ECOLOGY AND MANAGEMENT OF THE LITTLE CORELLA (*Cacatua sanguinea*) IN THE SOUTHERN FLINDERS RANGES, SOUTH AUSTRALIA.

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March 1994

Submitted in partial fulfilment of the requirements for the Master of Science Degree, University of Adelaide, South Australia.

Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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ERRATA

Page 2. 2nd paragraph should read "A review of the techniques .... in Appendix 1 (page 125).

Page 18. 4th paragraph should read "A list of all items found .... in Appendix 2 (page 135).

Page 25. 1st paragraph, 2nd sentence should read "Food items other than .... Little Corella diet; for example, psyllid casings, corms of *O. pes-caprae* and Lepidopteran larvae."

Page 31. 6th paragraph, 3rd sentence should read "A list showing the dates, locations.....in Appendix 3 (page 136).

Page 45. 3rd paragraph, 2nd sentence should read "Some unbred females were detected .... young born in that breeding season (i.e. most birds bore all primaries in good condition).

Page 126. 3rd paragraph, 3rd sentence should read " Mode of administration is usually a solid bait (whole grains, cracked grains, legumes, bread and margarine sandwiches)."

Page 127. 2nd paragraph, 3rd point should read "off target birds consuming bait can be captured and confined for later release (e.g. Woronecki 1990);"

Page 128. End of 4th paragraph should read "Ridpath *et al* (1961)

Page 146. Insert after 2nd paragraph
Murton, R. K., Isaacson A. J. and Westwood N. J. (1963). The use of baits treated with alphachloralose to catch wood pigeons. *Annals of Applied Biology* **52** 217-293.

Page 149. Insert after 9th paragraph
Woronecki P. P., Dolbeer R. A. and Seamans T. W. (1990). Use of alphachloralose to remove waterfowl from nuisance and damage situations. In 'Proceedings of the 14th Vertebrate Pest Conference". (Ed L. R. Davis and R. E Marsh). pp 343-349. (University of California, Davis).

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ABSTRACT

In the Flinders Ranges, South Australia, local communities are concerned about pruning damage by Little Corellas (*Cacatua sanguinea*) to River Redgums (*Eucalyptus camaldulensis*) used by the birds as roost trees. This study investigated the significance of pruning impact by Little Corellas on River Redgum health and longevity. The relationship between pruning impact and tree damage was examined first; in terms of the birds seasonal distribution and abundance, population structure and annual cycle, and second; in terms of tree response to environmental pressures including rainfall and pruning impact. This information was used to develop management techniques to control bird pruning pressure on roost trees.

Little Corellas congregated in large flocks in the southern Flinders Ranges during the summer months and birds from the entire Flinders Ranges participated in the summer congregation. Summer flocks comprised a mixture of adults (breeders and non breeders) and juveniles although relative proportions of each group varied between years of the study. Fallen grain was the major component of the diet during the summer months. Summer flocks dispersed in the autumn and the distribution of Little Corellas during the winter and spring was governed by the breeding status of individuals. Breeders returned to the northern Flinders Ranges to breed whilst non-breeders and juveniles remained in the southern Flinders Ranges. In subsequent summers, all birds re-assembled at known roosts in southern Flinders Ranges although individual birds were not necessarily faithful to roosts used in the previous year. In addition to their seasonal movements, Little Corellas also moved frequently during the summer with individuals moving between roosts and flocks shifting roost location.

Little Corellas made their roosts in River Redgums and, to a lesser extent, in Northern Cypress Pine (*Callitris columellaris*) situated along creeks. Not all creeks played host to Little Corellas and roosts were confined areas usually situated near accessible watering

points. Whilst roosting, Little Corellas pruned the upper and outer canopy of trees. Pruning caused a loss of canopy cover during the life of the summer roost and contributed to a perceived dieback in roost trees in the study area. The amount of pruning was positively correlated with bird dwell time (a combination of bird number and the amount of time that birds spent in the trees). Despite losing canopy during summer, roost trees were able to recover during the winter when the birds were absent, especially if average or above average winter rains were received. Although dieback was evident in roost trees, the widespread lack of tree regeneration was considered more important for the long term maintenance of River Redgum populations in the Flinders Ranges.

Techniques designed to reduce Little Corella impact on River Redgums were also investigated. Control techniques fell into two categories; population reduction and habitat modification. An experimental reduction of a Little Corella roost was conducted using the hypnotic drug, alphachloralose, administered in the stock trough where the birds drank. Although a large scale reduction was achieved (3050 of approximately 9,000 Little Corellas culled), flock size at the target roost was only temporarily (< 6 weeks) reduced. Trials of various habitat modification devices were also conducted and were based on exploiting the relationship between the roost and easy access to water and/or food. Restrictions to either resource caused birds to change watering and/or feeding behaviour although results did not conclusively demonstrate reductions in roost size or changes to roost location. Population reduction was an expensive option ($0.99 per bird) when compared to habitat modification ($0.36 per bird).

The failure of population reduction to reduce roost size and the promise of cheaper, more effective methods of habitat modification to alter roosting behaviour should encourage local communities wishing to reduce Little Corella impact on roost trees to pursue habitat modification further. Co-ordinated programmes to reduce bird impact and encourage tree regeneration are introduced and discussed.

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CHAPTER 1
GENERAL INTRODUCTION

In Australia, various native birds are pests in agricultural and non agricultural situations where they cause loss of ripening fruits, grains and germinating crops, damage to buildings and facilities, and hazards at airports. Birds can also act as vectors for the transmission of disease (Fitzwater 1989, Cooper 1990). The birds causing damage are taxonomically diverse and include the parrots (Lavery and Blackman 1970, Campbell 1975, Sinclair and Bird 1987, Rowley 1990), cockatoos (Beeton 1975, 1977, Saunders *et al.* 1985) and gulls (GC Smith 1991) as well as crows, silvereyes, currawongs (Hartridge *et al.* 1975), ducks (Davey and Roberts 1990) and geese (Robinson *et al.* 1982).

A common feature of pest birds is their increased abundance (generally and/or seasonally) as a result of the changes brought about by urban and agricultural use of the landscape (Rowley 1990, Saunders *et al.* 1985). Typically, the damage caused by pest birds is patchy in both time and space with some areas receiving far greater attention than others (Jarman 1986). Damage is often localised and restricted to areas near roosts or nests, or along known flight paths and migration routes (Beeton 1977, Wiens and Johnston 1977, Dolbeer 1989, Elliott 1990). The birds that are considered as pests of crops may also exert direct and indirect beneficial effects for example, by consuming insect pests and by consuming the grain that may otherwise support rodents (Dolbeer 1990).

An examination of the literature shows that a variety of techniques and substances have been employed in order to deter, capture and/or cull birds from situations in which they are perceived as a pest. The object is to reduce damage by either reducing the population of pest birds or by manipulating the feeding, roosting or loafing habitat so that the area is no longer attractive. Where problems with abundant birds are experienced, the destruction of the offending birds is often a popular option. However, efforts to reduce existing bird populations are not effective in the long term (Flegg 1980, Woronecki *et al.* 1989) and are often cost ineffective when compared to potential or real benefits (Dolbeer 1981, Weatherhead 1982). As a result, some programmes to control bird damage are uneconomic (Dyer and Ward 1977). Most workers conclude that no single method is effective in controlling the damage done by birds and that the best approach is a combination of non destructive techniques supplemented by destructive techniques where suitable (Rappole *et al.* 1989, Tipton 1989a, Dolbeer 1990). All successful methods rely on a thorough knowledge of the ecology of the pest bird such that control measures can be implemented in the most appropriate way.

A review of the techniques used to control pest birds is presented in Appendix 1 (page ~~101~~). 125

1.1. Little Corellas as pests in the Flinders Ranges

Flocks of Little Corellas (*Cacatua sanguinea*) are considered a pest in the Flinders Ranges, south of Hawker, during the summer months when they congregate in large, noisy roosts in creeklines and around townships. Little Corellas defoliate their roost trees and damage tree canopies to the extent that tree health and longevity may be affected. Little Corellas are also reported as pests on germinating grain in newly sown paddocks and they attack installations such as silos, temporary grain bunkers and field bins. The problems associated with large summer flocks of Little Corellas emerged in the early 1950's ("flock of thousands.... causing severe damage to the giant gums" Quorn *Mercury* 6 March 1952). Problems continued sporadically through the 1960's and are now an annual concern. The control of these birds is considered desirable by the local communities, especially with regards to the damage caused to roost trees in summer. Several communities have taken advantage of the unprotected status of the Little Corellas (National Parks and Wildlife Act 1972) and undertaken shooting exercises to destroy birds - without much success. Control programmes based on a knowledge of the ecology of the bird and which could be implemented by the local communities were needed.

Aspects of the biology and ecology of the Little Corella in the Ord River area of Western Australia have been described by Beeton (1977, 1985) but no ecological work on the species has been conducted in South Australia. The biology and ecology of other members of this genus and the related genus *Eolophus* have been described for the southern part of the continent. Rowley (1983a, 1990) studied Galahs (*Eolophus roseicapillus*) and Saunders (1977), GT Smith (1991) and Smith and Moore (1991, 1992) studied the Western Long-billed Corella (*Cacatua pastinator*) in Western Australia. Emison and Beardsell (1985) and Temby and Emison (1986) described the distribution, abundance and diet of the Long-billed Corellas (*Cacatua tenuirostris*) in South Australia and Victoria. Noske (1980) studied the behavioural ecology of Sulphur-crested Cockatoos (*Cacatua galerita*) in New South Wales.

This study of Little Corellas was undertaken between January 1988 and March 1991 and focussed on the summer flocks of Little Corellas that damaged River Redgums (*Eucalyptus camaldulensis*) in the southern Flinders Ranges. The aims of the study were:

1. **To gain a better understanding of the ecology of Little Corellas in the Flinders Ranges, especially population structure and daily and seasonal patterns of movement;**

2. **To assess the relative importance of the pruning impact of Little Corellas on roost trees in relation to other environmental influences such as water stress and salt stress;**

3. **To develop techniques for monitoring condition of roost trees and Little Corella flocks in the future; and**

4. **To formulate and test appropriate management techniques to reduce bird damage to roost trees.**

The summer flocks were those considered to be most destructive in terms of roost tree damage and therefore the study focussed on the ecology of these flocks.

The study area extended from Crystal Brook to Gladstone and Jamestown in the south to Balcanoona in the north. This area was divided into two sections based on current land use: a northern section, north of Hawker where the principal land use is pastoralism based on grazing of native chenopod shrubs; and a southern section, south of Hawker, where land use is mostly agricultural, that is a mixture of cereal cropping and sheep grazing (Figure 1.1). Most reports of damage to River Redgums came from the southern area.

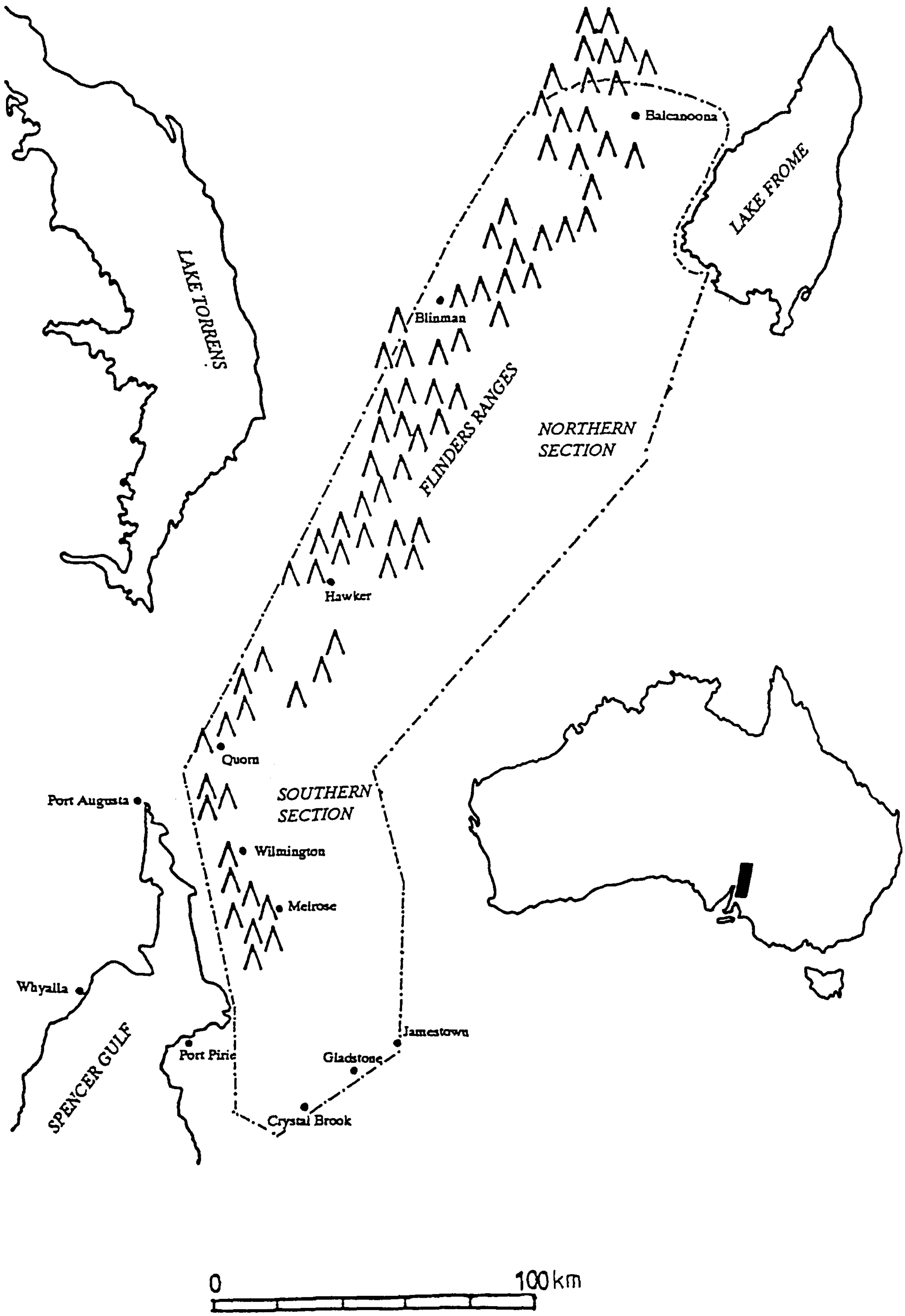

Figure 1.1

The study area extended from Crystal Brook to Gladstone and Jamestown in the south to Balcanoona in the north and was divided into two sections based on current land use. Land use in the southern section was predominantly agricultural and in the north pastoral.

CHAPTER 2

SEASONAL DISTRIBUTION AND ABUNDANCE OF THE LITTLE CORELLA IN THE FLINDERS RANGES.

2.1. INTRODUCTION

2.1.1. Historical distribution and abundance of the Little Corella in South Australia

The distribution of the Little Corella prior to European settlement is largely unknown and can only be inferred from the records of early explorers and pastoralists. In South Australia, early records suggest that until 1920 Little Corellas were largely restricted to the far north east of the State. Within this area, they were confined to the large watercourses e.g. Strzelecki and Cooper Creeks where they were locally and seasonally abundant (S. Parker pers. comm.[1]). In the period 1921 to the present, Little Corellas slowly extended their range southwards. The first records of Little Corellas in the southern Flinders Ranges did not appear until the 1950s ("flock of thousands" Quorn *Mercury* 6 March 1952). Little Corellas were recorded in the districts south of Adelaide in the period 1950-1954 (S. Parker pers. comm.). The first reports of Little Corellas along the Murray River date from the 1920s (S. Parker, pers. comm.) but they did not become established there until 1951-52 (Boehm 1960). Little Corellas were first reported on Kangaroo Island in 1955 (A. Lashmar pers. comm.[2]).

The provision of permanent watering points to service stock probably provided the means by which water dependent birds such as corellas and Galahs (MacMillen 1990) could extend their range (McGilp 1937, Davies 1977, Saunders *et al.* 1985).
Associated with this range extension was the drought mediated dispersal observed in this and other species during the drought of 1950-1951 (Glover 1952).

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[1]Mr S. Parker, Curator of Birds, South Australian Museum
[2]Mr A.F.C. Lashmar, Penneshaw, Kangaroo Island

In addition to an extension of range during this century, Little Corellas appear to have increased in abundance. Whilst the provision of permanent water assisted range extension in Little Corellas, increased abundance was probably facilitated by the widespread provision of suitable foods such as wheat, oats and barley. Broadscale clearing of native vegetation and replacement with pasture for sheep and cereal crops began soon after European settlement in 1836 (Harris *et al.* 1976). Due to their proximity to Adelaide, the Mount Lofty Ranges, Fleurieu Peninsula and Mid and Upper North districts had been cleared of vegetation by the end of the nineteenth century. The Murray Mallee followed in the period after the first world war and extensive areas were cleared in the remainder of the State (South East, Kangaroo Island and Eyre Peninsula) after the second world war (Harris *et al.* 1976). By the 1920s, Little Corellas had already extended their range into the grain growing areas of the Mid North and by the 1950s were poised to take advantage of the food resource supplied as cereals. Reports of Little Corellas from the Strathalbyn district south of Adelaide mention low numbers in the early 1950's followed by a gradual increase to the present time when flocks of more than 1000 Little Corellas are a regular occurrence (J. Eckert cited in S. Parker pers. comm.). Similarly Little Corellas have increased in abundance on Kangaroo Island and a resident flock of about 500 birds is now present (T. Dennis pers. comm.[3]).

Range extension and increased abundance have been reported in this species elsewhere (Jarman 1979) and in other parrot species e.g. Galahs (Rowley 1990) and Sulphur-crested Cockatoos (Saunders *et al.* 1985). Whilst abundance in these species has increased, other cockatoos like Carnaby's Cockatoo (*Calyptorhynchus funereus latirostris*) and Major Mitchell's Cockatoo (*Cacatua leadbeateri*) have declined in abundance due to a loss of native food resources following the clearing of native vegetation for agriculture (Saunders 1990, Saunders *et al.* 1985, Rowley and Chapman 1991). Little Corellas are now widely

[3]Mr T.E. Dennis, Senior Wildlife Ranger, South Australian National Parks and Wildlife Service, Kangaroo Island

distributed over the central and eastern parts of South Australia (Blakers *et al.* 1984; Figure 2.1).

2.1.2. Current distribution and abundance of the Little Corella in the Flinders Ranges

The problems associated with Little Corellas in the Flinders Ranges relate to the invasion of southern areas by large numbers of birds during the summer.

In documenting the distribution and abundance of Little Corellas in the Flinders Ranges, this study examined the following questions:

1. **How many Little Corellas are present in the southern Flinders Ranges during summer?**

2. **Does the distribution and abundance of Little Corellas vary seasonally?**

3. **If so, what are the patterns of their movements?**

4. **What is the origin of birds participating in the summer influx?**

5. **Of the birds participating in the summer influx, do the same individuals return in successive years?**

Native birds that are considered pests are often those that have adapted to exploit introduced plants and the availability of high quality food resources can affect the behaviour of a pest species; for example, reproductive success, survival rate and movements to areas of known abundance (Wiens 1990). Little Corellas were a problem in the sorghum growing areas of the Ord River and Long-billed Corellas are a pest of sunflower and winter cereals in Victoria and South Australia (Beeton 1977, Temby and Emison 1986, P. Alexander pers. comm.[4]).

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[4]Mr P.J. Alexander, Scientific Officer, Habitat and Wildlife Management, Department of Environment and Natural Resources, South Australia

Figure 2.1 Present day distribution (approximate) of the Little Corella in South Australia (information from Emison and Beardsell, 1985; Badman, 1987; Robinson *et al.*, 1988; unpublished data from South Australian Ornithological Association and Biological Conservation Branch, Department of Environment and Natural Resources, South Australia. Inset: Distribution of the Little Corella in Australia (after Blakers *et al.* 1984).

Therefore this study asked;

6. Does diet influence the pattern of seasonal distribution and abundance?

Complaints about Little Corellas usually refer to the birds destructive behaviour at the roost and emphasis was also given to the following questions;

7. Where do Little Corellas congregate?

8. Are Little Corellas faithful to a particular roost site over successive years?

9. Are Little Corellas faithful to a particular roost site within one summer?

2.2. METHODS

2.2.1. Distribution and abundance in the study area

Information about the distribution and abundance of Little Corellas in the study area was collected in two ways: (1) by aerial and ground surveys of both sections of the study area to locate major roosts and to estimate their size; and (2) by estimates of flock sizes taken throughout the study area and throughout the period of the study.

Two aerial surveys of the study area were conducted to determine the distribution of Little Corellas during the summer months. Financial constraints prevented additional aerial surveys during winter. In February 1989 and February 1990, a fixed wing aircraft containing two observers was flown low (*ca* 500 ft) along the major creeklines of the Flinders Ranges (Figure 2.2). All flights were conducted between 0700h and 0900h and all Little Corellas observed during the flights were recorded and mapped onto 1:250,000 topographical maps. No aerial survey was conducted in February 1991 and major roosts were located on the basis of information collected in the previous two years and from

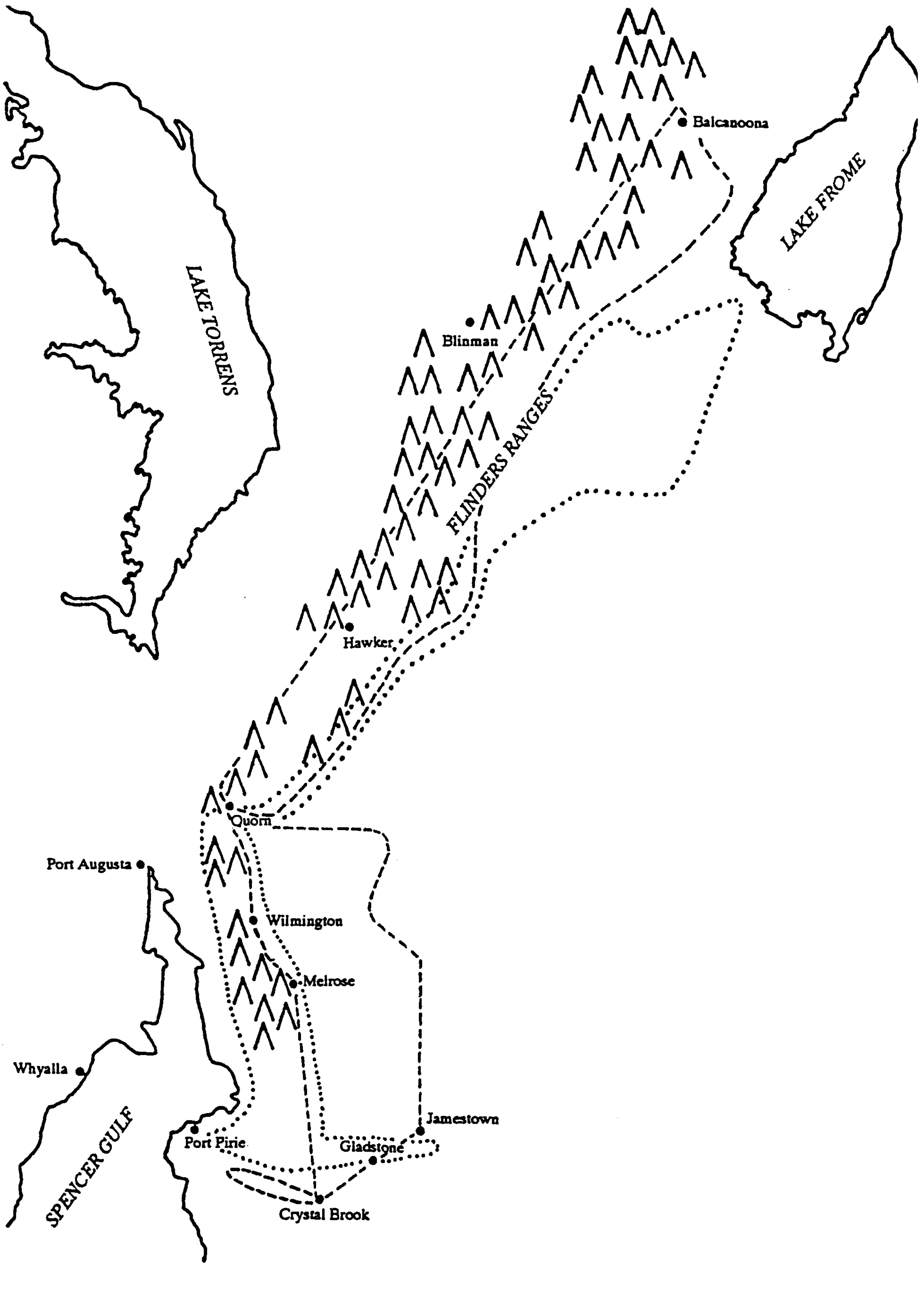


Figure 2.2

Map of flight lines for aerial surveys of Little Corellas in both sections of the study area conducted on 22 and 23 February 1989 (---) and 21 and 22 February 1990 (·····).

information from local landholders. A supplementary ground search for Little Corellas was made in the area north of Quorn and east of the ranges in January 1991.

