starling’s begin to form larger and larger flocks after the fledging of the last chicks of the year, eventually resulting in thousands of adult and juvenile birds roosting at night in less than one block on the main city street. These Starlings are loud when entering and leaving the communal roost, and continue to chatter throughout the night. Their faecal droppings pollute walkways, trees, cars and buildings and are thus considered a nuisance and potential health hazard. Additionally, the daily clean-up of faeces is a considerable yearly financial burden on Dubbo City Council. The reason behind these large congregations has been suggested to relate to the bird’s energy budget (i.e. keeping metabolic rate at an optimum temperature) and shelter (i.e. to escape extremes in weather). Climactic factors that may influence roost choice include temperature, wind speed and relative humidity (Kelty and Lustick 1977), but research into the physical characteristics of roost site selection are conflicting and may be site specific (Yom-tov, 1976; Kelty & Lustick, 1977, Clergeau & Simonnet, 1996). The purpose of this study was to determine the roost site characteristics of the Common Starling in Macquarie Street Dubbo with the aim of formulating sound, ecologically based integrated management strategies for the long-term control of these feral birds in the Dubbo area.

2. Methods

2.1 Study Area

This study was conducted on Macquarie Street, Dubbo (32°24’S, 148°61’E). Tree species and distribution are shown in Fig. 2 and all references to tree numbers are taken from notions made on that map. Table 4 details the location and characteristics of these trees.

<table>
<thead>
<tr>
<th>Map Code</th>
<th>Species</th>
<th>Starling Roost Category</th>
<th>Location Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>w3</td>
<td>C. australis</td>
<td>Occasional</td>
<td>Next to bus stop, north end of Macquarie St.</td>
</tr>
<tr>
<td>w9</td>
<td>C. australis</td>
<td>Yes</td>
<td>In front of SportsPower</td>
</tr>
<tr>
<td>c2</td>
<td>C. australis</td>
<td>Occasional</td>
<td>Centre strip, north end of Macquarie St.</td>
</tr>
<tr>
<td>c6</td>
<td>C. australis</td>
<td>Yes</td>
<td>Centre strip, in front of Amaroo Hotel</td>
</tr>
<tr>
<td>e4</td>
<td>C. australis</td>
<td>Yes</td>
<td>In front of Old Dubbo Gaol</td>
</tr>
<tr>
<td>e8</td>
<td>C. australis</td>
<td>Yes</td>
<td>In front of former Dubbo Post Office</td>
</tr>
<tr>
<td>p1</td>
<td>C. occidentalis</td>
<td>No</td>
<td>In plaza on Church St.</td>
</tr>
<tr>
<td>e15</td>
<td>C. occidentalis</td>
<td>No</td>
<td>In front of Myer</td>
</tr>
<tr>
<td>e16</td>
<td>C. australis</td>
<td>Yes</td>
<td>In front of Myer</td>
</tr>
<tr>
<td>e19</td>
<td>C. occidentalis</td>
<td>No</td>
<td>In front of Myer</td>
</tr>
</tbody>
</table>

2.2 Data Loggers

Ten Tinytag Plus 2 data loggers were deployed in the upper central canopy of seven C. australis (five of which were favoured Starling roost trees—w9, c6, e4, e8, e16, and two which were rarely used as roost trees—w3, c2) and three C. occidentalis trees (all of which were not roost trees—p1, e15, e19). These units measured temperature and relative humidity at 10 minute intervals for 114 days from 15:45 28 March to 21:25 19 July, 2013. Deployment was carried out on the morning of 28 March 2013, while recovery was accomplished on the morning of 27 August 2013 (Fig. 10).
3. Results
In 2013, large numbers of Common Starlings used Macquarie Street, Dubbo as a night-time roosting area from March until June. Peak roosting occurred during April and May. Common Starlings do not appear to use Macquarie Street in large numbers during the coldest month of the year (Table 5), and appear to desert these roosting sites once the leaves have dropped from the trees and winter rains begin. It is unclear if wind is a factor in determining when and where the Common Starlings decide to roost on Macquarie Street, although peak roosting does occur during the least windy time in Dubbo (Table 5).

Analysis of data logger temperature readings indicated that roost trees generally experience less dramatic fluctuations in temperature than non-roost trees during the peak roosting time of April and May (Fig. 11). After 1 June, when trees have lost their leaves, roost trees are generally warmer during the day than non-roost trees. Analysis of data logger humidity readings indicated that roost trees do not deviate significantly from the humidity of non-roost trees. There is some marginal support for the idea that roost trees are more humid than non-roost trees, but this was not statistically significant.
Table 5 Climactic summary statistics data for Dubbo (BOM, Dubbo Airport) 1993–2013. For each row, the intensity of the colour reflects the intensity of the reading.