Major roosts that were located during the aerial survey were subsequently visited by vehicle. Estimates of the size of major roosts were made as close as possible to the date of the aerial survey. Little Corellas began congregating in roost trees after the last feeding session of the day (2.5-3.0h before last light) and had left the night roost within 1.5h after dawn. Roost size was estimated by counting the number of Little Corellas arriving at the night roost after the last feeding session. Estimates from different roosts were combined to estimate the total population of Little Corellas in the study area in the summer months of 1989, 1990 and 1991.

In addition to the above counts, the sizes of most Little Corella flocks encountered during the course of the study were recorded along with the location, time and date. Where possible, counts of birds on the wing were made in preference to counts of birds on the ground as the former were found to be more accurate.

2.2.2. Movements

Observations of individual Little Corellas bearing coloured wing tags were used to determine short term movements of birds and movements between summer and winter sites. Little Corellas were captured at Richmans Valley, 10 km south of Quorn in February 1988, at Melrose in April 1988 and again at Richmans Valley in February 1989 (Figure 2.3). Little Corellas were captured using alphachloralose, a hypnotic drug, which was administered (1.5 g/l) to the stock trough where the birds were observed to drink (see section 5.2 for full details). Comatose and semi-comatose birds were picked up and confined in individual cages before wing (patagial) tagging and banding. Following tagging and banding, all birds were confined for periods of between 5-12 hours prior to release. All birds were tagged with either a blue or a red aluminium disc (3cm diam.) attached to the left or right wing using annealed stainless steel wire (after Parry 1967,

Figure 2.3

Locations of banding and tagging operations conducted in the southern section of the study area in 1988 (blue dots) and 1989 (red dots).

Rowley and Saunders 1980). Most birds were also banded with stainless steel leg bands provided by the Australian Bird and Bat Banding Scheme.

The short term movements of Little Corellas were investigated in 1989 by making daily searches for red tagged birds at all known roost sites within a 50 km radius of the tagging station in the days immediately following tagging. Movements of Little Corellas between summer and winter sites were inferred from observations of blue tagged birds made during regular and systematic searches in both the northern and southern sections of the study area in 1988, and from tag returns from the public.

2.2.3. Diet

Crop samples were collected from Little Corellas on a monthly basis from four sites in the northern section of the study area and from four sites in the southern section (Figure 2.4). In the north, crop samples were collected during the period April 1990 to March 1991 and in the south, during the period January 1990 to December 1990. Crop contents were collected from Little Corellas shot during or following the afternoon feeding session. The crop was slit open and the contents of the crop and the proventriculus were transferred to plastic sample bottles. The majority of samples were stored frozen until examined.

2.2.3.1. Analysis of crop samples

Crop samples were thawed, rinsed with water, blotted and examined under a dissecting microscope. Samples of each seed type were taken and stored both dry and in 70% ethanol. Crop samples were oven dried (45^{o}C, 48 hours) and weighed.

2.2.3.2. Identification of seeds

Most seeds were identified by comparison to a reference collection of seeds obtained from plants seeding at the time the birds were collected. Remaining seeds were identified by the

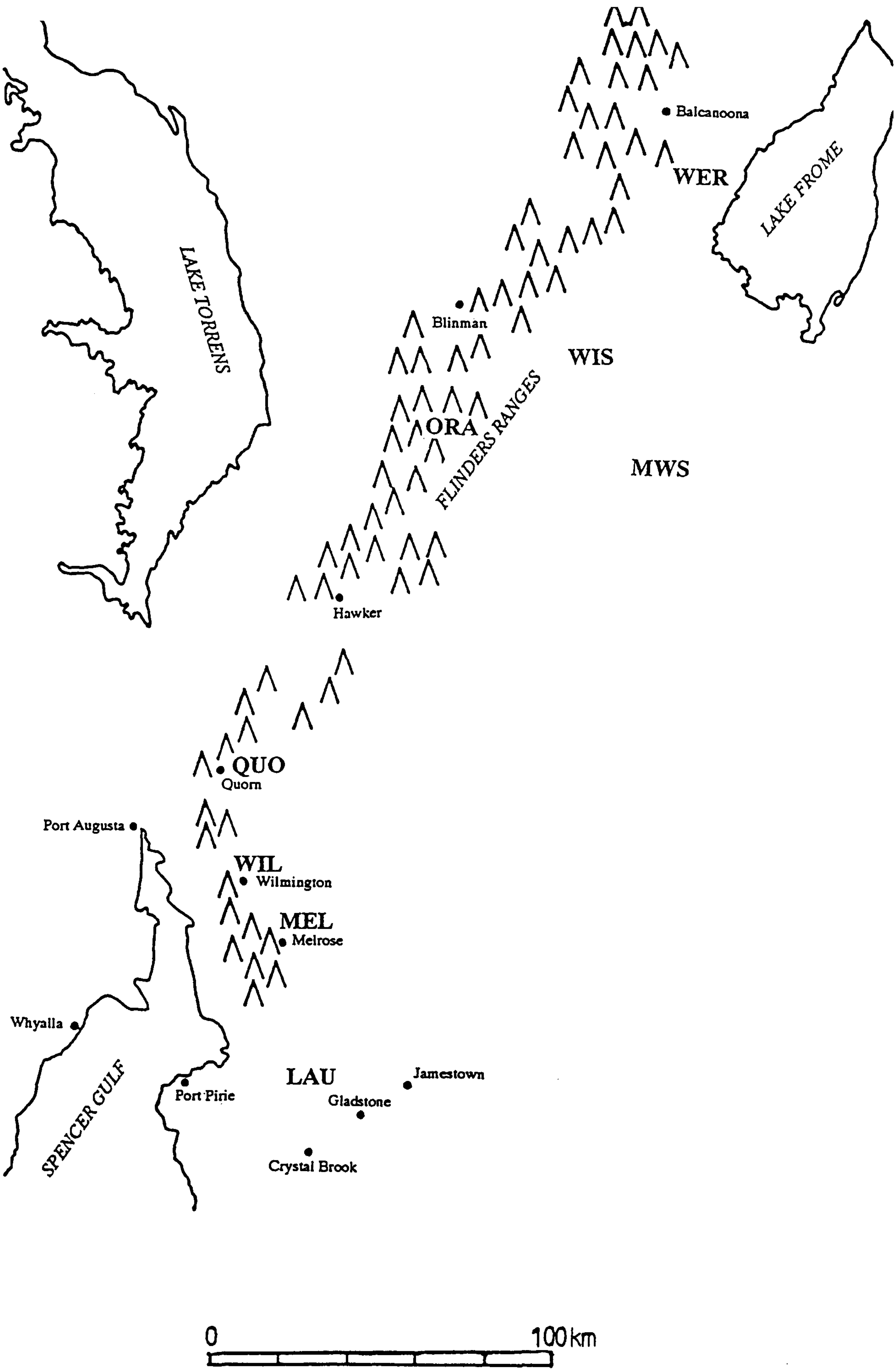


Figure 2.4

Locations where crop samples from Little Corellas were collected. Southern section; **QUO** Quorn, **WIL** Wilmington, **MEL** Melrose and **LAU** Laura. Northern section; **MWS** Martins Well Station, **WIS** Wirrealpa Station, **ORA** Oraparinna section, Flinders Ranges National Park, **WER** Wertaloona Station.

South Australian Department of Primary Industries[5]. Identification of seeds was difficult when the seed was immature, had been dehusked by the bird, or was broken during ingestion. Where possible, a subsample of mature specimens of unidentified seeds were taken fresh from the crop, dried (35°C, 3-4 days) and stored at room temperature. Several unsuccessful attempts were made to germinate these seeds and grow the plants to a stage where they might be identified.

2.2.3.3. Relative abundance of food items.

Each seed type in each crop was assigned to one of three abundance categories based on a visual assessment of its prominence where category 1 = seed type occupied <30% of the sample volume, category 2 = 31-70% of the sample volume and category 3 = >70% of the sample volume. The types of seed and the number of seed types (seed profile) contained in small (0-10g), medium (11-20g) and large (>20g) crop samples were similar. All crop samples contained approximately 2 types of seed per crop sample (small; mean 1.95, s.e. 0.06, n=220: medium; mean 2.07, s.e. 0.11, n=56: large; mean 1.70, s.e. 0.26, n=10) and all seed types found in the large and medium sized crop samples were found in the small crop samples with the exception of one seed type, a Gramineae. As seed profile was independent of the size of the crop sample, all abundance values were calculated as a proportion of the sample rather than as a proportion of the possible crop volume. Abundance values for each month were summed and divided by the total number of samples collected. Thus a value of 3 is the maximum score possible for a seed type and implies that all birds had >70% of that seed type (by volume) in their crops.

Food items were also classified into items of major and minor importance. Major food items were those with an average monthly abundance greater than or equal to 0.5 in at least one month. Minor food items were those with an average monthly abundance always less

[5]Ms. H. Lawrie, Senior Seeds Analyst, Seed Services, South Australian Department of Primary Industries, Northfield and Mr T. Reynolds, Scientific Officer, Animal and Plant Control Commission, South Austalian Department of Primary Industries, Netley.

than 0.5. A seed type was classified as occurring commonly if it was present in more than 20% of samples collected in any one month.

2.2.4. Roost use

Patterns of roost use were investigated in 1990 and two approaches were taken. First, the use made of one particular roost (Pichi Richi Creek roost) was studied by making regular counts at intervals of 1-25 days (most < 7 days) of the number of Little Corellas using that roost. Estimates were made by counting the number of Little Corellas flying into the roost in the period 2.5-3h before last light. Counts began when the roost was first established and continued until roosts were abandoned in the following autumn. The duration of the Pichi Richi roost was also assessed in each year of the study. Roost life was measured by counting the number of days between the date when Little Corellas first began investigating roost sites (usually the first week in November) until the date when less than 100 birds were observed roosting.

Second, fidelity to roost site was examined by following changes in roost size at several roost sites situated within a defined area. Since the size of several roosts had to be estimated in one counting session, estimates were made by counting the number of Little Corellas in one roost tree and extrapolating this number to all occupied trees in the roost. This count was usually made 0.5-0.8h before last light.

2.3. RESULTS

2.3.1. Distribution and abundance

2.3.1.1. Seasonal distribution and abundance

Both aerial surveys of the study area showed that Little Corella numbers in the northern section of the study area were low in the summer months. Although no Little Corellas were observed in this section during the aerial survey, Galahs were frequently observed indicating that if Little Corellas had been present they would have been detected. The aerial surveys located several large Little Corella roosts in the southern section of the study area in February of 1989 and 1990. Subsequent ground surveys showed that Little Corellas were present in both sections of the study area in all seasons. Ground surveys also showed that the size of Little Corella flocks varied according to location and time of year. In the northern section of the study area, most flocks encountered were small (usually less than 100 birds) and birds were most common in the winter months (Figure 2.5). In the southern section of the study area, large flocks (>1,000 birds) were commonly encountered during the summer (Figure 2.6). Flock sizes in the winter and spring were comparatively small.

2.3.1.2. Summer distribution and abundance

In the southern section of the study area, Little Corellas were detected at a total of 17 roost sites (Table 2.1). Estimates of roost size at each known roost site showed that 30,000-50,000 Little Corellas used the southern section in each of the three summers (Table 2.1). This figure is derived from roost counts made as close as possible to the aerial surveys and as such, is an approximation of the size of the total population. The number of birds returning to the southern study area varied between years. The highest bird numbers were recorded in 1989 (*ca* 53,000, Table 2.1). Roost size at each location also varied with some sites supporting large Little Corella roosts (>4,500 birds) in all three years (e.g. Pichi Richi Creek, Quorn and Capowie Creek, Richmans Valley) whilst other locations did not (e.g. Mt Remarkable Creek, Melrose; Table 2.1). Some roost sites were used in one year and abandoned in others (e.g. Stoney Creek, Quorn and Stony Creek, Wilmington; Table 2.1).

2.3.2. Seasonal movements.

A total of 1336 Little Corellas were marked with coloured wing tags and 921 birds were also banded with stainless steel leg bands (Table 2.2). Blue tags were attached to the left wings of all birds captured at Richmans Valley in 1988 and to the left wings of most birds captured at Melrose in the same year. Blue tags were attached to the right wings of the remaining birds captured at Melrose in 1988 (Table 2.2). In 1989, red tags were attached to the left wings of all Little Corellas captured at Richmans Valley (Table 2.2).

Figure 2.5 Seasonal patterns to the number and size of Little Corella flocks in the northern Flinders Ranges (pooled data from all years). Sample sizes are shown below the relevant month.

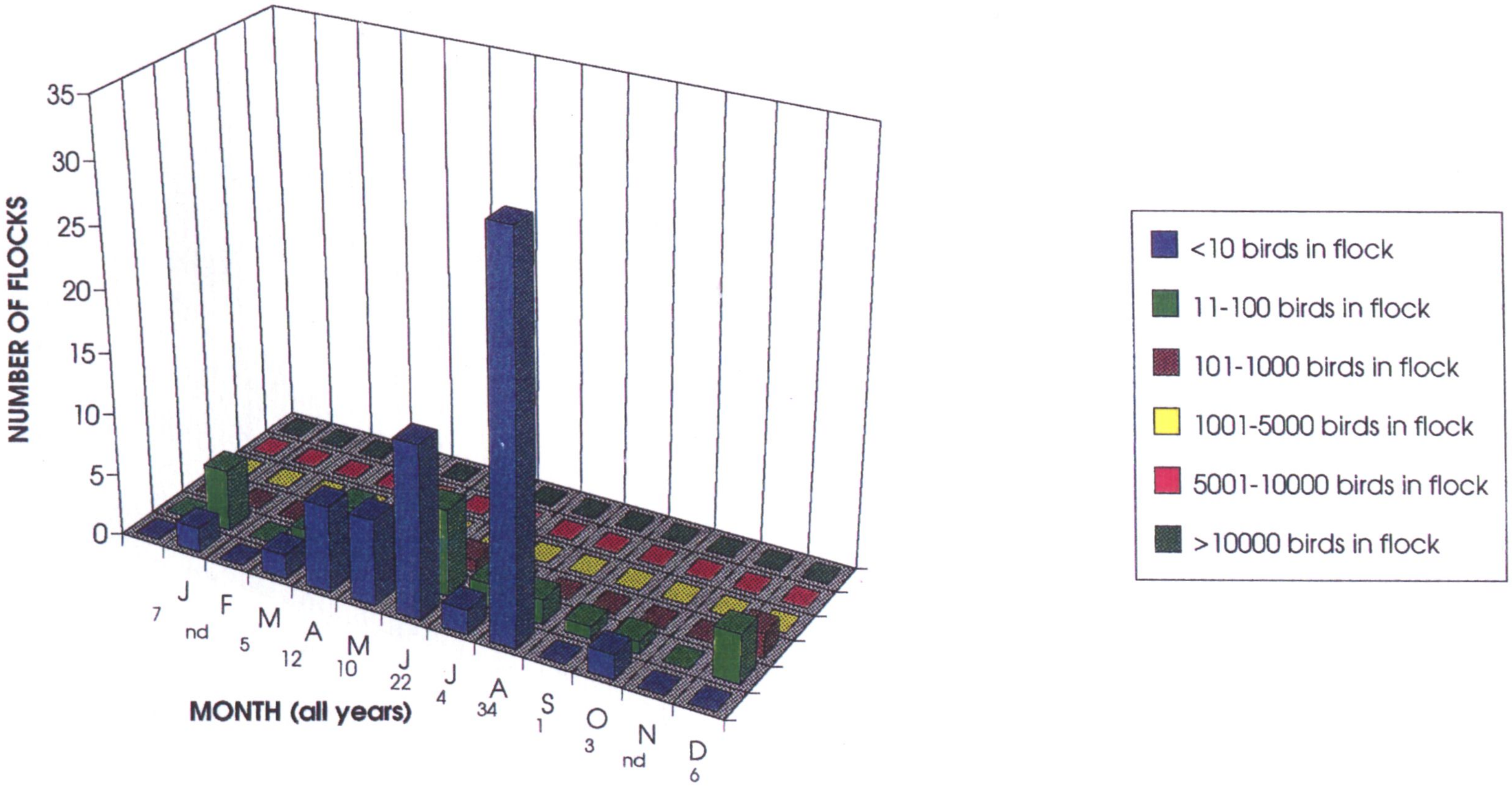


Figure 2.6 Seasonal patterns to the number and size of Little Corella flocks in the southern Flinders Ranges (pooled data from all years). Sample sizes are shown below the relevant month.

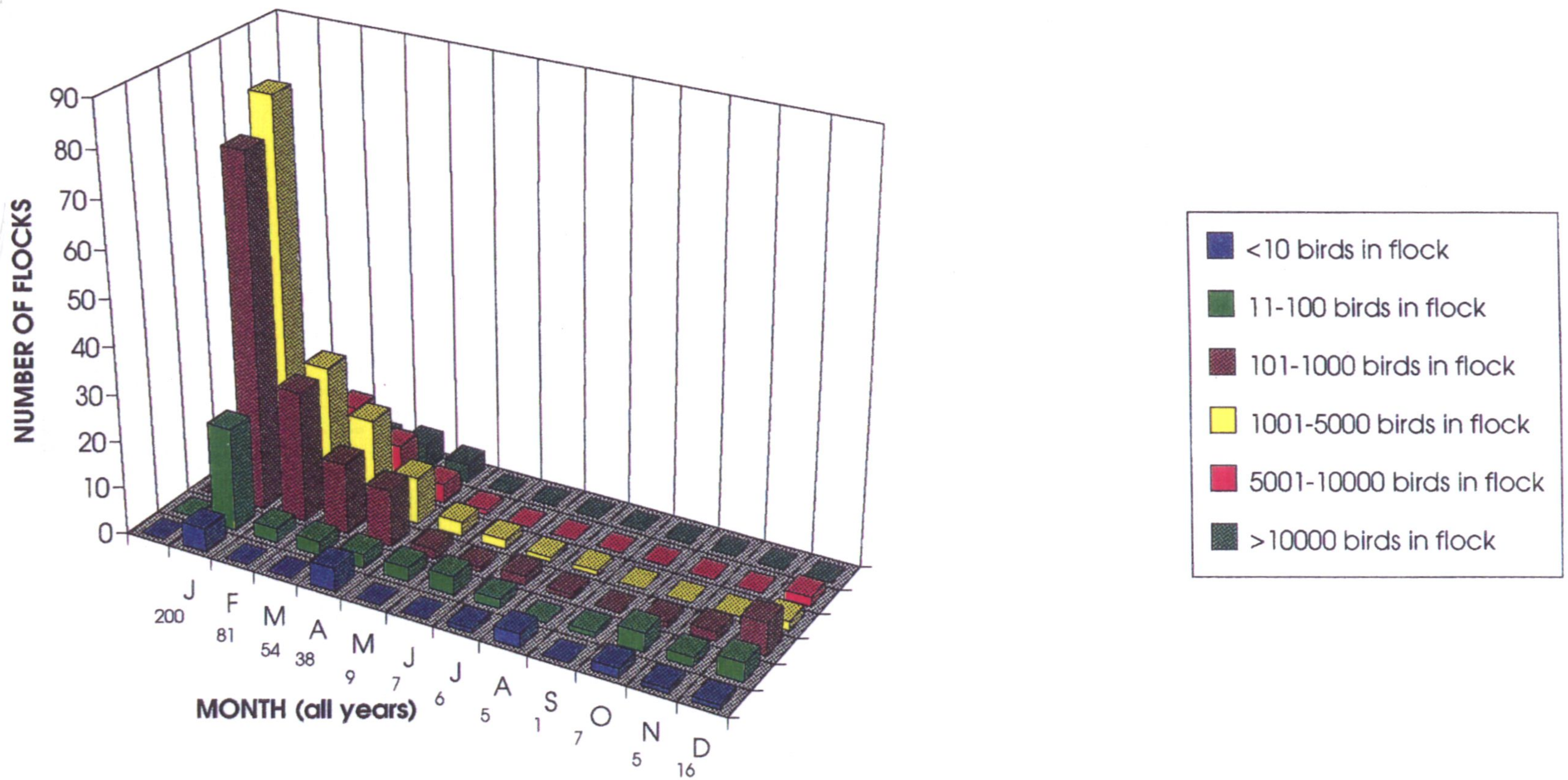


Table 2.1

Estimates of the size of the Little Corella population in the southern section of the study area in the summer months of 1989-1991. Estimates were derived from roost counts made in February of each year (as close as possible to the aerial survey) at each known roost. In cases where roosts could not be visited within the month of February, the count nearest to that time was used in compiling this table.

Roost location	**Number of Little Corellas counted**		
	1989	**1990**	**1991**
Quorn			
Stoney Ck	8,000	0*	0*
Pinkerton Ck	200	300J	0*
Pichi Richi Ck	6,000	8,145	10,910
Arden Vale	0*	nd	1,000
Richmans Valley			
Capowie Ck	5,200	10,485	5,200
Wilmington			
Spring Ck	3,000J	0*	0*
Stony Ck	0*	0*	4,050
Hawks Nest Ck	0*	0*	0*
Melrose			
Mt Remarkable Ck	8,000	2,058	4,200
Bangor	5,000	nd	4,000
Wirrabarra	4,500	3,195	400J
Wandearah			
Broughton Rv	7,500	0*	0*
Jamestown			
Sewerage ponds	1,500M	1,300M	850
Crystal Brook	0*	1,710M	1,700
Gladstone	nd	3,000M	0*
Baroota	4,500	0*	2,236
Nelshaby	nd	850J	4,300
TOTAL	**53,400**	**31,043**	**38,846**

0* no corellas were observed at that roost site during February.
nd denotes that no data were collected for that roost site.
J,M denotes roost counts made in months other than February(J= late January, M= early March).

Table 2.2

The number of Little Corellas banded and tagged at various locations in 1988 and 1989. All but 415 of the wing tagged birds also received leg bands.

		Location and date		
Tag colour	Wing	Richmans Valley 15-25 Feb 1988	Melrose 5-14 April 1988	Richmans Valley 31 Jan - 9 Feb 1989
Blue	Left	464	237	
Blue	Right		121	
Red	Left			514

Little Corellas appeared to develop a taste aversion to the drug as seen in the declining catch rate over successive days of drug exposure (Table 2.3). However, 53 individual birds were recaptured within days of their first exposure to the drug (42 in 1988, 11 in 1989) and one bird was captured on three occasions without any apparent ill effects (see Badman 1989). The use of alphachloralose for capture resulted in the deaths of some Little Corellas. Mortality rates were initially high (>5%) but declined once handling and processing techniques were improved, in particular more frequent pick up and longer confinement prior to banding and tagging (Table 2.4).

Table 2.3

Decline in daily catch rate of Little Corellas at two sites in 1988. Little Corellas were exposed to the drug, alphachloralose (1.5g/l administered in the stock trough) on two three-day occasions in both cases. Results for each day were combined and expressed as a percentage of the number caught on day 1 (205 at Richmans Valley, 147 at Melrose). Results for 1989 are not presented because birds were not permitted access to the drug on consecutive days.

Day	Richmans Valley	Melrose
1	100 %	100 %
2	61.5%	72.8%
3	40.5%	14.3%

Table 2.4

Mortality rate amongst Little Corellas captured using alphachloralose (1.5g/l administered in the stock trough).

Date	Location	No. captured	Mortality (%)
15-25 Feb 88	Richmans Valley	506	5.9%
5-14 April 88	Melrose	367	5.7%
31 Jan - 9 Feb 89	Richmans Valley	531	2.3%

2.3.2.1. Short term movements

1988 Blue tagged birds

In February 1988, Little Corellas tagged at Richmans Valley were observed both in the immediate area (i.e. the roost) and some 15km north of the banding station in the period immediately following capture. Birds tagged in February were also observed at

Wilmington (approximately 30km south) in April following rain in the intervening March. Tagged birds originating from Richmans Valley were also captured during tagging/banding operations at Melrose (approx. 50 km south of Richmans Valley banding station) in April.

1989 Red tagged birds

Red tagged birds were observed to radiate progressively from the banding/tagging station in Richmans Valley to Quorn, 10 km north, within three days of tagging and release (Figure 2.7). Within three weeks, two red tagged birds were observed roosting at Melrose approximately 50 km south.

2.3.2.2. Movements between summer and winter sites

During winter and spring 1988, blue tagged birds were observed at four locations in the study area. The precise origin of blue tagged birds could not be determined because tags were affixed to birds captured at both Richmans Valley and Melrose in that year. Three of these locations were situated in the southern section of the study area (Melrose, Laura and Pt Pirie, a total of 6 tags). Tag returns were also received from two locations in the southern study area (near Port Pirie, 6 tags; Laura, 4 tags). The fourth observation was of two tagged birds east of Blinman in the northern section of the study area during August 1988 (>150 km north of the northern banding station at Richmans Valley). No tag returns were received from the northern section of the study area during 1988. Despite the continued presence of a small number of Little Corellas in the Quorn area during winter and spring of 1988, no tagged birds were observed there during this time. The locations of all sightings of blue tagged Little Corellas during 1988 are shown in Figure 2.8.

Following the extensive autumn rains in March 1989, Little Corellas with blue tags were again observed in both the southern and northern (Price Creek, >80km north-east of banding station) sections of the study area. The locations of all sightings of blue tagged Little Corellas during 1989 are shown in Figure 2.9.

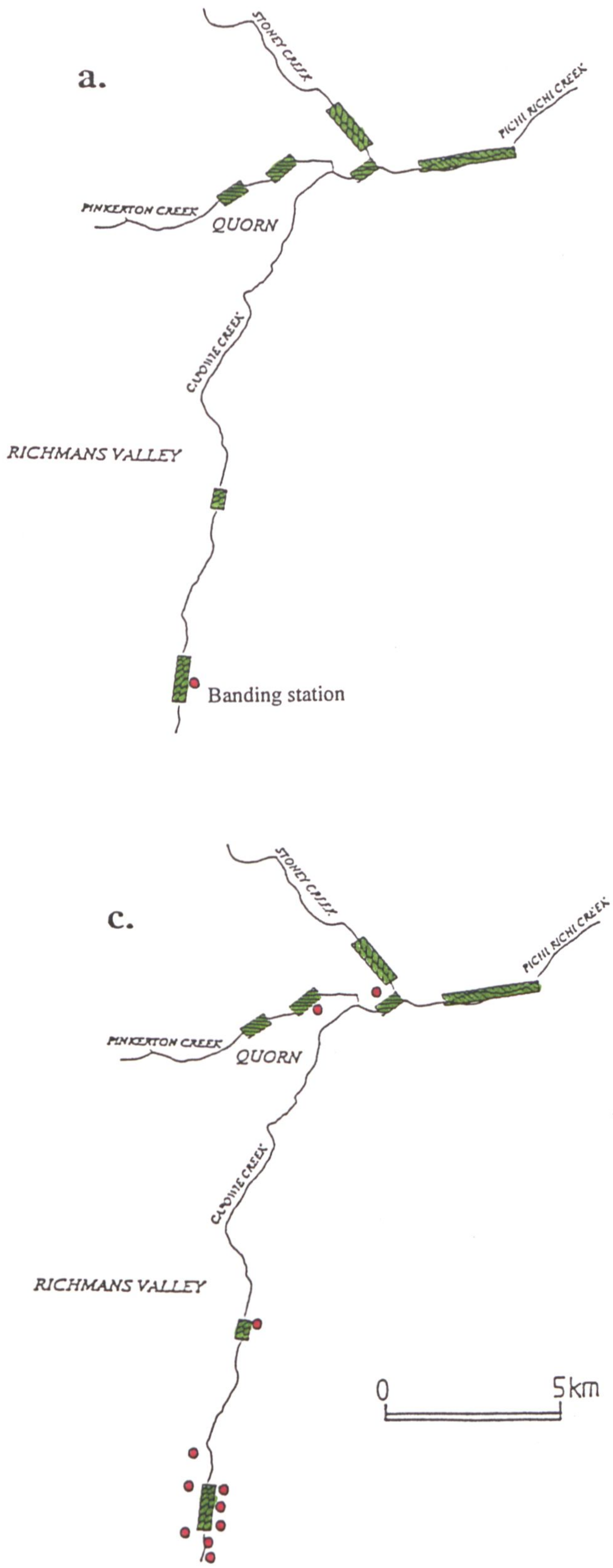


Figure 2.7

Location of all sightings of red tagged Little Corellas over successive days in February 1989 **a.** 3 February, **b.** 4 February and **c.** 5 February. [hatched symbol] denotes known roost areas and red dots indicate sightings of red tagged Little Corellas.

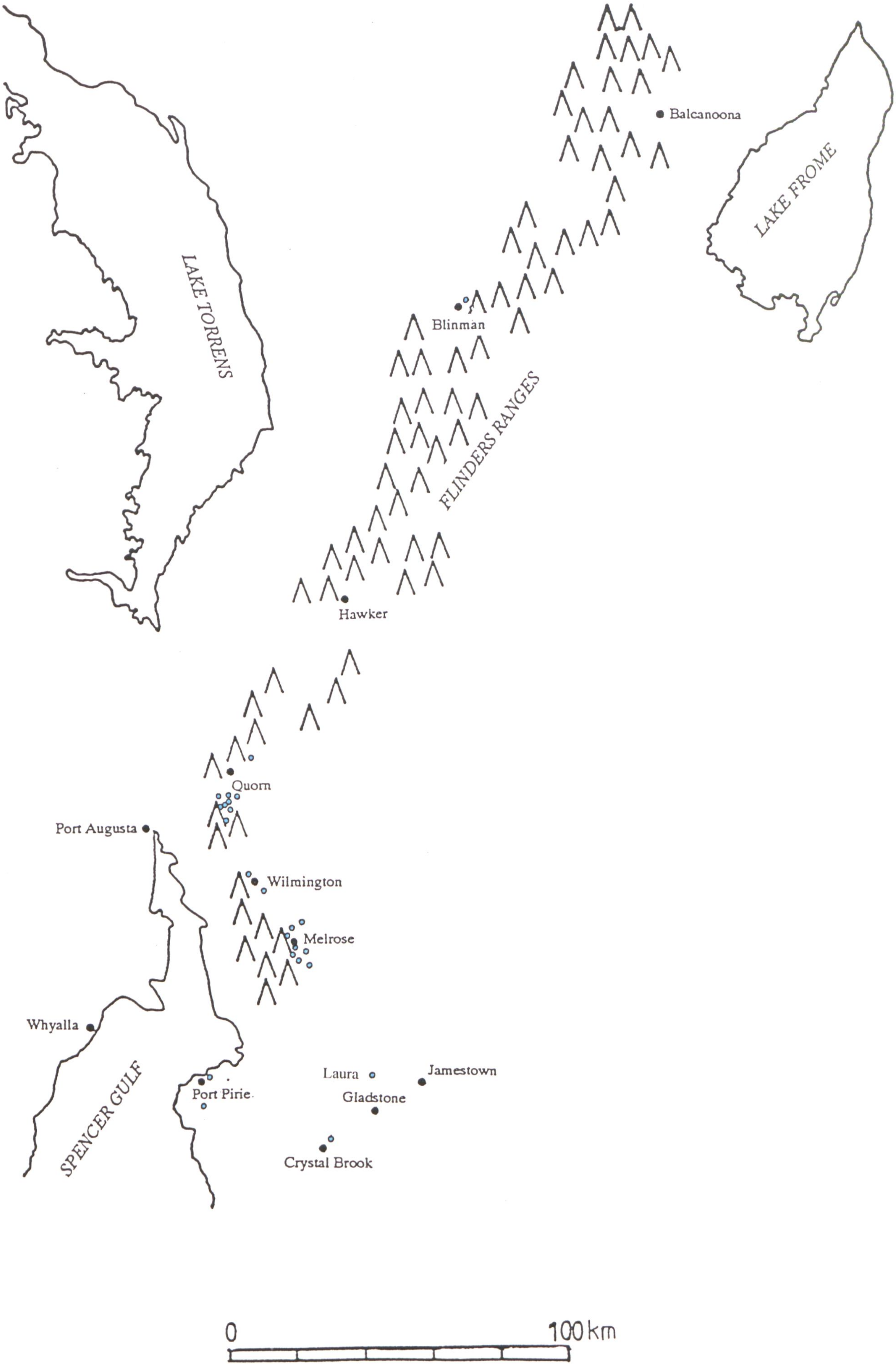


Figure 2.8

Distribution of observations of blue tagged Little Corellas in 1988.

Figure 2.9

Distribution of observations of blue tagged Little Corellas in 1989.

Although Little Corellas occur further south, no observations of tagged birds were made further south and no tag returns were received from areas south of the study area during the period of the study.

2.3.2.3. Returns to summer roost sites in subsequent years

In the summer of 1989, a total of 47 blue tagged birds (i.e. those tagged in February and April 1988) were observed at Quorn, particularly around the roost where 464 had been captured and tagged the previous year (29 tag observations-although this may reflect observer bias; Figure 2.9). The remaining 18 observations were recorded at other locations in the southern section of the study area (Melrose, Wandearah, Baroota and Jamestown). Birds known to have been tagged at Melrose in April 1988 (tagged on the right wing) were observed around Quorn (10 tags) and at Melrose (2 tags) (Figure 2.9).

In the summer of 1990, both red and blue (left and right wing) tagged Little Corellas were again observed in the southern section of the study area and not in the north.

2.3.3. Diet

The crops of 333 Little Corellas were examined. Of these, 181 came from birds shot in the southern section of the study area in the period January 1990 to December 1990. The remainder (152) came from birds shot in the northern section in the period April 1990 to March 1991. A list of all items found in the crop samples is presented in Appendix 2 (page 109).

2.3.3.1. Northern section

In the periods April-June 1990 and January-March 1991, the most common and abundant seeds were those of *Citrullus* sp. and *Cucumis* sp. (Figure 2.10, Table 2.5). The number of food items taken by Little Corellas increased during the autumn and winter months, with birds taking up to 20 different seeds although only 12 of these were frequently used (Table 2.5). *Cucumis* and *Maireana* seeds were abundant in crop samples in early winter (Figure

2.10). *Rumex vesicarius* was the most important food item in the late winter and early spring and *Hypochoeris* sp was also abundant at this time (Figure 2.10). *Acacia* seeds were the most common and abundant seeds in all crops collected in late spring/early summer (Figure 2.10). Seeds of *Carthamus/Emex* were also present but were less abundant (Figure 2.10). The three remaining commonly occurring seed types were *Sclerolaena* sp, ?*Raphanus* and *Echium plantagineum* although none were abundant (Table 2.5).

Figure 2.10 Relative abundance of major seed types in the crops of Little Corellas collected in the northern Flinders Ranges (see text). Numbers above columns are sample sizes.

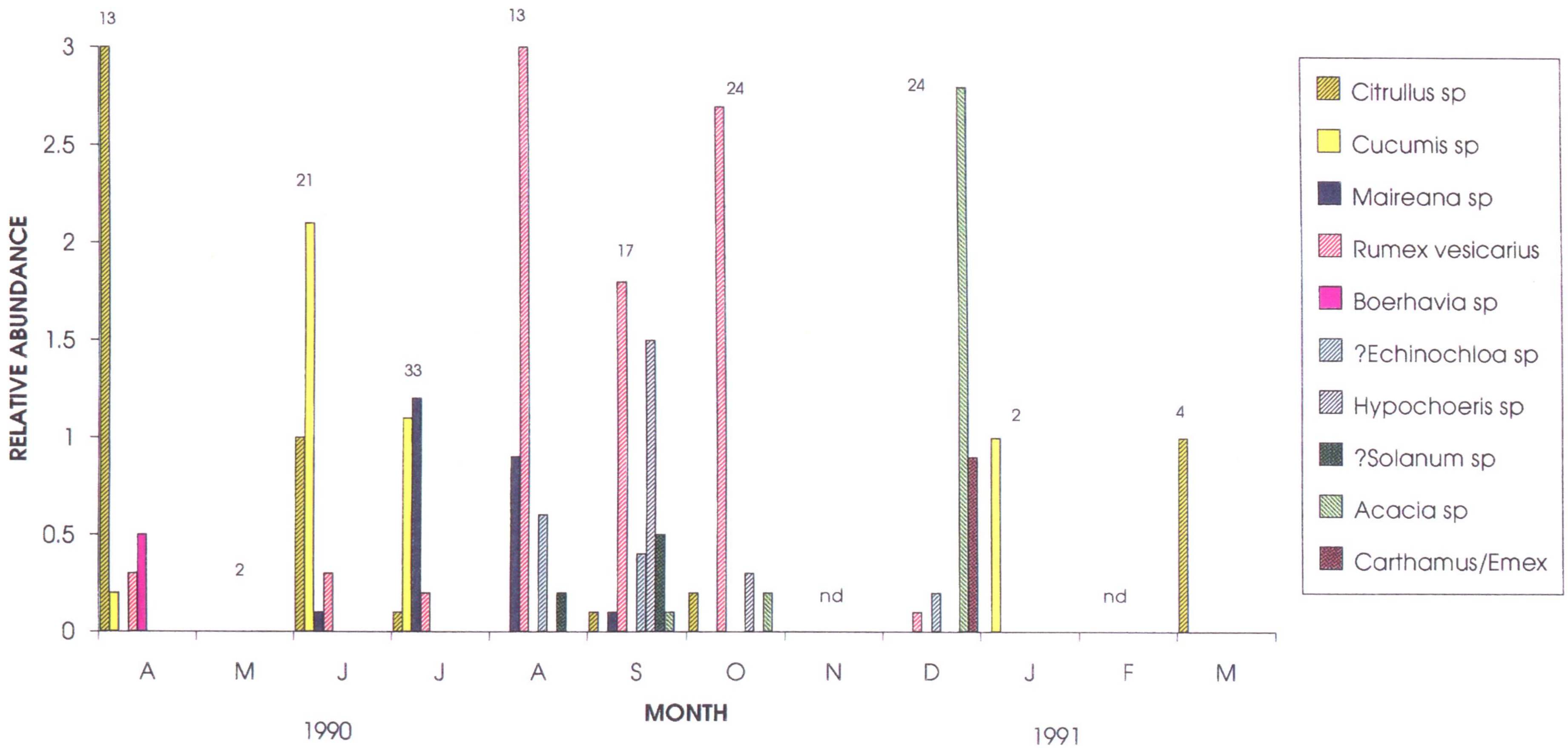


Table 2.5
Percentage incidence of different seeds in the crops of Little Corellas shot in the northern section of the study area in the period April 1990 to March 1991. No Little Corellas were shot in November 1990 and in February 1991. * denotes introduced plants. ? denotes that seeds could not be identified further (see Appendix 2, page 109).

	1990									1991		
	A	M	J	J	A	S	O	N	D	J	F	M
n	13	2	21	33	13	17	24	0	24	2	0	4
Citrullus sp	100		38	9		6	17					100
Boerhavia sp	46											
Maireana sp			15	85	92	12	4					
?*Raphanus*			29									
Sclerolaena sp	15		24									
*Echium plantagineum**		8		24								
Phalaris sp 2*	8											
*Rumex vesicaruius**	31		24	12	100	71	92		13			
Dactyloctenium radulans			5									
Medicago sp*				12			4					
Brassica tournefortii *				3								
?*Echinochloa*					62	35			21			
Hypochoeris sp*						53	17					
?*Solanum*					8	23						
Sonchus sp *				3		18						
Acacia sp						12	17		100			
Erodium sp*						6						
Cucurbitaceae ? sp						4						
?*Carthamus*/*Emex**									46			
Cucumis sp*	15		76	55						100		

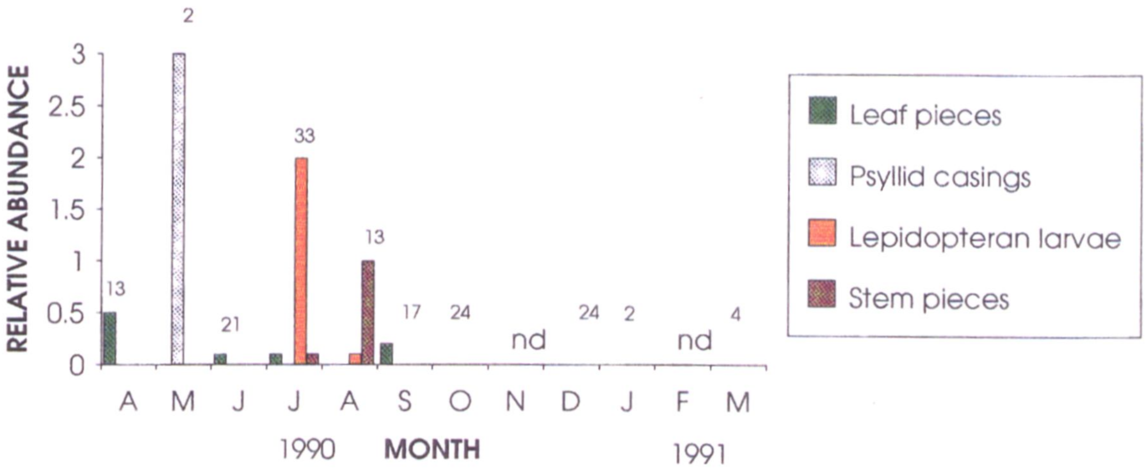
Psyllid casings comprised the entire crop contents of two Little Corellas collected in May 1990. Lepidopteran larvae were also important food items in early winter (Table 2.6, Figure 2.11). Pieces of stem and bark were also commonly detected although only the former was abundant (Figure 2.11). Pieces of leaf and gravel were often present although usually in small quantities (Table 2.6).

Table 2.6

Percentage incidence of different types of non seed material in the crops of Little Corellas shot in the northern section of the study area in the period April 1990 to March 1991. No Little Corellas were shot in November 1990 and in February 1991.

	1990								1991		
	A	M	J	J	A	S	O	N	D	J	F	M
n	13	2	21	33	13	17	24	0	24	2	0	4
Leaf pieces	46		10	6		18			4			
Gravel	38			3		6	17					
Psyllid casings		100										
Lepidopteran larvae				94	8				4			
Stem pieces			5	6		100						
Plant Flesh			5									
Compositae capitulae						6						
Bark pieces	8			3		18	25					
Acacia arils							12		17			

Figure 2.11 Relative abundance of non seed material in the crops of Little Corellas collected in the northern Flinders Ranges (see text). Numbers above columns are sample sizes.



2.3.3.2. Southern section

Wheat (*Triticum aestivum*) and *Carthamus/Emex* were the most common and abundant seeds in Little Corella crops collected from the southern Flinders Ranges (Figure 2.12, Table 2.7). In the summer months, crops consisted almost entirely of these two types of seed. Although diversity increased in the autumn and winter months with birds taking up to 11 different types of seed, only *Hordeum vulgare, ?Raphanus, Echium plantagineum, Polygonum ?aviculare* and *Boerhavia* sp (other than *T. aestivum* and *Carthamus/Emex*) were common (Table 2.7). Of these only *?Raphanus* was of major importance (average abundance 0.5 in April 1990). Other seeds were present infrequently and were never abundant (Table 2.7).

Non seed items were often found in crop samples including plant materials such as the corms of *Oxalis pes-caprae* and the capitulae of an unidentified composite. In June, Little Corellas were shot whilst feeding at a pig feedlot and crops contained the swill fed out to the pigs. Only Lepidopteran larvae comprised a significant proportion of non seed materials in crops (August 1990, see Figure 2.13 and Table 2.8). Leaf pieces and gravel were often present although usually in small quantities.

2.3.3.3. Comparison of diets in northern and southern Flinders Ranges.

Little Corellas ate a wide variety of seed and non seed material. Of the 28 seed types found in Little Corella crops, 18 (64%) came from introduced plants. Usually, only one or two items were abundant in crop samples and the remainder comprised a variety of less common and less abundant items. Only eight seed types were common to both areas, five of which belonged to introduced plant genera.

Figure 2.12 Relative abundance of major seed types in the crops of Littlle Corellas collected in the southern Flinders Ranges during 1990 (see text). Numbers above columns are sample sizes.