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>13.4</td>
<td>13.8</td>
<td>28.7</td>
<td>24.6</td>
<td>19.9</td>
<td>16.3</td>
<td>15.4</td>
<td>17.4</td>
<td>21.1</td>
<td>24.6</td>
<td>28.3</td>
<td>31.0</td>
<td>24.4</td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>18.2</td>
<td>17.7</td>
<td>14.3</td>
<td>10.1</td>
<td>6.4</td>
<td>4.3</td>
<td>3.1</td>
<td>3.3</td>
<td>6.1</td>
<td>9.2</td>
<td>13.6</td>
<td>15.7</td>
<td>10.2</td>
</tr>
<tr>
<td>Min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>33</td>
<td>48.4</td>
<td>55.2</td>
<td>31.8</td>
<td>42.8</td>
<td>47.5</td>
<td>40.2</td>
<td>37.7</td>
<td>41.7</td>
<td>46.9</td>
<td>68.7</td>
<td>58.8</td>
<td>572.0</td>
</tr>
<tr>
<td>Rain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave</td>
<td>4.7</td>
<td>4.9</td>
<td>4.9</td>
<td>2.8</td>
<td>4.0</td>
<td>5.6</td>
<td>5.2</td>
<td>4.2</td>
<td>5.0</td>
<td>5.1</td>
<td>5.9</td>
<td>5.0</td>
<td>57.3</td>
</tr>
<tr>
<td>Rain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>18.9</td>
<td>18.1</td>
<td>17.9</td>
<td>16.8</td>
<td>16.2</td>
<td>17.1</td>
<td>17.1</td>
<td>19.0</td>
<td>19.7</td>
<td>20.1</td>
<td>20.2</td>
<td>19.4</td>
<td>18.4</td>
</tr>
<tr>
<td>Wind</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 11 Daily maximum and minimum temperature readings of ten trees on Macquarie Street, Dubbo from 28 March, 2013 to 19 July, 2013. Black lines are Common Starling roost trees. Green lines are trees that are not used as roost trees or are only rarely used as roost trees. Note that the black lines show a higher minimum temperature and a lower maximum temperature during peak roosting season (April and May) indicating that roost trees generally experience less fluctuation in temperature than non roost trees.
Table 6 Statistical analyses of average daily minimum and maximum temperatures and %humidity between roost trees (n=5) and non-roost trees (combined non-roost (n=3) and occasional roost (n=2)) of the Common Starling in Dubbo, NSW from 01 April to 31 June, 2013. Significant p-values are marked with an asterisk.

<table>
<thead>
<tr>
<th></th>
<th>Roost</th>
<th>Non-roost and occasional roost (combined)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ave Daily Min ± SD</td>
<td>Ave Daily Max ± SD</td>
</tr>
<tr>
<td><strong>Temp (°C)</strong></td>
<td>12.3 ± 3.2</td>
<td>27.7 ± 4.7</td>
</tr>
<tr>
<td><strong>Humidity (%RH)</strong></td>
<td>24.4 ± 9.4</td>
<td>96 ± 4.7</td>
</tr>
</tbody>
</table>

4. Discussion

The trees that Common Starlings are choosing to roost in are significantly warmer at night (approx. 4°C warmer) and cooler during the day (approx. 2°C cooler) than non-roost or occasional roost trees. These roost trees do not differ significantly in humidity from non-roost or occasional roost trees. Based on this information, any deterrent methods used should aim to alter the temperature profile of the problem street trees. Long term control options, aimed at the total population of Common Starlings in the Dubbo area, must be employed at the same time as deterrent methods, or else the roosting site will simply relocate to other areas within Dubbo.
Part D: Review of Starling Control Options

1. Previous Management & Control Options Used in Dubbo

The Common Starling has been noted as a problem in Dubbo since at least 1914 (Director Parks & Landcare Services, 2013). Control measures, including shooting, have been used in Dubbo, to little known effect (Director Parks & Landcare Services, 2013). Common Starlings began roosting on Macquarie Street sometime in the early 2000s, probably due to the maturation of the street trees planted in the early 1990s. Council have trialled several deterrents over the years on the Macquarie Street roosting sites, including raised mist netting, laser guns, distress call devices, tree pruning, high pressure water jetting and Tanglefoot® or polybutene (Director Parks & Landcare Services pers. comm.). These trials have not resulted in a significant decrease of overall Common Starling numbers nor a long-term shift of the Macquarie Street roosting site (Manager Landcare Services, pers. comm.).

2. Management & Control Options Used Elsewhere

2.1 Poisoning and Bait Stations

Poisoning Common Starlings using DRC-1339 have been carried out in the U.S. since the 1960s (Besser et al., 1967; Carlson et al., 2011; West, 1968). These poisons are effective as part of an integrated pest management system in and around cattle feedlots or other large concentrations of pest birds. DRC-1339, or Starlicide®, has also been trialled on the closely related Indian Myna (Feare, 2010). Trials were to be conducted on the Common Starling in feedlots around Orange, according to Bentz et al. 2007, however, there are no published reports on the effectiveness of these trials, or even information indicating if the trials took place. Avian poisons are an effective tool if care is taken to distribute the poison in situations where non-target birds are not likely to be affected (Linz et al., 2010).