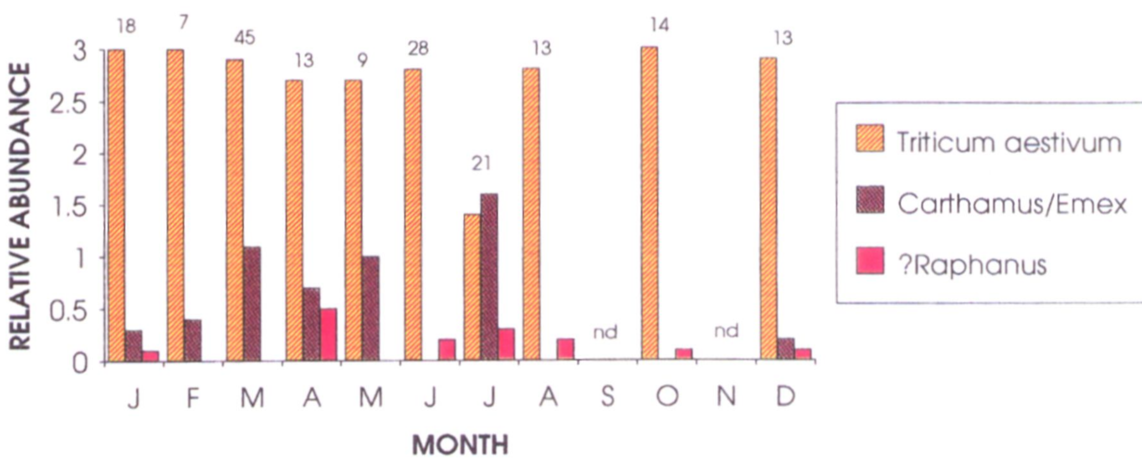


Table 2.7

Percentage incidence of different seeds in the crops of Little Corellas shot in the southern section of the study area in the period January 1990 to December 1990. No Little Corellas were collected in September 1990 and November 1990. * denotes introduced plants. ? denotes that seeds could not be identified further (see Appendix 2, page 109).

	J	F	M	A	M	J	J	A	S	O	N	D
n	18	7	45	13	9	28	21	13	0	14	0	13
Triticum aestivum *	100	100	100	100	100	100	67	100		100		100
?*Carthamus*/ *Emex**	33	43	89	61	67		71					15
Ehrharta sp*	16		2		11			8				
Maireana sp	6							8				
?*Raphanus**	6		2	46		21	24	23		7		8
Echium plantagineum *	6		11	31	11	4		31		7		
Unidentified seed			2									
Phalaris sp 1*			2									
Citrullus sp*					11		14					
*Hordeum vulgare**					22		5					8
Cucurbitaceae ?sp					11							
Polygonum ?*aviculare* *		14	2	8		21	19	23				
Avena sp*			2	8								8
Boerhavia sp			2			4	29					
?*Solanum*							9					
Gramineae ?sp							5					
Phalaris sp 2*								15				

Figure 2.13 Relative abundance of non seed material in the crops of Little Corellas collected in the southern Flinders Ranges during 1990 (see text). Numbers above columns are sample sizes.

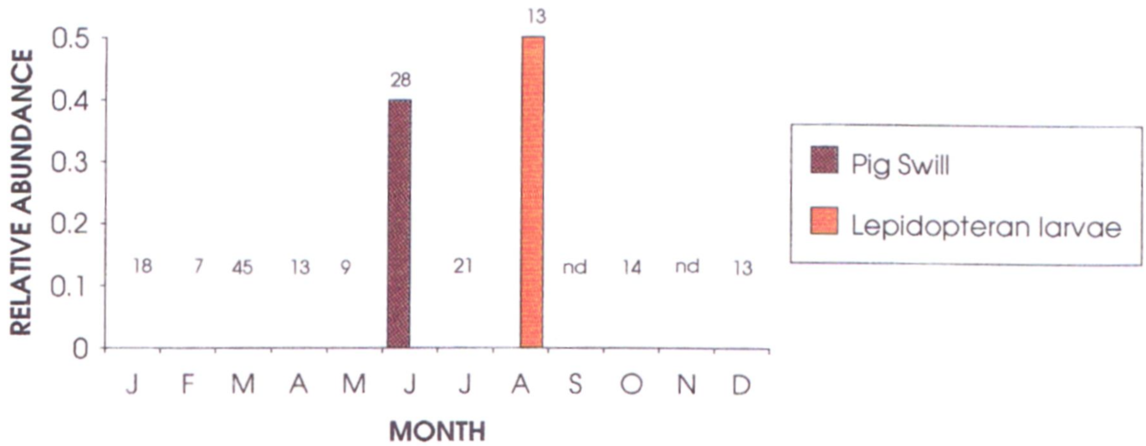


Table 2.8

Percentage incidence of different types of non seed material in the crops of Little Corellas shot in the southern section of the study area in the period January 1990 to December 1990. No Little Corellas were collected in September 1990 and November 1990.

	J	F	M	A	M	J	J	A	S	O	N	D
n	18	7	45	13	9	28	21	13	0	14	0	13
Gravel	33		18	15		25	19	15				8
Leaf pieces	17		2		22	11		23				23
Pig swill						18						
Corms *Oxalis pes-caprae*						14						
Dried plant material			2		11							
Lepidopteran larvae							5	38				
Compositae capitulae									8			

There was a greater diversity of seed types found in the crops from the north as compared to the south, especially if major seed types only are considered (Table 2.9). In the southern section, the number of food items found in crop samples was low during the summer months and increased during the autumn and winter. However, summer food items remained common and abundant throughout the year. In contrast food items in crops collected in the north showed a sequential pattern with one or two different items dominating at different times of the year (Figure 2.10). Summer food items were present in crop samples throughout the year but were not necessarily abundant.

Table 2.9

Number of seed types found in Little Corella crop samples in the northern and southern sections of the study area. Major seed types were those with an average monthly abundance greater than or equal to 0.5 in at least one month.

All Seed types	No. genera (% introduced)
Northern Section	19 (63%)
Southern Section	16 (67%)
Major Seed types only	
Northern Section	10 (50%)
Southern Section	3 (100%)

Food items other than seeds were important components of the Little Corella diet. For example, psyllid casings, corms of *O. pes-caprae* and Lepidopteran larvae. The latter were found in crops from both areas although they were abundant only in crops from the north. A potential source of bias in these data arises from the ease of shooting birds whilst they are feeding. Thus the crop sample may reflect seed availability at a feeding site as much as dietary preference. Considering that no sustained efforts were made to shoot Little Corellas feeding in a variety of feeding situations, the results shown above are only an indication of the food items preferred by Little Corellas in the study area. Also, crop samples were collected in one year only and thus cannot be considered to represent the entire suite of food items that could be found in the diet of the Little Corella.

2.3.4. Roost use during summer

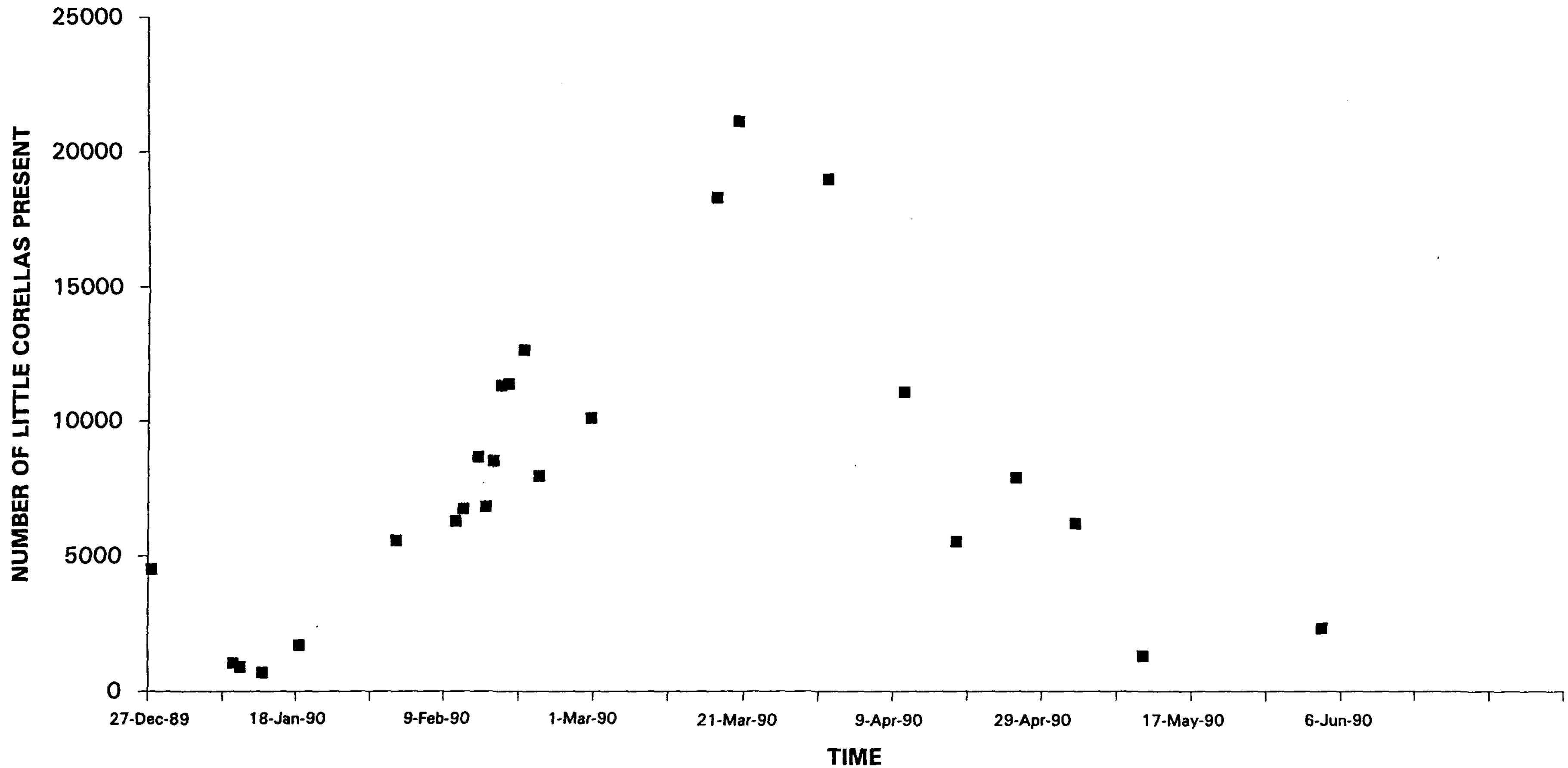
Patterns of roost use during summer were similar at most sites with peak numbers occurring in midsummer. For example, a few birds began using the Pichi Richi Creek roost site in early November 1989 after which the number of birds using that site gradually increased and reached a peak of around 21,000 Little Corellas in late March. Thereafter roost size declined steadily until rain fell in late April 1990 when the roost was largely abandoned (Figure 2.14). During the life of the roost, roost size varied from day to day, indicating that some Little Corellas at least had altered their roost preference. The duration of the summer roost varied in each year of the study from 148 days in 1989 and 215 days in 1990 to 145 days in 1991.

Observations in Richmans Valley in the summer of 1990 showed that Little Corellas occupied a total of six roost sites along a 12 km section of Capowie Creek in the period November 1989 - April 1990 (Figure 2.15). The total number of birds using the area varied, with a peak occupancy of 10,000 Little Corellas in mid January. Not all roost sites were occupied simultaneously and the birds showed marked preferences for particular sites. Site 2 was briefly popular at the start of the summer and appeared to act as staging areas for birds moving into the valley. Initially, roosting Little Corellas were divided between sites 1, 3 and 4 (Figure 2.16). By early January, Little Corellas were using two roosts, sites 2 and 5. Site 2 was then abandoned in favour of site 5 and some birds chose to roost at site 6 also. By early February, site 6 was the preferred location for the remainder of the summer although site 5 was visited briefly before the birds left the valley completely in mid April (Figure 2.16). These results indicate that Little Corellas changed their roost site regularly.

2.4. DISCUSSION

In South Australia, Little Corellas have extended their range during the past 40 years by virtue of their ability to use the food and water resources supplied by agricultural and pastoral practices. Exploitation of agricultural crops has been reported in this species and other cockatoos by other workers (Little Corella, Beeton 1985; Western Long-billed Corellas, Smith and Moore 1991; Long-billed Corellas, Temby and Emison 1986, P.Alexander pers. comm.).

Figure 2.14 Changes in the size of the Little Corella roost at Pichi Richi Creek, near Quorn between December 1989 and June 1990.



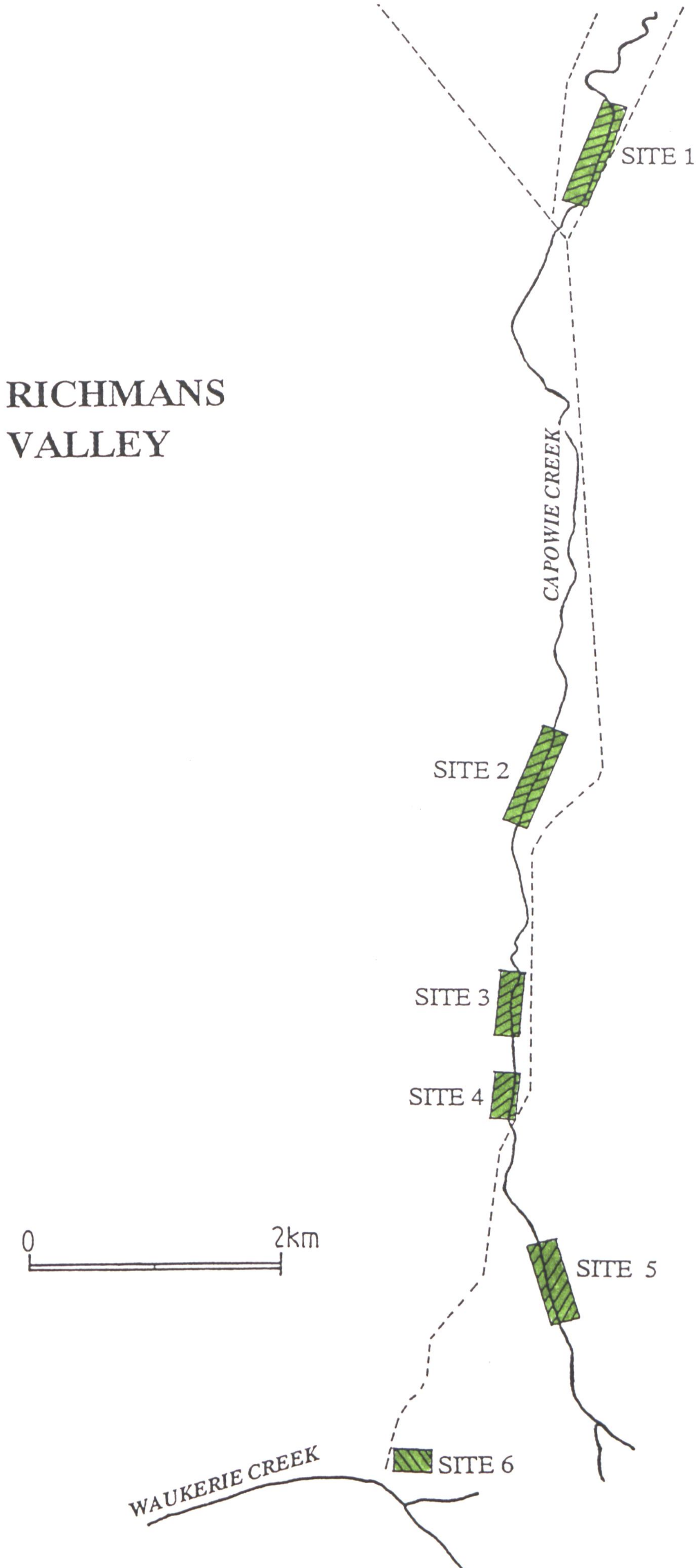
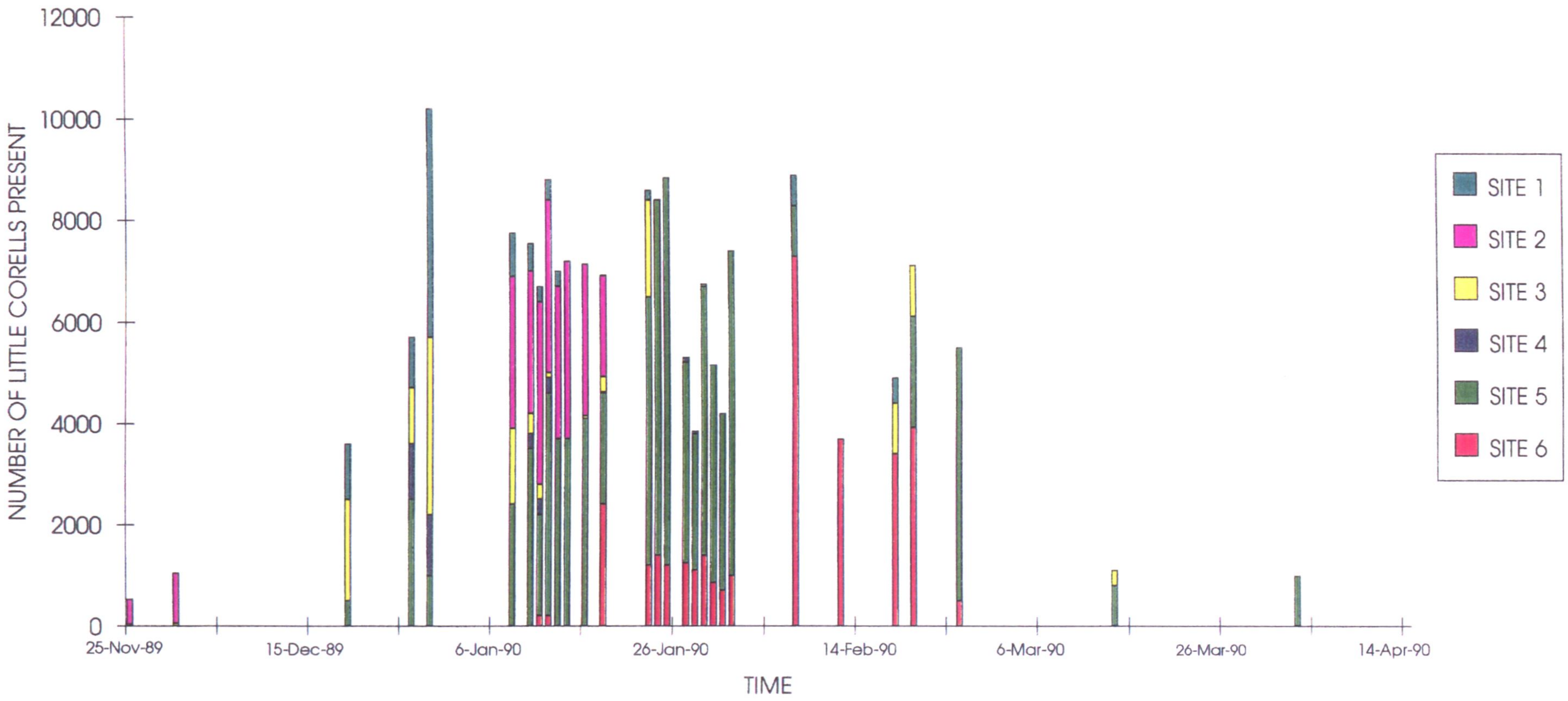


Figure 2.15

Map showing the locations of all roost sites in Richmans Valley, south of Quorn used in 1990 (----road).

Figure 2.16 Changes in roost size and roost location within Richmans Valley between November 1989 and April 1990.



Although no large scale pattern of seasonal movement has been noted for this species (Blakers *et al.* 1984), results from this study showed that Little Corellas in the Flinders Ranges undergo an annual cycle of congregation in the southern part of the study area in the summer followed by dispersal from this area during the winter.

Tagging studies confirmed that Little Corellas dispersed throughout the study area during winter, and found that the same individuals returned to roost sites in the southern section of the study area during subsequent summers. Returning birds did not necessarily choose those roosts used in the previous year. The dispersal and return of tagged individuals, combined with the absence of Little Corellas from the northern study area during summer suggests that the birds participating in the summer congregation are drawn, at least in part, from the entire Flinders Ranges.

Congregations during the summer have been noted in this species in other areas (Beeton 1985, Smith and Moore 1992) and also in Western Long-billed Corellas in Western Australia (Smith and Moore 1992). Beeton (1985) related bird movements to a seasonal dearth in the availability of seeds from native plants. Smith and Moore (1992) speculated that, due to the continuing availability of food and water in natal areas, seasonal movement patterns away from natal areas were relic behaviour from the time when food and/or water during the summer was limiting. Whether the annual movement of Little Corellas away from the northern study area is related to traditional (either relic or learnt) behaviour as suggested by Smith and Moore (1992) or to a seasonal dearth of food in the north (Beeton 1985) is not resolved by the results presented here. Little Corellas congregate in the southern study area every summer despite the continuing availability of water (that provided for stock) in the northern parts of the study area during this time. During their sojourn in the south, Little Corellas fed almost exclusively on the fallen grain left in stubble paddocks after harvest. The prevalence of wheat in the diet of Little Corellas probably relates to its easy availability, at least during the summer, but also suggests that birds may rely on that food resource at this time. Thus, bird movements may be related to relic behaviour from the time when water supply in the northern Flinders Ranges during the summer was limiting and/or to changes in the availability of native foods.

Analysis of crop contents does not describe food availability. Quantitative studies comparing seed production and seed distribution in the northern and southern study areas would be required to determine whether food was scarce in the northern study area during the summer. Even if food was not scarce in the north, the abundant and predictable food supply in grain growing areas may be sufficient to attract Little Corellas to the south in the summer. Drought mediated dispersals were recorded in South Australia in this and other species of cockatoos at the time when very large flocks of Little Corellas were first recorded (early 1950s) in the southern section of the study area and summer influxes are now an annual event. This suggests that there may also be some element of learned behaviour in the annual movement of Little Corellas in the Flinders Ranges.

The duration of the summer congregation varied between years and was affected by seasonal conditions. Roosts were established soon after the birds arrived in an area and were not abandoned until sufficient rain had fallen in the following autumn to cause germination of fallen grain. Loss of this food supply is reflected in the increased variety of food items in the birds diet at this time. If autumn rains were delayed or insufficient to cause germination of grain in the stubble, the life of the summer roost was extended (see also section 4.4.2.). Once the birds had amassed for the summer period, flock sizes and roost sizes tended to increase, reaching peaks in midsummer before declining. The number of birds in the southern section of the study area varied annually and may be related to the effects of seasonal conditions on food supply elsewhere in the study area. Insufficient data were collected to determine whether or not the summer population of Little Corellas in the south was increasing.

Bird use of particular roost sites varied on an annual basis with some roosts occupied in all years of the study (traditional roosts) and others not. Tagging studies indicated that although the same individuals returned to the southern part of the study area each summer, they did not necessarily return to the same roost site used in the previous year. Tagging studies also indicated that individual birds moved around within one summer and that flocks were capable of intermixing. Thus, Little Corellas were not faithful to roost site either within or between summers. Smith and Moore (1992) also found that mixing occurred between flocks of Western Long-billed Corellas although they concluded that interchange was infrequent. Whether flock mixing is infrequent or otherwise, these data do suggest that individual Little Corellas cannot be regarded as faithful to a flock. Despite the appearance of cohesive behaviour on any one day, each Little Corella flock in the study area was a labile unit with a changing membership involving birds from other flocks within the region. Tagging studies suggested that birds comprising the summer congregations had come from all parts of the study area. However, the mobility of individual Little Corellas implies that the birds inhabiting the study area cannot be viewed as a closed population but rather as potentially capable of mixing with the Little Corella flocks inhabiting other areas of the State such as the Cooper and Strzelecki Creeks system in the far North East and the Olary Ranges.

Movements of individual birds found during tagging studies were confirmed by results from intensive studies of roost size. Fluctuations in the size of roosts showed that Little Corellas were capable of moving between roost sites and that they frequently altered their use of roosts and regularly shifted the locations of roosts.

CHAPTER 3

POPULATION STRUCTURE AND ANNUAL CYCLE OF THE LITTLE CORELLA IN THE FLINDERS RANGES

3.1. INTRODUCTION

Many workers have emphasised the importance of understanding the population dynamics of a pest species before developing an integrated pest management programme to reduce damage (Flegg 1980, Dolbeer 1990, Wiens 1990). Thus in a study of the life history of Quelea (*Quelea quelea*), Ward (1979) described bird damage in terms of flocking and foraging behaviour and Elliott (1979) combined an understanding of Quelea movements with deliberate adjustments to the harvest of irrigated rice in Chad to reduce both bird damage to the crop and the amount of avicide used to reduce bird numbers. An understanding of the biology of the bird should also reveal those areas in which management effort is best not spent. In studies in the control of Red-winged Blackbirds (*Agelaius phoenicius*), Weatherhead (1982) found that both species composition of the roosting flock and the sex ratio and age of roosting birds changed over the life of the roost. Although destruction of spring roosts was identified as most likely to affect subsequent breeding performance, the disproportionate representation of male birds in roosts at a time suitable for the aerial application of surfactant (the control method under study) would reduce the effectiveness of any cull efforts.

Similarly, the most effective management of the problems associated with Little Corellas depends on an assessment of vulnerable aspects of the birds biology which is then combined with management strategies to enhance those biological processes which are already operating. For example, manipulating the factors affecting survival such as identifying and extending periods of stress (highest water requirements, lowest body mass, least fat reserves) by manipulation of food and/or water supply. Understanding the biology and ecology of the Little Corella may indicate where management efforts may not be worthwhile. For example, understanding the incidence of diseases affecting free-living cockatoos (e.g. psittacosis, viral diarrhoea) and assessing their importance relative to imposed population reduction measures. Although a definitive study of the ecology of Little Corellas was not possible within the time period and financial restraints of this project, basic information about the structure of the Little Corella population and the birds annual cycle was sought and obtained. The study focussed on summer flocks inhabiting the southern Flinders Ranges and asked the following questions:

1. **What is the age structure and sex ratio of the summer flock? Does age structure of the summer flock vary between years? Does age structure of the summer flock differ from age structure of the winter flock?**

2. **At what times are Little Corellas likely to be stressed (lowest body mass, least fat reserves)?**

3. **Do diseases such as psittacosis occur in the summer flock of Little Corellas?**

4. **What other factors may influence natality, survival and mortality of Little Corellas?**

3.2. METHODS

3.2.1. Collection of specimens

During 1989, Little Corellas were collected from the northern section of the study area during winter and spring and from the southern study area in summer and autumn. During 1990, monthly collections were made in both sections of the study area. A list showing the dates, locations and numbers of Little Corellas collected in the study area is presented in Appendix 3 (page 110). Birds were usually shot with either a .22 rifle or a 12 gauge shot gun. Birds were also collected by drugging their water point with the hypnotic drug, alphachloralose, at a final concentration of 6.0g/l (see section 5.2 for full details). Some carcasses were examined immediately but most were stored frozen until dissection.

3.2.2. Mensural data

The following data were collected from each carcass; mass, bill width (widest point), bill length (exposed culmen), mesenteric fat score, sex and the moult pattern of primary feathers in the left wing. Condition of the ovary and oviduct in females and the dimensions of the testes in males were also recorded (Smith and Brereton 1976, Beeton 1985).

Body condition in Little Corellas was assessed using carcass weight and a visual estimate of the amount of mesenteric fat present in the gut cavity. Little Corellas stored excess body fat as lobes of yellowish fat in the gut cavity between the skin and the viscera. The amount of body fat in each carcass was scored as none (0), some (1) and copious (2). Results for Little Corellas collected in the northern and southern sections of the study area were analysed separately. Data from fat scores were pooled for each season and differences in fat scores between seasons and between the northern and southern study areas were tested using χ^2 analysis.

Gonad material was excised from carcasses (thawed and fresh), fixed in 10% phosphate buffered formalin for 2-4 days, rinsed with distilled water and stored in 70% ethanol (Disbrey and Rack 1970). Fixed material was then transported to the laboratory for further examination. Fixation in phosphate buffered formalin and storage in 70% alcohol causes tissues to shrink (Disbrey and Rack 1970). To overcome possible differences in gonad dimensions between fresh and fixed material, gonad dimensions were measured on fixed material only.

A visual assessment of the condition of the oviduct in most females was made (Smith and Brereton 1976, Beeton 1985) and the sizes of the five largest ova were recorded for females collected in September 1989 and September 1990. Testes were occasionally damaged or destroyed when the bird was shot. Dimensions of the larger testis were recorded for most males and, assuming testis shape was similar to that of a cylinder, the formula $(\pi)r^2h$ was used to calculate testicular volume. Ischial width was measured on 240 carcasses. A visual assessment of the size of the bursa of Fabricius was made in 237 birds collected between mid December 1990 and late March 1991.

3.2.3. Determination of age

3.2.3.1. Using breeding status of females

Female Little Corellas were assigned to one of three age classes according to the condition of the ovary and oviduct. Those with differentiated ovaries (surface covered with ova) and with distended, convoluted oviducts were considered to be birds that had bred and were classified as sexually mature adults (Figure 3.1). Those with undifferentiated ovaries and straight oviducts (i.e. no egg had passed through the oviduct) were considered to be unbred birds and were classified as sexually immature (Figure 3.2). Some female Little Corellas had differentiated ovaries but had not passed eggs, and were classified as capable of breeding but unbred as yet.

3.2.3.2. Using bursa of Fabricius

No detailed study of the changes in bursa size with regard to age of Little Corellas was made during this study. Therefore, interpretations of bursa size and age were restricted to distinguishing young Little Corellas (large bursas) from older birds (small/absent bursas) (King and McLelland 1984). The size of the bursa of Fabricius was used to age Little Corellas collected during summer 1991.

3.2.4. Seasonal dispersal based on breeding condition

The breeding condition of all female Little Corellas collected during the period January-December 1990 was used to investigate the patterns of dispersal in breeding and non breeding birds. As before, bred females were those with differentiated ovaries and convoluted oviducts and unbred females were those with undifferentiated ovaries and straight oviducts. Any differences in the patterns of seasonal dispersal of adults and

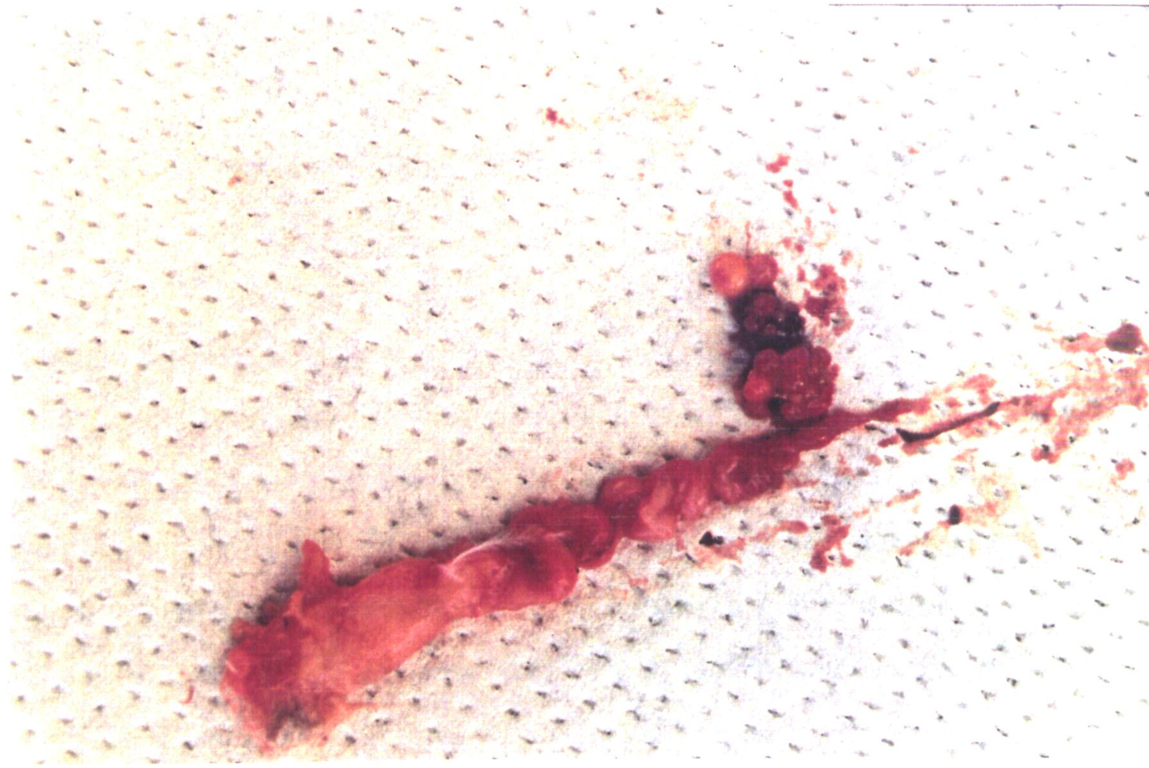


Figure 3.1

Condition of the gonads in a bred female. The surface of the ovary is covered with ova (differentiated) and the oviduct is convoluted and distended.

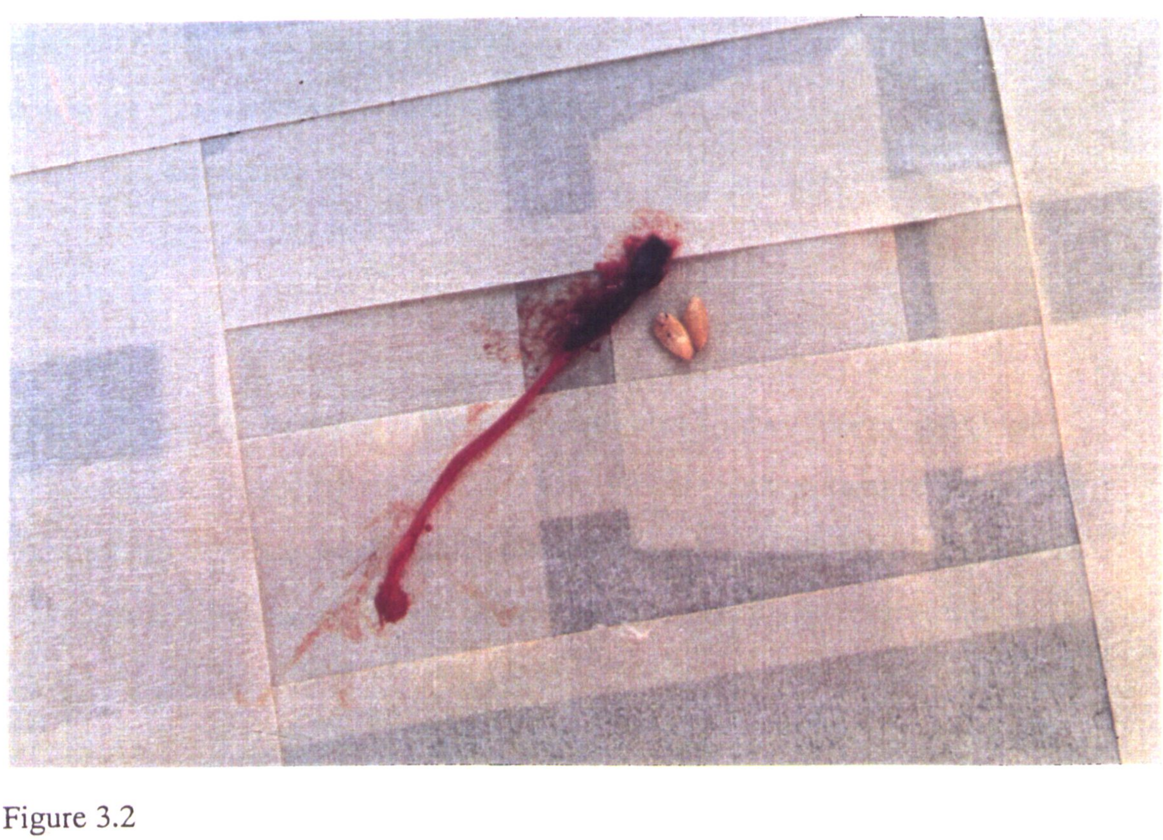


Figure 3.2

Condition of the gonads in an unbred female. The surface of the ovary is smooth (undifferentiated) and the oviduct is straight and narrow.

immatures was inferred from changes in the proportions of these two age classes in the population.

3.2.5. Psittacosis Testing

In March 1991, spleens were collected from 140 Little Corellas. Spleen smears were made on glass microscope slides, air dried and fixed with acetone. Specimens were exposed to fluorescein isothiocyanate-labelled (FITC) mouse monoclonal antibodies directed against *Chlamydia psittaci* and *C. trachomatis*. Specimens were exposed to ultra-violet light (excitation peak FITC 490nm) and elementary bodies of chlamydiae were detected as bright apple-green spheres (size *ca* 300nm). This was an adaptation of a standard laboratory technique (Bartels Chlamydiae Fluorescent Monoclonal Antibody Test manufactured by Microscan R) developed for the detection of chlamydial infections in humans (R Wilkinson pers. comm.[6]).

The results were interpreted thus;

a. negative = < 5 elementary bodies per slide.

b. weak positive = 5-11 elementary bodies per slide.

c. positive = > 11 elementary bodies per slide.

3.3. RESULTS

3.3.1. Sex Ratio

The sex ratio in Little Corella flocks in the whole study area for the entire period of the study was 1 male: 0.96 female (n=1212). The sex ratio in the southern summer flocks was not significantly different from a 1:1 ratio, (1 male: 1.1 female, n=658) inferring that equal numbers of males and females moved into the southern Flinders Ranges during the summer.

[6]Mr R. Wilkinson, Laboratory Manager, Institute of Medical and Veterinary Science, South Australia

3.3.2. Determination of sex using external characters

Carcass weight varied seasonally and according to time of collection. Birds collected in the mornings prior to the first feed weighed significantly less than birds collected in the afternoon after the last feed (females; $t=7.4$, df 569, $p<0.001$ and males; $t=5.3$, df 596, $p<0.001$). On average male Little Corellas weighed significantly more than females (Table 3.1), although there was considerable overlap between the sexes in carcass weights in both morning and evening collections (Figure 3.3). Male birds were heavier than female birds in all months of the year (Figure 3.4). Although the length and width of the exposed culmen were significantly greater in male Little Corellas than in females (Table 3.1), there was considerable overlap between the sexes in both characters (Figure 3.5). Ischial width in females was significantly greater than ischial width in males (Table 3.1), but again there was overlap between the sexes in values (Figure 3.6). Ratios of carcass weight : ischial width, bill width : ischial width and carcass weight X bill width : ischial width failed to distinguish the sexes as did log : normal and log : log plots of bill width *vs* ischial width (results not shown).

Table 3.1

Measurements of external characters for male and female Little Corellas collected between March 1989 and March 1991 in the Flinders Ranges. * Student's t-test was used to test for significant differences between means.

Character	Males	Females	Significance		
	Mean ∓ s.e. (n)	Mean ∓s.e. (n)	t	df	p
Body mass (g) (morning)	461 ∓3 (268)	415 ∓3 (256)	12.7	522	<0.001
Body mass (g) (afternoon)	478 ∓2 (330)	439 ∓2 (315)	12.6	643	<0.001
Culmen width (mm)	15.8 ∓0.03 (615)	15.2 ∓0.02 (593)	17.7	1206	<0.001
Culmen length(mm)	31.0 ∓0.10 (615)	29.6 ∓0.10 (593)	14.9	1206	<0.001
Ischial width (mm)	7.1 ∓0.2 (212)	8.8 ∓0.2 (240)	7.2	449	<0.001

Figure 3.3 Histograms showing the distribution of body mass in male and *female* Little Corellas collected in the mornings and afternoons in the Flinders Ranges. a: males, morning. b: females, morning. c: males, afternoon. d: females, afternoon.

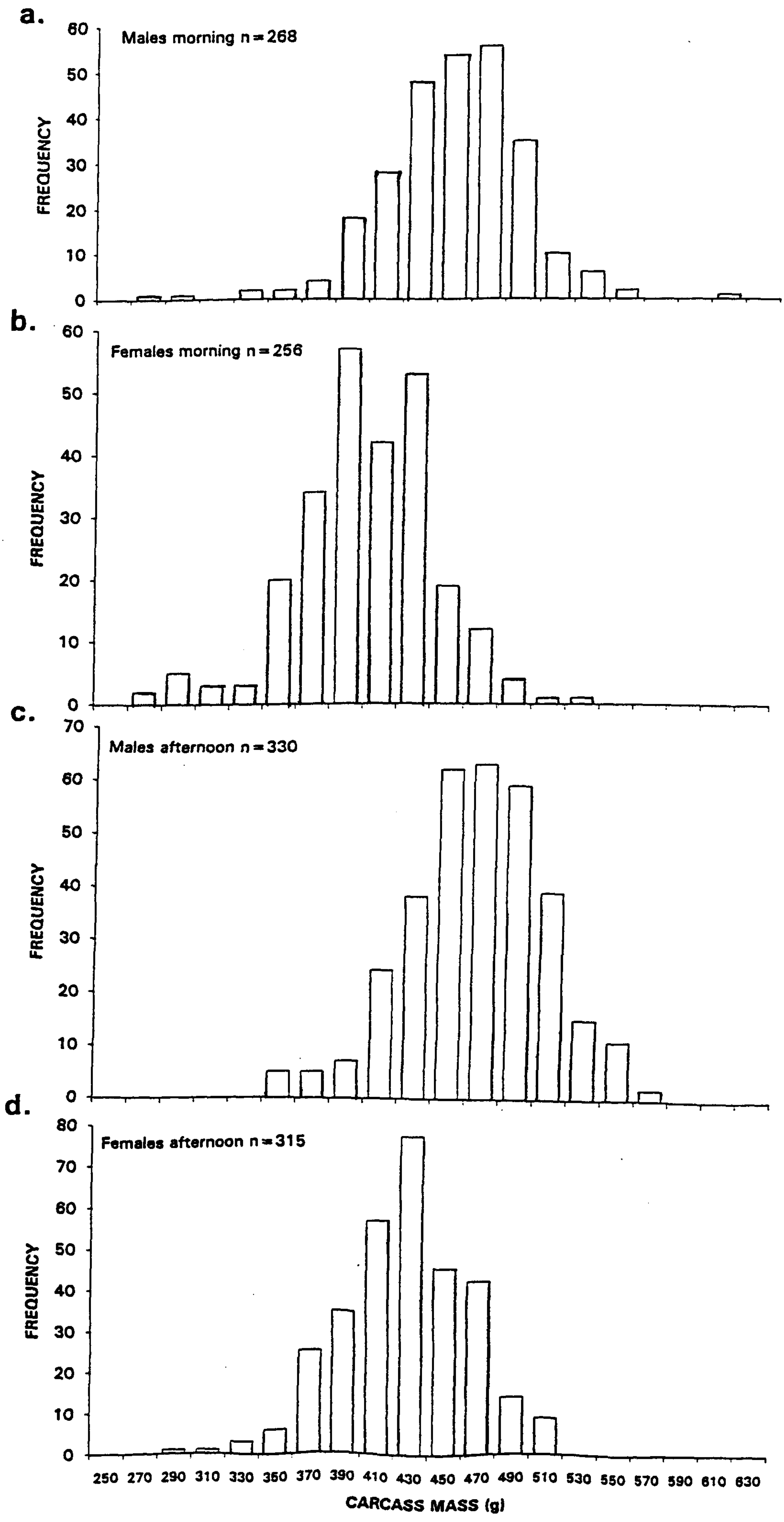


Figure 3.4 Seasonal variation in masses of male and female Little Corellas (data pooled from all years). Numbers appearing above and below data points are sample sizes and vertical lines show ±S.E.

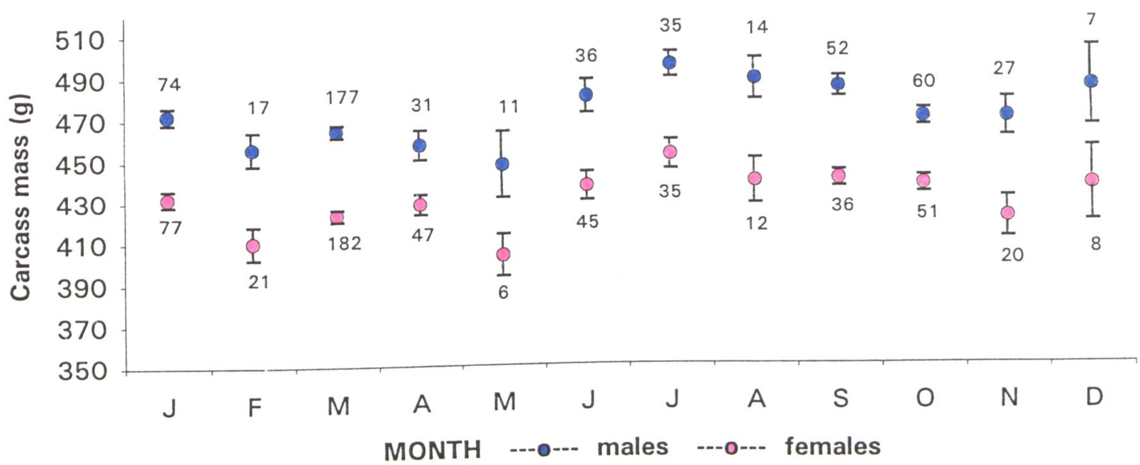


Figure 3.5 Histograms showing the distribution of bill lengths in a. male and b. female Little Corellas and bill widths in c. male and d. female Little Corellas collected in the Flinders Ranges.