2.2 Scaring

Many visual and sound devices have been tried on Common Starlings in both vineyards and airports. These include gas guns, electronic devices which emit sounds disturbing to birds, radios to mimic human presence, lights, scarecrows (both human-shaped and predator models), reflective mirrors, glass or tape, balloons and kites. These methods are generally ineffective unless accompanied by lethal control (i.e. shooting) (Belant et al., 1998; Tracey, et al. 2007). The only effective method appears to be a compressed-air method requiring daily dispersal at dusk by a team using a modified leaf blower and/or vehicle-mounted compressor (White et al., 2005).

2.3 Falconry

Falconry is regularly used in Europe and North America around airports to reduce air strikes (Bryant, 2004). Usually used to disperse birds from runways, there is limited evidence for its efficacy in urban and agricultural settings (Erickson et al. 1990). In the 1970s, Sydney Airport trialled falcon as a bird deterrent, but the trial was abandoned after 5 months (Sydney Morning Herald, 1976). Some vineyards in the U.S. and Europe have used falcons to deter pest birds before harvest (Hillard, 2009; Schofield, 2010). Recent use of trained birds-of-prey in Australia at the MCG (Melbourne Cricket Ground) has garnered much media attention and may provide a viable alternative strategy for dispersing Common Starlings before they settle for night-time roosting (G Coles, Full Flight, pers. comm.).

2.4 Habitat modification ( revegetation)

Common Starlings prefer cleared agricultural and peri-urban areas (Tracey et al., 2007), especially for feeding. The more dense vegetation, especially native trees, in an area, the less likely the Common Starling is to feed in that area (EPNRMB, 2010). Additionally, Common Starlings nest primarily in degraded remnants with little understory (EPNRMB, 2010). However, the effectiveness of these management strategies has not been evaluated.
2.5 Reduce water availability
Stock trough modification to reduce water availability has been suggested as a strategy to employ in areas where watering points are limited (EPNRMB, 2010). The spread of the Common Starlings appears to be water-limited (Feare, 1984), so in situations where watering points can be controlled, this is a viable control strategy.

2.6 Removal of roost sites
In order to disperse a roost, two-thirds of the roosting vegetation must be removed or modified (Garner, 1978). This may be an effective strategy in urban settings.

2.7 Long-term Trapping and Euthanasia
Long-term trapping has been an effective tool in preventing the establishment of the Common Starling in Western Australia. The aim of this program is to prevent the establishment of a breeding colony. In this program, large walk in traps coupled with shooting have kept the numbers of Common Starlings in Western Australia to between 1,000 and 10,000 individuals (ACIL Tasman, 2006).

While not tried on Common Starlings, a community program aimed at controlling the spread of the Indian Myna in Canberra has successfully reduced the population by 42,342 individual birds over a 7 year period using 1400 traps (Thompson, 2013). Several Australian councils (e.g. Sutherland Shire, Port Stephens and Shoalhaven City Councils) have taken up trapping-based control options with community support to attempt control of Indian Mynas (Indian Myna Regional Conference, 2009).

2.8 Repellents
Repellents are chemical substances that Common Starlings find distasteful to eat, troublesome to eyes or throat (irritants), or uncomfortable to perch on. There are several repellents commonly used in the control of pest birds:

- Methyl anthranilate—a taste aversive compound that repels pest birds from feedlots and fruit production facilities. It is not widely used (Glahn et al. 1989), but has been suggested as a component to be added to misters to aid in dispersal of pest birds (see 3.3 below) because of its irritating effects.
- Citronellyls—plant derived flavours and fragrances that have been shown to repel Common Starlings in the laboratory, but have yet to be tested in the field (Hile, 2004). The suggested use is to spray these compounds on crops to repel pest birds.
- Polybutene—commonly called Tanglefoot®, is a sticky cream that irritates bird’s feet and is usually applied to buildings to prevent birds from landing.

3. Novel Control Options

3.1 Remote-controlled model aircraft in the shape of birds of prey
Because of the high cost of using trained falconry birds and the relative ineffectiveness of remote-control aircraft to disperse birds around airports, a Falco Robot Gregarious Birds Removal System model was trialled at an Italian airport in 2008 with results suggesting it may be a viable option for dispersing pest birds (Battistoni et al., 2008).