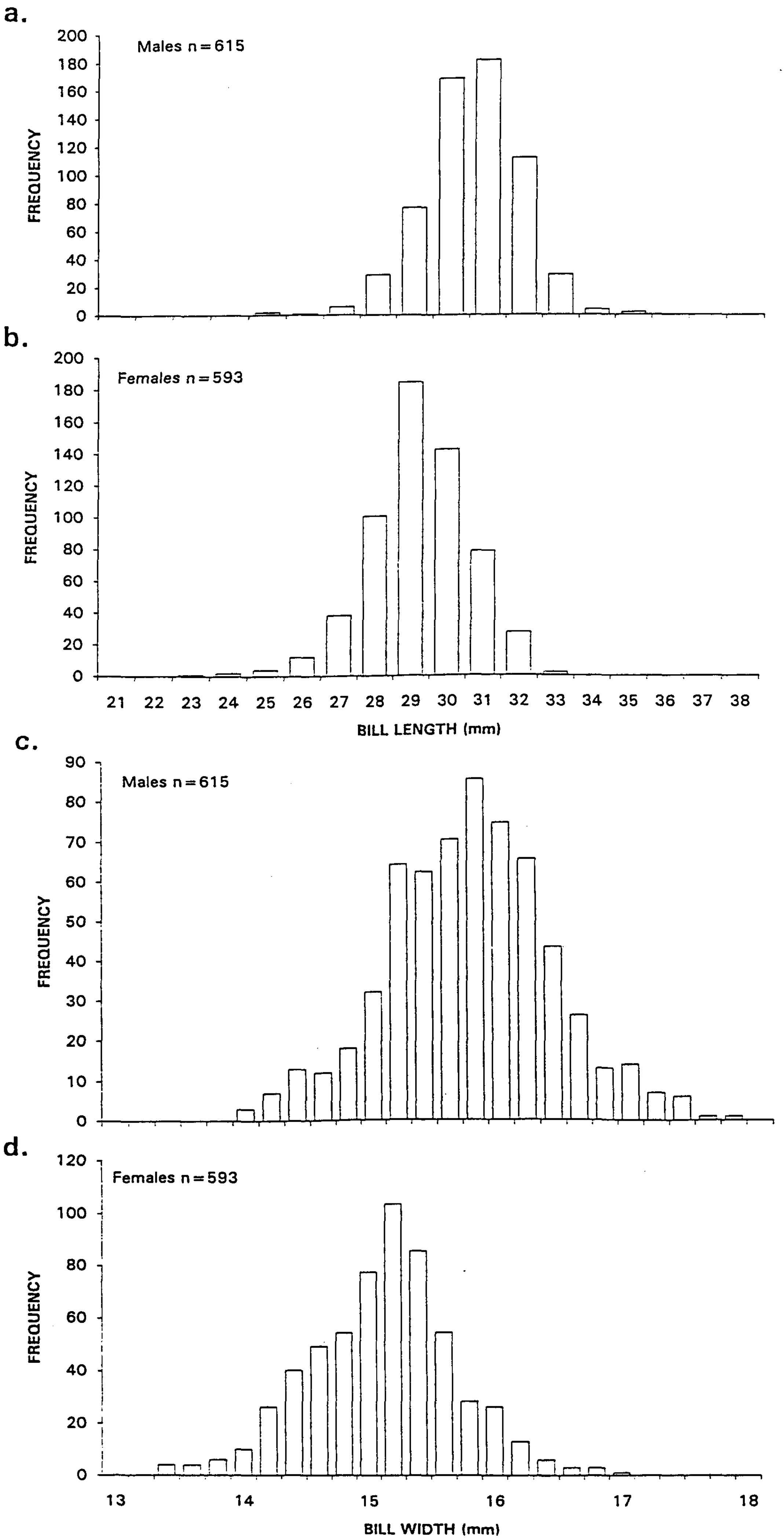
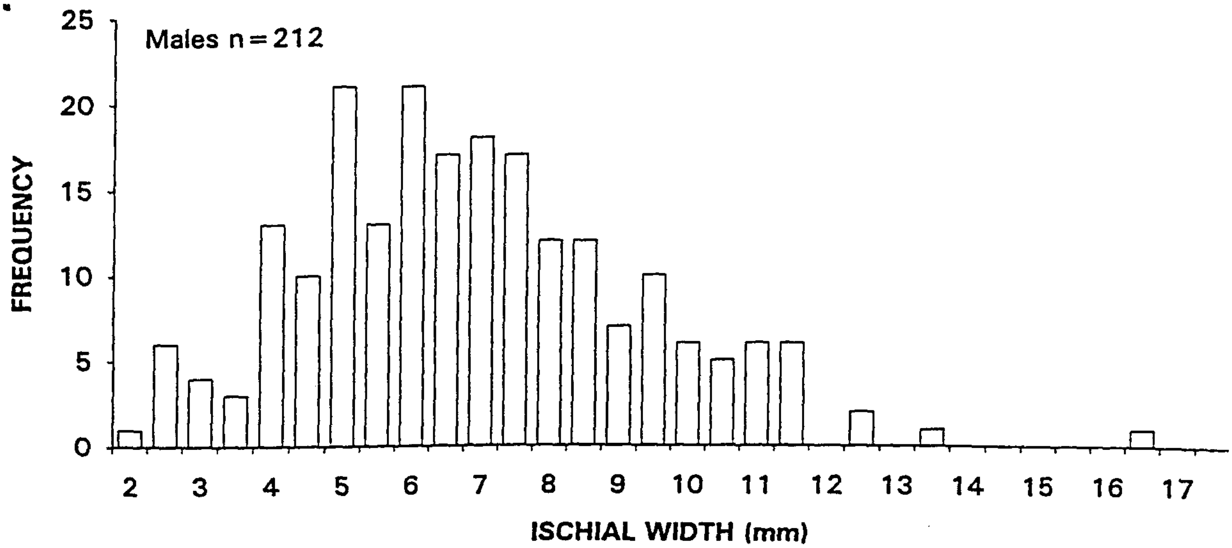
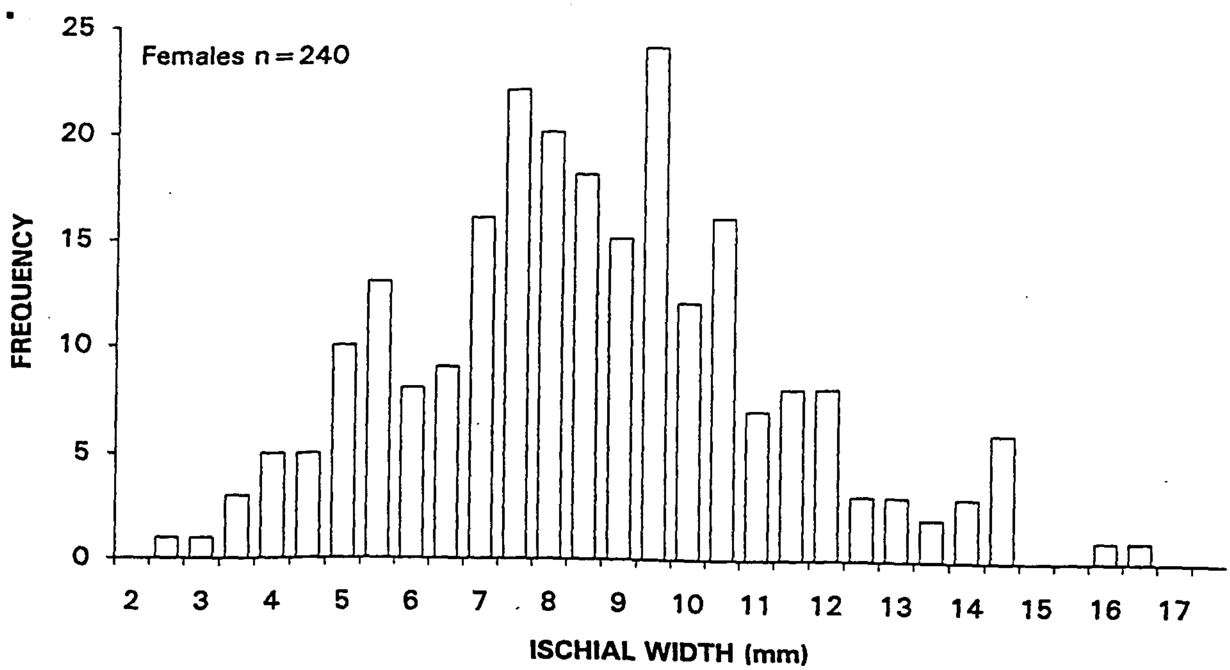


Figure 3.6 Histograms showing the distribution of ischial widths in a. male and b. female Little Corellas collected in the Flinders Ranges.

a.



b.



3.3.3. Seasonal variation in body condition

Carcass weight varied seasonally and peak weights were recorded in the winter and spring (Figure 3.7). Fat scores in male and female Little Corellas did not differ significantly during any season (Figure 3.8, χ^2 values ranged from 0.2 to 3.0, df 2, p values ranged from 0.2 to 1.0) despite seasonal changes in fat scores in both sexes and significant differences between the sexes in body mass (Figure 3.4).

In the northern part of the study area, fat scores in Little Corellas did not change significantly between summer and autumn nor between autumn and winter (χ^2= 2.6 and 3.5, df 2, p= 0.3 and 0.2 respectively) although there was a significant overall increase between summer and winter (χ^2= 14.1, df 2, $p<0.001$; Figure 3.9). Fat scores in spring were significantly less than in the preceding winter months (χ^2=17.7, df 2, p=0.001). In the southern part of the study area, fat scores in Little Corellas were high in summer, declined significantly in autumn (χ^2= 10.6, df 2, p= 0.005), improved in winter (summer and winter fat levels were not significantly different) and declined again in spring. Fat levels were significantly lower in spring when compared to autumn (χ^2=11.8, df 2, p=0.003; Figure 3.9).

Little Corellas collected in the southern section of the study area had significantly higher levels of stored body fat during the summer and winter months (χ^2=15.4 and 13.5, df 2, p=0.0004 and 0.001 respectively) than did Little Corellas collected in the northern section (Figure 3.9). Fat levels were not significantly different between southern birds and northern birds during the autumn and spring (Figure 3.9, χ^2=1.8 and 0.4, df 2, p=0.4 and 0.8 respectively). However, carcass weights of northern birds collected in spring were higher than carcass weights in southern birds for the same period (Figure 3.10).

3.3.4. Seasonal variation in gonad size

Gonads in both male and female Little Corellas changed according to time of year. Increase in the size of ovarian follicles began in June, reached a peak in September and

Figure 3.7 Seasonal variation in the mass of all Little Corellas collected throughout the Flinders Ranges (data pooled from all years). Numbers appearing above data points are sample sizes and vertical lines show ±S.E.

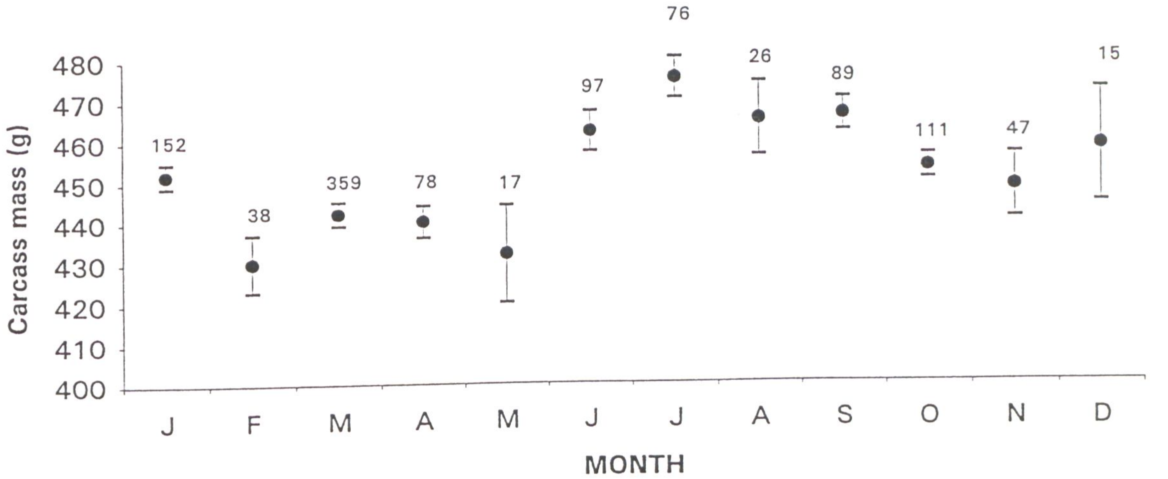


Figure 3.8 Mean fat scores for male and female Little Corellas collected in the Flinders Ranges in different seasons (data pooled from all years). Numbers appearing above and below data points are sample sizes and vertical lines show ±S.E.

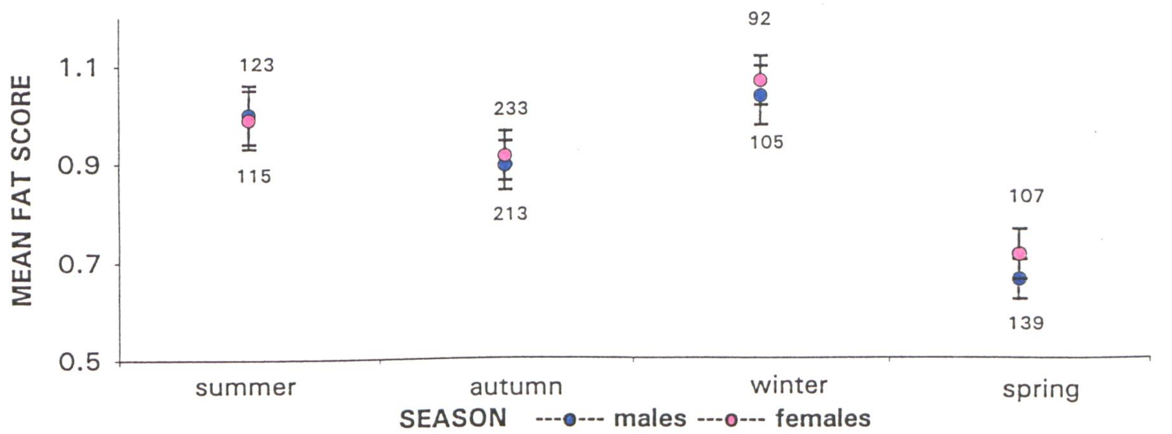


Figure 3.9 Mean fat scores for all Little Corellas collected in the northern and southern Flinders Ranges in different seasons (pooled data from all years). Numbers appearing above and below data points are sample sizes and vertical lines show $\pm$S.E.

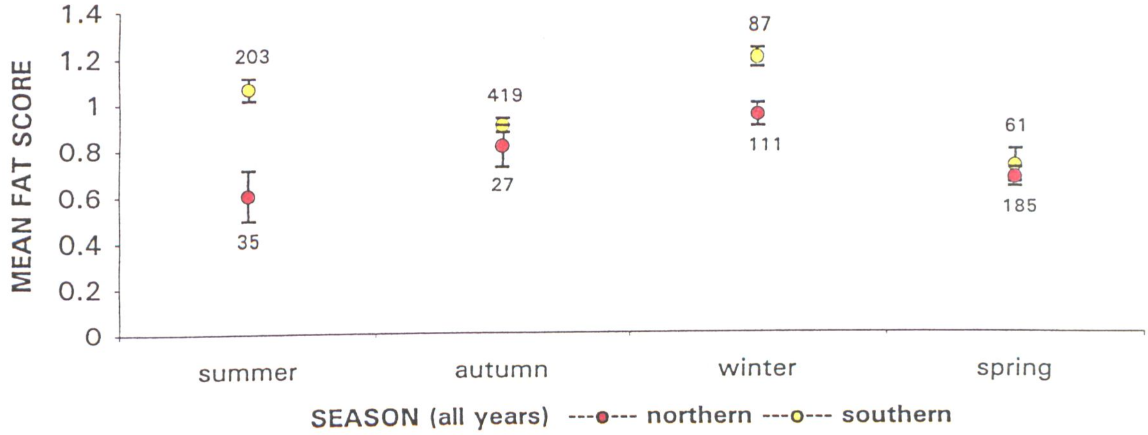
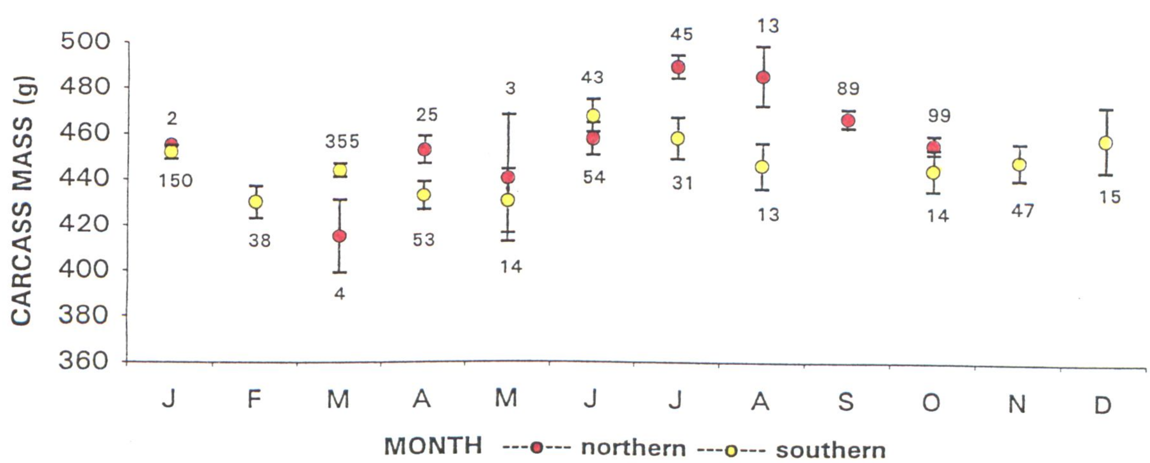


Figure 3.10 Seasonal variation in mass of all Little Corellas collected in the northern and southern Flinders Ranges (data pooled from all years). Numbers appearing above and below data points are sample sizes and vertical lines show $\pm$S.E.



thereafter declined (Figure 3.11). Increase in testicular volume also began in June and reached peak volumes in September. Thereafter testicular volume declined indicating regression of testes (Figure 3.12). During the months June to October, testes volume in northern birds was consistently greater than 150 $\mu\ell$ whereas testes volume in southern birds was always less than 100 $\mu\ell$ (Figure 3.13). Also, seasonal variation in testicular volume was more marked in Little Corellas collected in the northern section of the study area than in birds sampled from the southern section (Figure 3.13).

Peak size in both ovarian follicles and testes volume during late winter and early spring confirm that Little Corellas breed at these times in the Flinders Ranges.

Gonad development in Little Corellas was also affected by year-to-year changes in seasonal conditions. In males, peak testicular volume varied over two consecutive breeding seasons with peak volumes in July 1989 (no data available for August 1989) and in September 1990 (Figure 3.14). In 1989 and 1990, rainfall differed in both amount and timing (Figure 3.15) but daylength in each year was similar (Figure 3.16). The earlier onset of the increase in testis volume in 1989 may have been prompted by the record rains in the previous March. In females, the diameter of the largest ovum increased in late winter to reach a peak in August/September (Figure 3.17). There was no difference in the timing of peak ovum size between breeding seasons. i.e. females did not respond to high rainfall in early autumn. This suggests that the physiological changes associated with breeding in females may be more closely linked to photoperiod than to preceding rainfall. The consequences of asynchronous timing between males and females were not investigated further. Although the timing of peak ovum size did not differ between breeding seasons, mean sizes of the five largest ova were greater in 1989 than in 1990 (Figure 3.18) and indicates that favourable conditions in 1989 may have influenced breeding in terms of say, clutch size.

Figure 3.11 Seasonal variation in the diameter of the largest ovum in female Little Corellas (data from all females with differentiated ovaries collected in all years at all locations). Sample sizes are shown below data points, vertical lines show ±S.E.

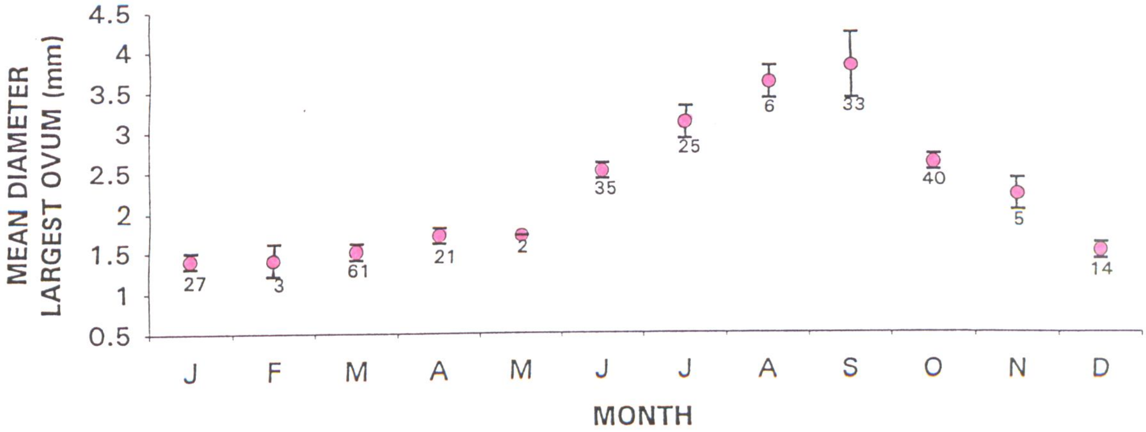


Figure 3.12 Seasonal variation in the volume of the larger testis in male Little Corellas (pooled data from all males collected in all years at all locations). Sample sizes are shown above data points and vertical lines show ±S.E.

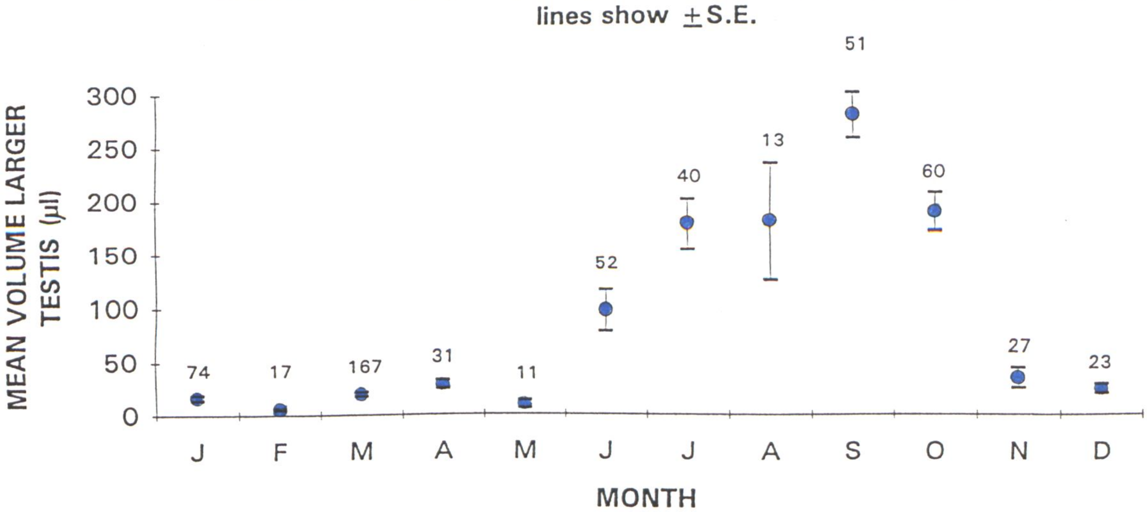


Figure 3.13 Seasonal variation in the volume of the larger testis in male Little Corellas collected in the northern and southern Flinders Ranges (data pooled from all years). Sample sizes are shown above and below data points and vertical lines show ±S.E.

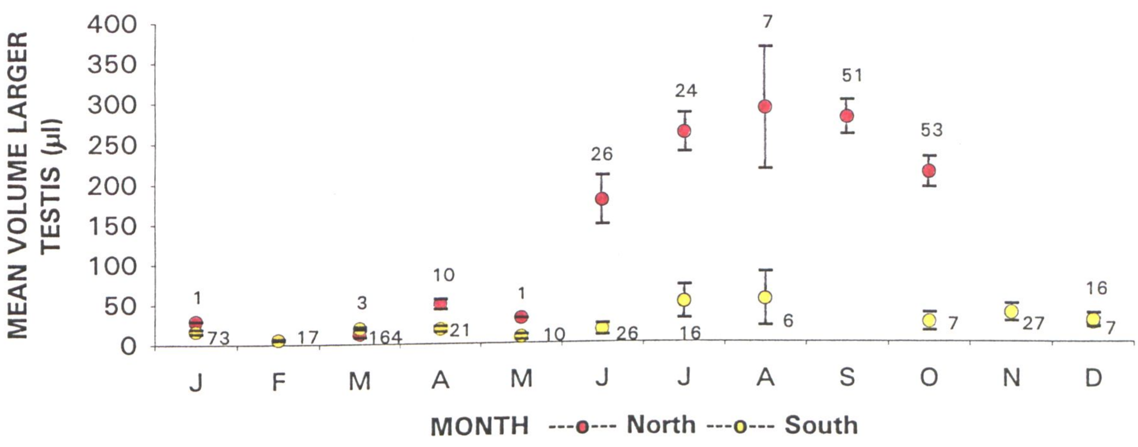


Figure 3.14 Change in the mean volume of the larger testis in male Little Corellas collected in the Flinders Ranges from March 1989 to March 1991. Numbers above data points are sample sizes and vertical lines show ±S.E.

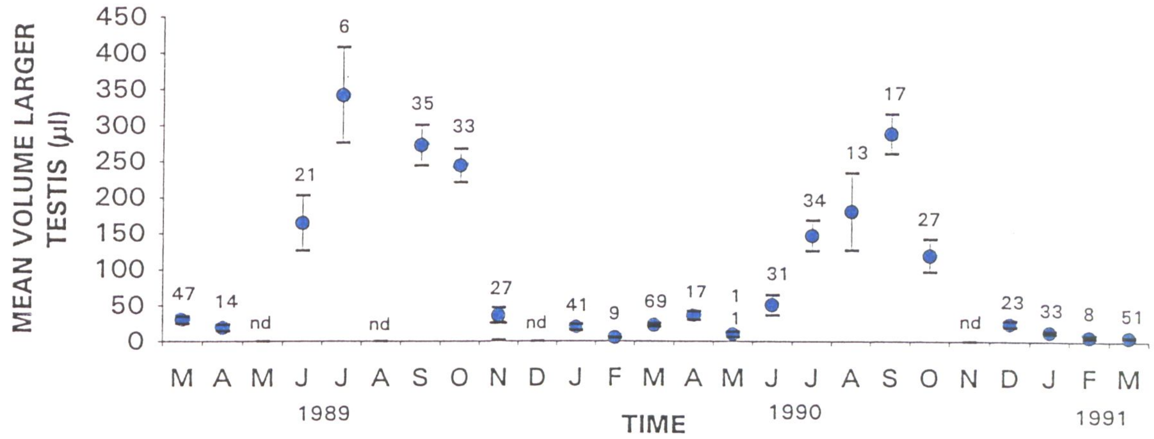


Figure 3.15 Monthly rainfall gaugings recorded at Quorn Post Office, South Australia, during the period March 1989 to March 1991.

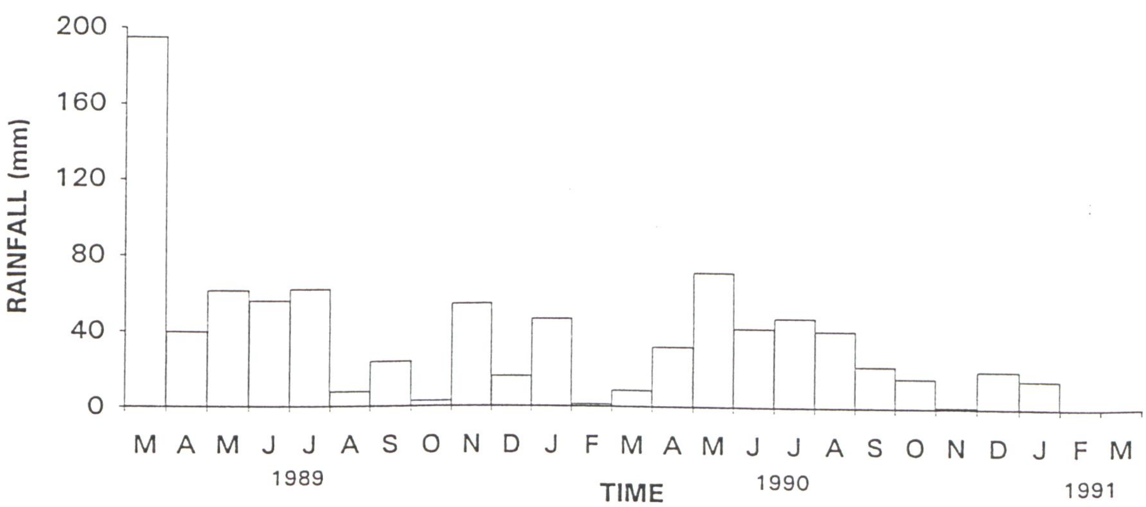


Figure 3.16 Change in average daylength during the period March 1989 to March 1991. Daylength was calculated from sunrise and sunset times for Quorn, South Australia*.

*Data were supplied by the Australian Surveying and Land Information Group, Department of Administrative Services, Canberra.

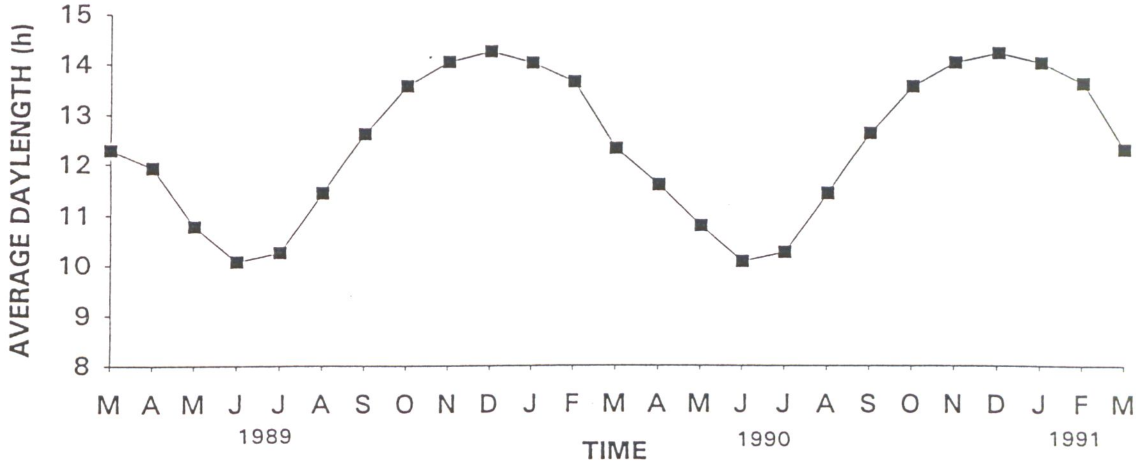


Figure 3.17 Change in the mean size of the largest ovum in female Little Corellas collected in the Flinders Ranges from March 1989 to March 1991. Numbers shown above the data points are sample sizes and vertical lines show $\pm$S.E.

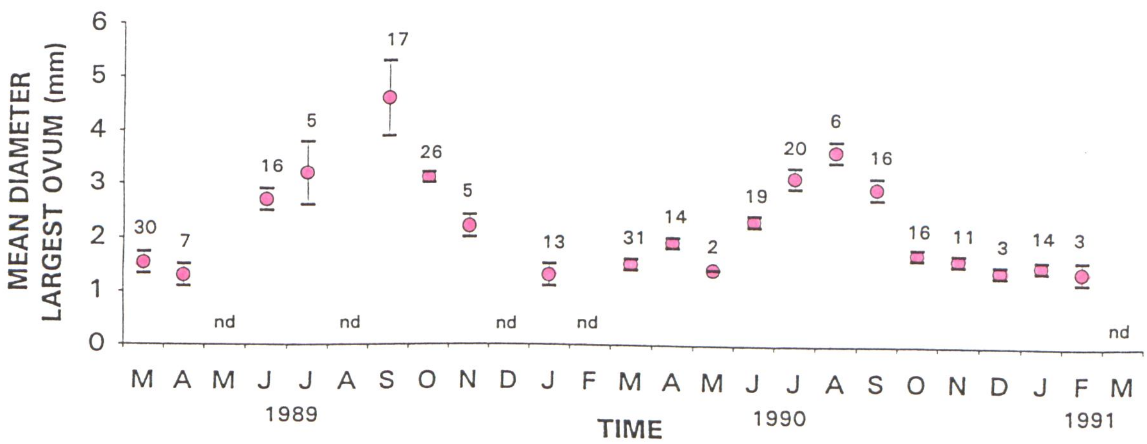
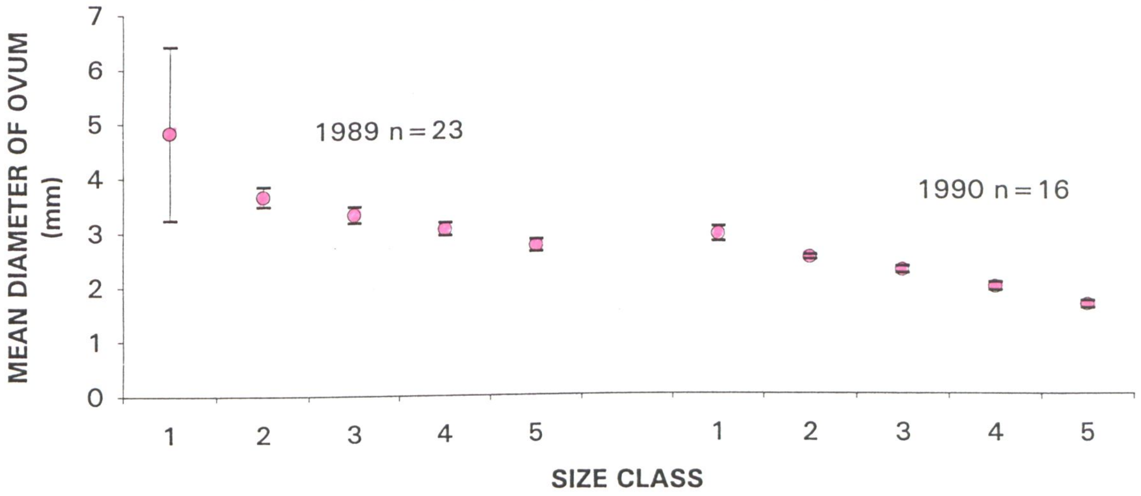


Figure 3.18 Average size of the five largest ova in female Little Corellas shot in September 1989 and September 1990.

Figures shown are mean diameter (±S.E.) where class 1 respresents the mean diameter of the largest ovum and class 5 represents the mean diameter of the fifth largest ovum.



These data should be interpreted with caution as only limited information from two breeding seasons was collected. In particular, increased testis volume does not necessarily imply spermatogenesis (see Smith and Brereton 1976). However these data do suggest that breeding activity in Little Corellas may be affected by differences in seasonal conditions between years.

3.3.5. Seasonal timing of moult

Little Corellas underwent active primary moult in most months of the year although moult activity was least in the breeding season (June-September, Figure 3.19). There was no significant difference between the proportion of males and females in active moult during any month of the study (Range χ^2 values 0-3.2, df 1-3, $p>0.3$). However, timing of moult in bred and unbred females appeared to vary. Bred females tended to moult primaries in the period following breeding (November-May), particularly in the period January to May (Figure 3.20a). Most unbred females moulted primary feathers in October and November but not during the period January to May (Figure 3.20b).

Data on moult patterns were collected from March 1989 to March 1991 encompassing a total of nine summer months over a three year period (March and April 1989, January-April 1990 and January-March 1991). The proportion of bred and unbred females in active moult was significantly different in seven of nine summer months namely, March and April 1989, January, March and April 1990 and January and February 1991 (Table 3.2). The proportion of bred and unbred females in active moult were not compared in the remaining two summer months (February 1990 and March 1991) as no bred females were collected. The proportion of bred and unbred females in active moult was not significantly different in any month during the period April-December in any year of the study (Table 3.2).

Figure 3.19 Seasonal variation in the proportion of Little Corellas in active moult (data pooled from all birds collected in all years). Sample sizes are shown above columns.

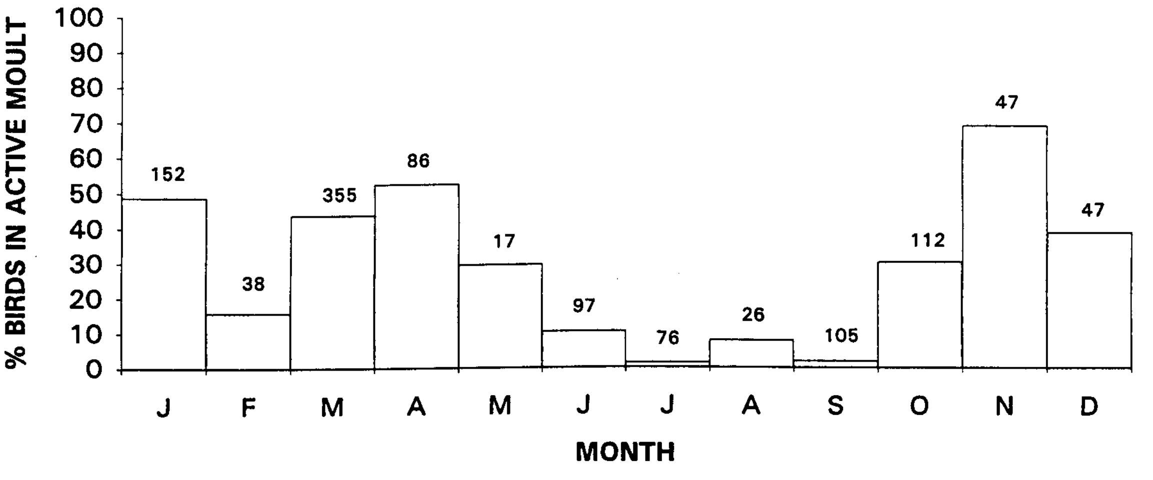
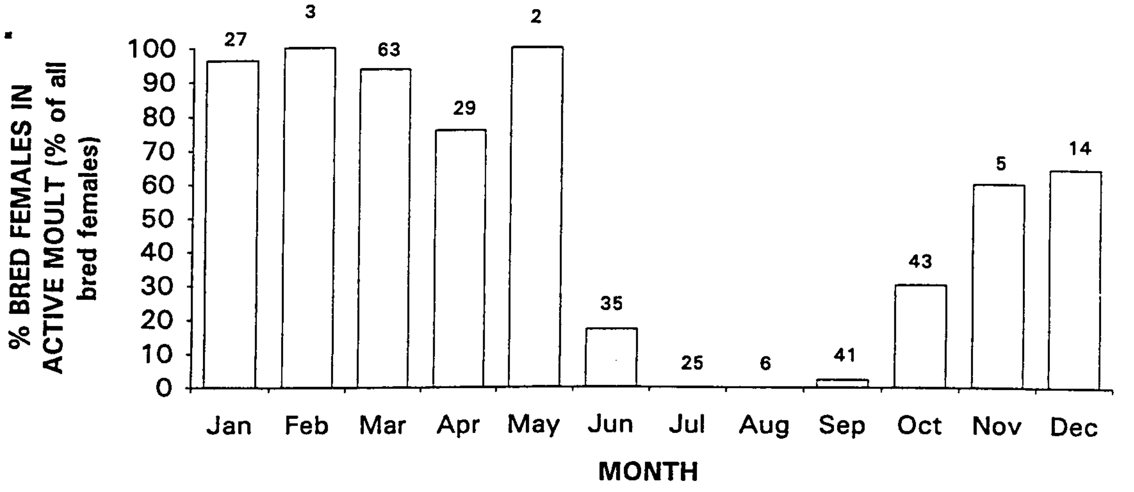


Figure 3.20 Seasonal variation in the proportion of a. bred females and b. unbred females in active moult (data pooled from all birds collected in all years). Numbers above columns are sample sizes.

a.



b.

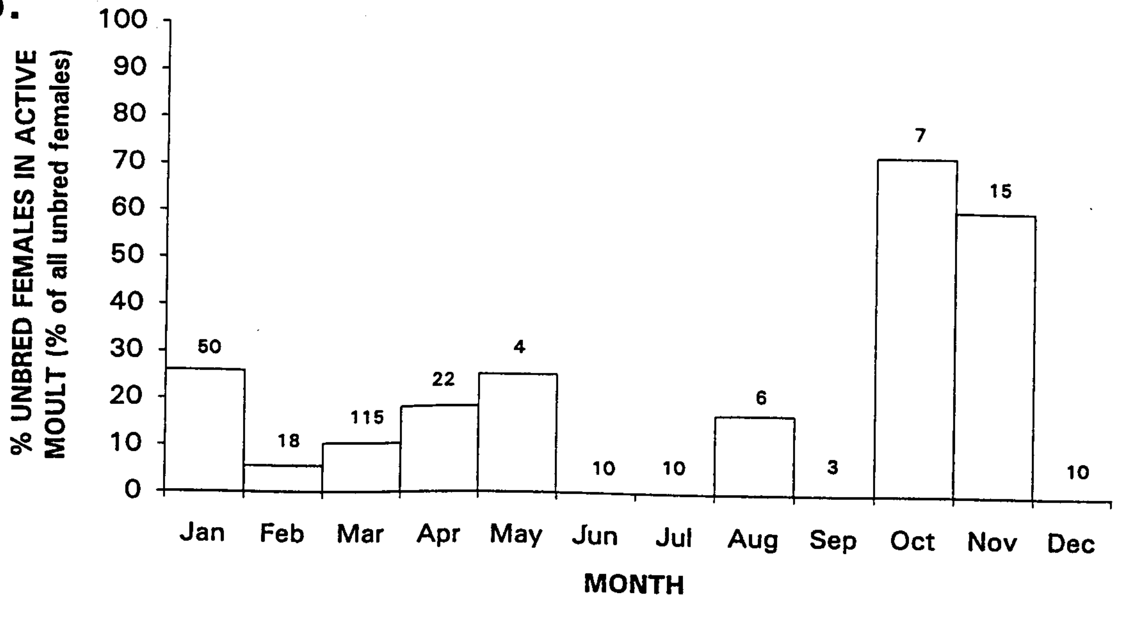


Table 3.2

Differences between the proportions of bred and unbred female Little Corellas involved in active moult in all months in each year of the study. Raw scores were analysed using Fisher's exact test and 2 by 2 contingency tables where appropriate. NS denotes no significant difference.

Year	Month	n bred females	% bred females in active moult	n unbred females	% unbred females in active moult	p
1989	March	32	90.6	14	14.3	<0.001
	April	9	88.9	14	28.6	0.04
	May					
	June	16	0	4	0	NS
	July	5	0			
	August					
	September	25	4	3	0	NS
	October	27	18.5			
	November	5	60	15	60	NS
	December					
1990	January	13	92.3	19	5.3	<0.001
	February			6	0	
	March	31	96.7	38	10.5	<0.001
	April	20	70	8	0	0.04
	May	2	100	4	25	NS
	June	19	31.6	6	0	NS
	July	20	0	10	0	NS
	August	6	0	6	16.7	NS
	September	16	0			
	October	16	50	7	71.4	NS
	November					
	December	14	64.3	10	0	NS
1991	January	14	100	31	38.7	<0.001
	February	3	100	12	8.3	0.01
	March			64	9.4	

As these results suggest, two distinct moult patterns were evident in Little Corellas collected during the summer period in the southern study area. First, a pattern in which none of the ten primaries were growing (primaries were new, slightly worn or old) and second, a pattern in which some primary feathers were being replaced. Correlation of moult pattern with characters used to distinguish adults (males and females) from immature birds i.e. the size of the bursa of Fabricius revealed a characteristic summer moult pattern in young male and female birds.

Of all the birds with large bursas (immature birds), only a small proportion were in active moult during the summer (8%, Table 3.3). The remaining birds with large bursas were not in active moult and condition of the primaries was variable in most (77%) and good in some (15%, Table 3.3). Of the birds with small bursas, most were in active moult during the summer (80%, Table 3.3). The remaining birds with small bursas were not in active moult and condition of the primaries was variable. None had all primaries in good condition (Table 3.3). Thus birds with all primaries in good condition during summer had large bursas and were immatures.

Table 3.3

Condition of primary feathers and the size of bursa of Fabricius in Little Corellas collected between December 1990 and March 1991 in the Flinders Ranges. Figures shown are the number and percentage (brackets) of birds in each condition.

Bursa	n	All primaries in good condition	Primaries in variable condition but no active moult	Active primary moult
Large	162	24 (15%)	125 (77%)	13 (8%)
Small	88	0 (0%)	18 (20%)	70 (80%)

3.3.6. Age structure of summer flocks

The age structure of the southern summer flocks was determined in two ways;

a. using gonad characters from female Little Corellas, and

b. using the pattern of moult in primary feathers.

The breeding status of males was difficult to establish due to the confusion between unbred males (i.e. small testes) and active but currently quiescent males (i.e. testes fully regressed). A frequency distribution of testicular volume during the non breeding period (November to April) failed to distinguish quiescent males from unbred males (results not shown). Therefore, testicular volume was not used for the determination of age in individual Little Corellas.

3.3.6.1. Confounding factors

Analysis of moult patterns obtained from Little Corellas caught over successive days using the alphachloralose technique showed that the proportion of mature Little Corellas (those birds in active moult) captured tended to decrease over successive days of drugging (Table 3.4). Concomitant to this, the proportion of young birds captured increased over time. Moult pattern was used to age Little Corellas in this case because carcasses were not retained for dissection from each day of drugging.

Table 3.4

Changes in the numbers of mature and immature Little Corellas culled over successive days of drugging on two drugging occasions (21 and 22 Jan 91 and 9-11 Feb 91). Little Corellas that were replacing primary feathers were assumed to be mature birds and Little Corellas with all primaries in good condition were assumed to be immature birds. Data were analysed using 2 by 2 contingency tables and Fisher's exact test where appropriate. * denotes a significant difference in the number of mature birds captured ($p=0.05$) between this day and the previous day. NS denotes no significant difference.

Date	n	All primaries in good condition (immature birds)	Primaries in variable condition but no active moult	Active primary moult (mature birds)
Trial 1				
21/01/91	305	21 (7%)	118 (39%)	166 (54%)
22/01/91	166	13 (8%)	105 (63%)	48 (29%) *
Trial 2				
09/02/91	102	27 (27%)	46 (45%)	29 (28%)
10/02/91	65	15 (23%)	29 (45%)	21 (32%) NS
11/02/91	107	44 (41%)	60 (56%)	3 (3%) *

As the alphachloralose collection technique appeared biased towards young Little Corellas on all but the first day of any drugging exercise, the age structure was estimated from shot birds and those birds drugged on the first day of any drugging operation. Moult status in all birds and the status of female gonads were compared between shot and drugged birds in each of four summer months (December, January, February and March) in three years (total of 12 comparisons). The number of birds in active moult differed significantly between shot samples and samples obtained from the first day of drugging (χ^2=6.2; df 1;

p=0.01). Similarly, the number of bred females differed significantly between shot samples and first day drugged samples (χ^2=14.8, df 1, $p<0.001$) although unbred females were more numerous than bred females in both data sets. However, the validity of these comparisons was confounded by very small sample sizes (<20 birds) in four of the 12 cases. Therefore age structures were constructed using pooled data (shot plus first day drugging) and only trends are discussed.