3.2 Microclimate Alteration (Temperature)
Outdoor misting fans, such as those used in outdoor restaurants and dairies, are used to reduce ambient temperature by evaporation in areas of low humidity. This method has not been used to deter birds or any other temperature-dependent pest species.
3.3 Fogging With Repellents
Outdoor fogging units that spray repellents (methyl anthranilate) in large open spaces are available for the commercial pest control market (Bird-B-Gone Mist; www.birdgone.com). Each unit has 64 drop stations that each can spray an area of 550m². However the effectiveness of this method has not been evaluated.

3.4 Predator Relocation
The introduction of predators to an area to control or deter pest bird species (including the Common Starling) has been trialled in New Zealand vineyards (Kross et al., 2012). In this experiment, New Zealand Falcon (Falco noaescelandiae) chicks had been relocated four years prior to the study (Falcons for Grapes Programme). The results showed a significant reduction in the numbers of pest bird species in the vineyard and significantly less damage to the crops.

3.5 Control insects at feeding sites
The recent commercial development of endophyte-infected grass for reduction of insect numbers and thus feeding birds around airports is a viable option for the control of Common Starlings where main feeding grounds are mown grass fields. Trials at three New Zealand airports saw an overall reduction of bird numbers by 87% over a twelve month period (Pennell & Rolston, 2011). The grass cannot be grazed by livestock or other non-target grazing animals (including ducks) as it may cause death.
Part E: Recommendations for the Control of Starlings in Dubbo

The selection of roost sites by the Common Starling in the urban landscape is highly flexible (Clergeau & Quenot, 2007). These birds will switch at any time their roost sites irrespective of historical location and tree species. The only limiting factors appear to be (1) protection from wind (Clergeau & Quenot, 2007), (2) high availability of small branches (Lyon & Caccamise, 1981; Clergeau & Quenot, 2007; this study), and (3) warmer night time temperature within the canopy (Clergeau & Quenot, 2007; this study).

1. Manage Common Starlings at their roosting sites

As part of this project, it is recommended to trial the following management options on Macquarie Street Dubbo:

- Alteration of temperature microclimate of roost trees by installing misters.
- Alteration of temperature microclimate of roost trees by ensuring that all overhanging roof awnings on Macquarie Street are white on their upper sides.
- Trial the use of falconry to deter Common Starlings from roost trees.
- Trial the use of programmable misters with methyl anthranilate (chemical deterrent).
- Trial the use of micro misters (without chemical deterrent) to lower the temperature of the roosting tree.
- Select replacement trees for Macquarie Street with open canopies and fewer small inner branches than current species (e.g. Jacaranda *Jacaranda mimosifolia*). Do not replant *Celtis australis*; if *Celtis occidentalis* is used, continue to prune trees to prevent the formation of small inner branches.

2. Manage Common Starlings at their staging sites

As part of this project, it is recommended to trial the following management options to prevent Common Starlings from staging near Macquarie Street, Dubbo:

- Removal or alteration (e.g. predator models, spikes, netting or chemical sprays) of the Riverdale Shopping Centre tower
- Removal or alteration of the Oliver House aerials
- Identification of additional staging areas within the city of Dubbo and placement of deterrents (e.g. predator models, spikes, netting or chemical sprays) on these sites

3. Control Common Starling populations at their feeding sites

- Identify parkland feeding areas (i.e. sports fields) of the Common Starling and consider replanting these areas of irrigated, short grass with endophyte-infected grass to reduce overall insect availability.
- Identify non-parkland feeding areas of the Common Starling within the Dubbo area. These may be grain stores, abattoirs, feed storage facilities and peri-urban farm lots. Install lethal chemical control (DRC-1339) stations at these key areas.

4. Control Common Starling populations within the region

- Begin a long-term integrated community-Council based trapping program modelled on similar programmes targeting the Indian Myna. Small traps would be available for hire from Council, or available for purchase from Council. These traps can be manufactured by the local men’s sheds for hire or sale (see Pee Gee’s Myna Trap Plan at Byron Shire Council www.byron.nsw.gov.au/files/pages/indian-mynas/Pee_Gees_Myna_trap_-_Plan.pdf). Captured birds would be euthanised by the general public or Council workers depending on Council preference. Large walk-in traps would be placed in key areas (such as sporting ovals), and cleared by Council workers at regular intervals.
• Recruit other Councils within the area to begin similar trapping programmes.
• Identify feeding grounds outside of the Dubbo City area such as feed lots and vineyards and begin trapping and lethal control programmes at these sites.
• Apply for funding for these programmes from NSW Environment & Heritage Environmental Research Grants (Project Category: Threats to the Environment—pests & weeds).


**Part F: References**


Tracey, J., Saunders, G. (2003) Bird damage to the wine grape industry. Report to the Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry, NSW, Australia.

Verheyen, R.F. (1969) Arrival at the breeding area, maturity for breeding and onset of laying according to age in the Starling population (Sturnus v. vulgaris L.) of Lower and Middle Belgium. Gerfaut 59: 378–384