3.3.6.2. Using female gonad characters

Information obtained from gonads was used to age all females collected during each summer period during the study. Age structure in summer flocks varied over the three year period from a predominance of bred females in 1989 to a predominance of unbred females in the following two summer periods (Table 3.5). The change in the relative proportions of bred and unbred females was significant between 1989 and 1990 (χ^2=9.3, df 1, p=0.003) and between 1990 and 1991 (χ^2 =21.6, df 1, $p<0.001$) (Table 3.5).

Table 3.5

Age structure of female Little Corellas in summer flocks based on gonad morphology. Only data from shot birds and those captured during the first day of any drugging operation were used in the following analysis. Raw scores were analysed using 2 by 2 contingency tables. # denotes that change in the relative proportions of unbred and bred females was significant ($p<0.05$) between that year and the preceding year.

	Summer of 1989	Summer of 1990	Summer of 1991
Sample size	69	123	129
Unbred (incl capable)	41%	63% #	88% #
Bred	59%	37% #	12% #

3.3.6.3. Using moult pattern

Having established that moult patterns in bred and unbred females were significantly different and that the sex ratio of the summer flocks was 1:1, an age structure based on moult pattern alone was constructed. Moult data from all birds caught during the period January to April in all years were used. For the purposes of age structure analysis, this technique assumes that all birds moulting primaries are adult birds and all birds not moulting primaries are immature birds. Because a small proportion of unbred females also moult primaries during the summer (see Figure 3.20b), this technique overestimates the relative proportion of adult birds in the flock. According to this analysis, age structure in summer flocks varied from a predominance of adult birds at the start of the study in summer 1989 to a predominance of immature birds at the end in summer 1991 (Table 3.6). The change in the relative proportions of immature and adult birds was significant between 1989 and 1990 (χ^2=4.9, df 1, p=0.03) and between 1990 and 1991 (χ^2=9.5, df 1, p=0.002) (Table 3.6).

Table 3.6

Age structure of summer flocks based on moult data. Only data from shot birds and those captured during the first day of any drugging operation were used in the following analysis. Raw scores were analysed using 2 by 2 contingency tables. # denotes that change in the relative proportions of immature and adult birds was significant ($p<0.05$) between that year and the preceding year. * denotes immature birds (those not in active primary moult) and ** denotes adult birds (those birds in active primary moult).

	Summer of 1989	Summer of 1990	Summer of 1991
Sample size	134	298	558
immature*	39%	50% #	61% #
adult**	61%	50% #	39% #

3.3.6.4. Using bursa of Fabricius

Bursa size was used to identify young Little Corellas in the summer of 1991. Of the 250 Little Corellas sampled in that season, 162 (65%) were birds with large bursas.

Results obtained from gonad-based and moult-based analyses of age structure were in general agreement. Both suggested that immature birds were less numerous than adults in the 1989 summer season (41% of females and 39% of all birds were adults according to gonad-based analysis and moult-based analysis respectively). Thereafter, the proportion of immature birds progressively increased in successive years (88% of females and 61% of all birds were immature according to gonad-based analysis and moult-based analysis respectively in the summer of 1991). The predominance of young birds in the summer flocks was also confirmed by results obtained from the examination of bursas from 250 Little Corellas in 1991.

3.3.7. Seasonal dispersal based on breeding condition

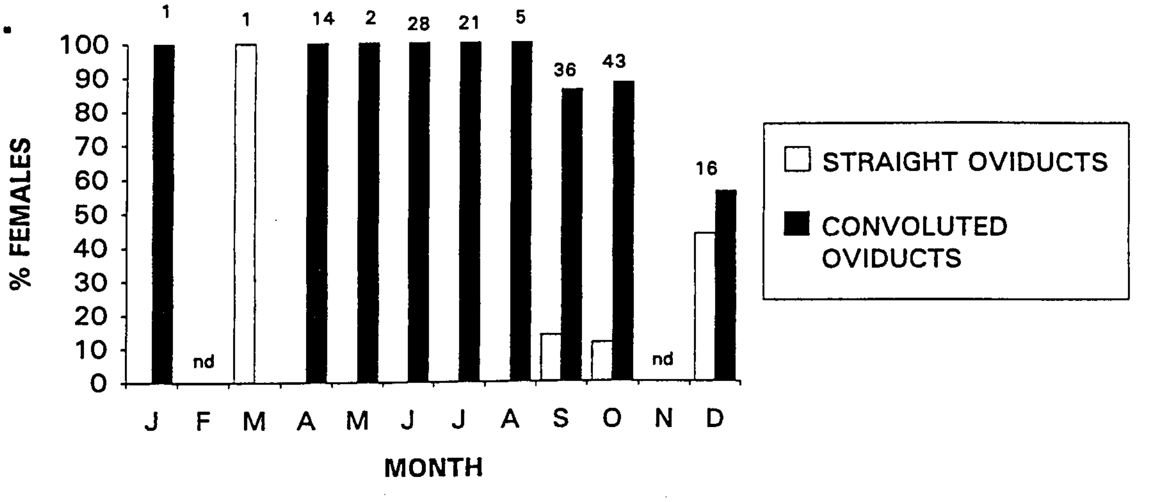
Most female Little Corellas encountered in the northern section of the study area in 1990 were birds of breeding status (Figure 3.21a). Some unbred females were also detected from September to December and these were probably young born in that breeding season. Few females were collected in the northern section during January-March. In contrast, the majority of female Little Corellas encountered in the southern section of the study area in 1990 were unbred birds (Figure 3.21b). Some females in breeding condition (less than 40%) were present in the southern section in most months.

3.3.8. Psittacosis status

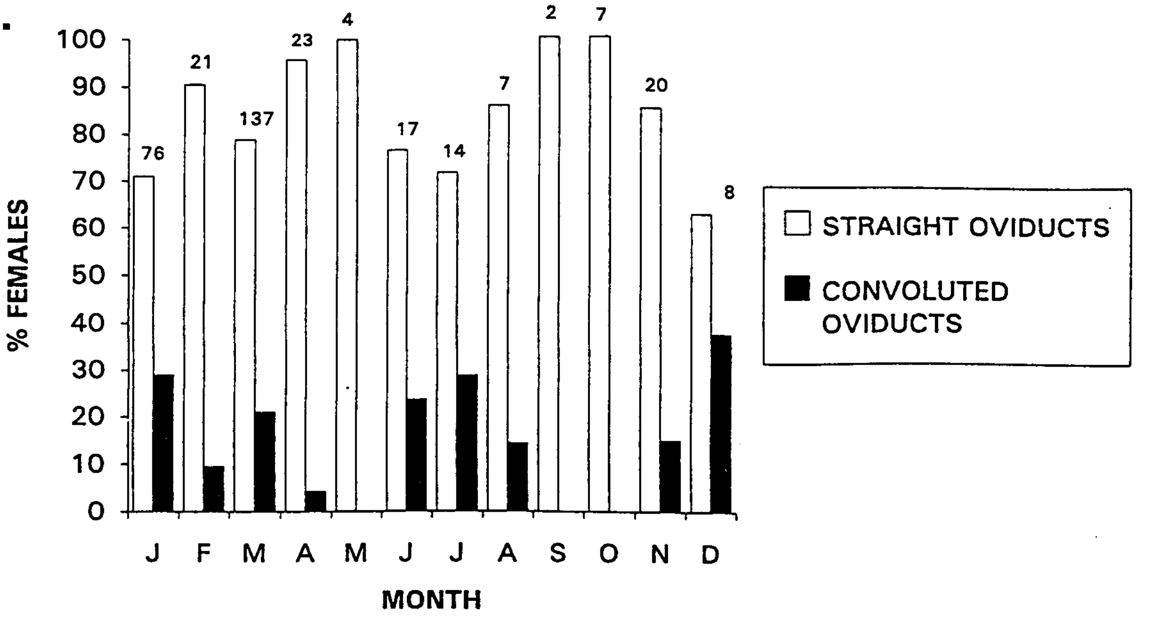
Disease-like states were reported in Little Corellas and Galahs in the southern study area in all years of the study. Sick or weakened birds were identified by their slowness to lift when startled and on capture, by a serous nasal discharge and severe diarrhoea resulting in

Figure 3.21 Breeding condition of female Little Corellas collected in the a. northern and b. southern Flinders Ranges (data pooled from all years). Numbers appearing above columns are sample sizes.

a.



b.



exposure of the keel and very low body weights (R. Henderson pers. comm.[7], pers. obs.). These symptoms tended to appear in large flocks during the autumn and were more noticeable if warm, wet weather conditions prevailed (pers. obs.). *Chlamydia psittaci* was isolated from Little Corellas and Galahs showing the above symptoms (M. Barton pers. comm.[8]) although, due to difficulties in obtaining suitable material, only a few birds were tested. A further 140 Little Corellas were tested for the disease as part of this study. Of these, approximately 40% were positive for *C. psittaci* (Table 3.7). There was no difference in psittacosis status according to sex and of the females tested, all were unbred birds (Table 3.7). Therefore the relative incidence of psittacosis in young and older birds could not be tested in this group of birds.

Table 3.7

Psittacosis status of Little Corellas captured on 21 March 1991 at *Depot Flat*, near Quorn. Birds were captured using the alphachloralose technique. All females were unbred birds.

Sex	n	Negative	Positive	Weak Positive	Total Positive
Females	73	62%	30%	8%	38%
Males	67	61%	36%	4%	40%
Total	140	61%	33%	6%	39%

[7]Mr R.C. Henderson, Senior Wildlife Ranger, South Australian National Parks and Wildlife Service, Port Augusta.

[8]Dr M. Barton, Chief Veterinary Microbiologist, Institute of Medical and Veterinary Science, South Australia.

3.4. DISCUSSION

3.4.1. Sexing

In the genus *Cacatua*, the sexes are difficult to distinguish on the basis of plumage alone although eye colour distinguishes male from female in the Pink Cockatoo (*Cacatua leadbeateri*, Forshaw and Cooper 1981). Eye colour and the size of the periopthalmic caruncülation are used to distinguish male from female in the related genus *Eolophus* (Rowley 1990). Other workers have used a variety of other morphological characters including measurements of bill dimensions and carcass weight to distinguish between the sexes in *Cacatua* (Table 3.8).

Table 3.8
Morphological characters used to distinguish between the sexes in the genus *Cacatua*.

Species Common name	Scientific name	Character	Source
Sulphur crested Cockatoo	*Cacatua galerita*	wing length culmen length	Forshaw 1968
		weight wing length culmen length tail length tarsus length	Forshaw & Cooper 1981
Little Corella	*Cacatua sanguinea*	weight wing length culmen length culmen width tarsus length tail length diameter of periopthalmic ring	Saunders 1978
		weight wing length culmen length tail length tarsus length	Forshaw & Cooper 1981
Long-billed Corella	*Cacatua tenuirostris*	weight wing length culmen length tail length tarsus length	Forshaw & Cooper 1981
Pink Cockatoo	*Cacatua leadbeateri*	weight wing length culmen length tail length tarsus length	Forshaw & Cooper 1981

Measurements of bill dimensions and carcass weights of Little Corellas collected in the Flinders Ranges show that males are heavier (regardless of collection time) than females and that their bills are larger. In contrast, female Little Corellas have wider ischia than males, presumably to facilitate the passage of eggs. There was considerable overlap between the sexes in the values for all characters and their usefulness in distinguishing between the sexes is doubtful. Results from this study indicate that mensural data from external characters are not sufficient to reliably distinguish male Little Corellas from female Little Corellas. These results are similar to those found by previous workers for this and other species of *Cacatua* (Forshaw 1968, Saunders 1978, Forshaw and Cooper 1981, Rowley 1990).

Saunders (1978) compared wing lengths and bill dimensions in male Little Corellas collected from Kununurra and the Pilbara-Gascoyne region in Western Australia. He found the Pilbara-Gascoyne males to be significantly smaller than Kununurra males and concluded that there were regional differences in the sizes of male birds. Regional differences in the sizes of Little Corellas in South Australia were not investigated in this study. However, a comparison of mean culmen length and mean culmen width between males collected from Kununurra WA, Pilbara-Gascoyne WA and Flinders Ranges SA suggests that Flinders Ranges males are more similar to Pilbara-Gascoyne males than to Kununurra males.

The overlap between the sexes in all parameters measured in this study and the regional variation in bird sizes found by Saunders (1978) suggest that Little Corellas can be reliably sexed only by internal examination.

3.4.2. Age structure of summer flocks

In a study of the Little Corella population of the Ord River development in Western Australia, Beeton (1985) used three techniques to determine the age structure of the population: the condition of the reproductive tract in females; the number of young fledged from a known number of nests; and counts of group sizes made during flyout from the evening roost (assuming that groups of 3 and 4 were family groups).

In this study, age structure analysis focussed on the post breeding congregation of Little Corellas in the summer months in the southern section of the study area. Three features were used to age Little Corellas and to construct an age structure for summer flocks: the condition of the gonads in females; the condition of the primaries; and the size of the bursa of Fabricius. The gonad-based technique was similar to that used by Beeton (1985). The moult-based method was applied to males and females collected during the summer months in each year of the study. The bursa-based technique was applied only to birds collected in summer 1991.

The techniques employed in this study used different criteria to classify "age". The gonad-based technique distinguished females that had bred either in the previous year or at some time in the past from females who were yet to breed. This, however, does not accurately describe the breeding history of any one female. Assuming that Little Corellas, like other psittacines, are capable of breeding at age three (Long-billed Corellas, GT Smith 1991; Galahs, Rowley 1990), this technique distinguishes birds of more than or less than three years of age.

The moult-based technique assumed that all birds moulting primaries were adult birds and all birds not moulting primaries were immature birds. Although moult pattern was strongly correlated with breeding condition, not all birds moulting primaries were of breeding status (Figure 3.20b) and this technique underestimated the relative proportion of immature birds in the flock.

The bursa of Fabricius, an organ situated near the cloaca, grows rapidly between hatching and 3 weeks of age, then regresses in the period preceding the onset of sexual maturity (e.g. within 8 weeks for the domestic fowl, (Glick 1983) and within 2 years for the domestic goose (King and McLelland 1984)). Interpretations of bursa size and bird age were restricted to distinguishing young Little Corellas (large bursas) from older birds (small/absent bursas) (King and McLelland 1984).

Despite these differences, age structure analysis by gonad condition and by moult pattern gave broadly similar results. Both showed that there was a predominance of adult birds/bred females in southern summer flocks in 1989 and both suggested that younger birds dominated summer flocks in the following two years. Results from the bursa-based technique in 1991 confirmed age structure analysis based on condition of the female gonads and of primaries i.e. that summer flocks in the southern section of the study area comprised a mixture of mature and immature birds and that immature birds were more numerous. Beeton (1985) also found that Little Corella flocks comprised mostly non breeding birds (*ca* 70%) and that breeding pairs made up only a small proportion (*ca* 20%) of the population.

Assuming that the breeding status of female Little Corellas accurately reflected breeding status of the flock as a whole, gonad-based analysis implied that in 1989, the summer flock comprised mainly sexually mature birds whilst sexually immature birds were in greater proportion in the following two summer periods. The predominance of breeding birds in summer flocks in the first year of the study could be explained by low productivity of breeding birds or high mortality rate amongst juvenile/unbred birds in the years preceding the study. The shift in proportions of breeding to non breeding birds could be interpreted as a high breeding success in the season following the record rains in March 1989 which resulted in a high proportion of young birds in the flocks returning to the southern Flinders in the following summer (1990). The continuing predominance of unbred birds in 1991 could result from (1) high breeding success in 1990, (2) a high survival rate amongst juveniles born in spring 1989 or both.

Seasonal conditions may also influence the pattern of bird movements in the study area to the extent that changes in the relative proportions of adults and juveniles in southern summer flocks are masked. For example, in dry years when food availability is low, more adults (breeders and non breeders) may move south in the summer in order to feed, and thus shift the composition of the flock towards older individuals. Similarly, after a good season, non breeding adults may remain dispersed and only breeding adults accompanied by their young may move into southern areas and thus bias flock composition towards younger birds. Further clarification of these issues was beyond the scope of the study except to note that poor winter seasons appeared to concentrate birds in the southern study area during summer.

3.4.3. Annual cycle of the Little Corella in the Flinders Ranges

Little Corellas showed a distinct annual cycle in the Flinders Ranges in South Australia. The birds congregated in the southern study area during the summer and flocks comprised mainly juvenile and non-breeding birds. Adult birds moulted in summer when body masses were relatively low. At this time, testes in males were regressed and ovarian follicles in females were small suggesting that no breeding activity took place. Fat levels in southern birds were high in the summer when birds were feeding on fallen grain in the stubble paddocks. Fat levels declined significantly in autumn and this corresponds to loss of food sources caused by germination of grain following autumn rains.

Little Corellas dispersed from the southern study area during autumn and winter. Gonad-based analysis of the females in both sections of the study area during the winter months showed a predominance of non-breeding females in the south and of breeding females in the north. In male Little Corellas, seasonal variation in testicular volume was more marked in northern birds than in southern birds. These data suggest a seasonal partitioning of birds based on breeding status. Breeding birds may leave their young and other immature birds behind in the southern study area during winter and these then form local nomadic flocks. Rowley (1983a, 1990) and Smith and Moore (1992) found similar trends in the Galah

(*Eolophus roseicapillus*) and the Western Long-billed Corella (*Cacatua pastinator*) respectively.

Little Corellas breed in the gum-lined creeks of the northern section of the study area. Males and females of breeding status experienced a steady increase in the size of testes and ovarian follicles during late winter and spring (June-September), and young hatched as early as September. Fat levels in northern birds improved from summer to winter and high fat levels in winter coincided with peak carcass weights (Figures 3.7 and 3.9). Thereafter fat levels and body weight declined, presumably in response to the energetic demands of egg-laying, incubation and rearing of young. The level of stored body fat in birds remaining in the northern study area during summer was low. Low fat levels during the summer may be the stimulus for northern birds to move south into the agricultural areas to feed on the predictable and abundant supply of grain fallen in the stubble paddocks.

Fat levels in birds overwintering in the southern study area were as high as those recorded in summer and then declined in the spring. The demands of breeding could account for a loss in body condition during spring except that few Little Corellas in the southern section were birds of breeding status, and the decline in body condition was noted in birds with undeveloped gonads. Young birds underwent moult in spring. In addition, the predominant seed found in spring crop samples was wheat (*Triticum aestivum*, see Figure 2.12 and Table 2.7) although all seeds were unripe (green and/or doughy stage). When compared to fully ripened grain, doughy grain or green wheat has a high moisture content and a low dry matter content (S. Jefferies pers. comm.[9]). i.e. the birds principal food source during spring was of poor quality. Either the energetic demands of moulting or the consumption of poor quality food (or a combination of both) could account for the decline in body condition noted in birds in the southern flocks in spring.

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[9]Mr S. Jefferies, Research Agronomist, Northfield Research Laboratories, South Australian Department of Primary Industries, Northfield.

In late spring, Little Corellas from the entire study area again congregated in the southern study area for the duration of the ensuing summer.

3.4.4. Incidence of disease in summer flocks

As noted for Galahs (Rowley 1990), Little Corellas fall prey to predators such as cats (*Felis catus*) and raptors (e.g. Wedge tailed Eagle *Aquila audax* and Peregrine Falcon *Falco peregrinus*). They collide with vehicles, especially when feeding on grain spills along roads, and are often shot. Environmental factors can also cause deaths e.g. GT Smith (1991) showed that extreme summer temperatures adversely affected survival of juvenile Long-billed Corellas. However, predators including humans are of less threat than contagious diseases. Rowley (1990) reported high mortality rates (>60%) in Galahs that contracted an unidentified "wasting syndrome" in the nest. Other contagious diseases such as beak-and-feather syndrome, viral diarrhoea and psittacosis may also be important in free living psittacines.

Beak-and-feather syndrome is caused by an enterovirus-like organism and is widespread in free living psittacines (D. Pass pers. comm.[10]). The disease causes progressive loss of primary feathers and body feathers and members of the genus *Cacatua* appear to be more susceptible than other psittacines e.g. *Calyptorhynchus, Nymphicus*. Viral diarrhoea is caused by an enterovirus and usually occurs concurrently with beak-and-feather syndrome (D Pass pers. comm.).

Psittacosis is caused by the bacterium *Chlamydia psittaci* and is often endemic in wild populations of psittacines. There are no characteristic clinical signs of the disease in birds (Campbell and Lack 1985) and the disease can vary from a subclinical to an acute systemic infection (Cooper 1990). Infection is by ingestion and aerosol inhalation (Brand 1989) and possibly avian lice in flocking species (Burkhart and Page 1971). Behavioural traits such as communal roosting, allopreening and drinking from common water may enhance the

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[10]Dr D. Pass, Animal Resources Centre, Murdoch University, Western Australia

transmission of the disease (Brand 1989) and stressful conditions such as moulting, feeding young and extremes in temperature may determine the severity of the infection (Burnett 1939 in Burkhart and Page 1971, Brand 1989). In the case of all diseases mentioned, younger birds appear to be more susceptible than older birds suggesting that adult birds can develop immunity (Campbell and Lack 1985, Rowley 1990). The significance of disease to populations of wild psittacines is not fully understood although some authors postulate that psittacosis and beak-and-feather syndrome are endemic to Australia and probably co-evolved with the avifauna (Brand 1989). Mykytowycz *et al.* (1955 in Brand 1989) suggested that ornithosis (*syn* psittacosis) may be a factor in controlling Short-tailed Shearwater (*Puffinis tenuirostris*) populations. Brand (1989) points out that whilst widespread mortalities directly attributable to disease may not be common, the chances of detecting an epizootic event are extremely small. Diseases may also be responsible for sublethal effects on bird populations such as retarded growth and depression of egg laying, with greater consequences for the population than outright mortalities.

Chlamydia psittaci was isolated from Little Corellas and Galahs in the southern study area during summer. A high proportion of Little Corellas tested for psittacosis were positive. This does not describe the incidence or likelihood of the fully expressed disease, nor can it predict lethal or sublethal effects on the population. However it does suggest that diseases such as psittacosis could be important factors affecting mortality rates in free flying populations of Little Corellas.

3.4.5. Other factors affecting natality, survival and mortality

This study focussed on the behaviour and ecology of the Little Corellas forming large flocks in the period following breeding, particularly those congregating in the southern section of the study area during the summer months. Time constraints prevented long term studies of the breeding biology of the Little Corella in this area. Therefore interpretations of the factors influencing natality, survival and mortality in Little Corellas have been drawn from studies of Little Corellas in other parts of the continent (Beeton 1977, 1985) and studies of related species (e.g. Long-billed Corella, GT Smith 1991; Galahs, Rowley 1990). Where possible, conclusions from other studies are discussed with reference to results from this study.

Beeton (1977) found that the Little Corella population in the Ord River was comprised largely of non breeding and unpaired birds (*ca* 80% of all birds) and a small breeding core (*ca* 20%). The size of the breeding core appeared constant over time despite the availability of suitable unoccupied nest hollows in the preferred *Adansonia gregorii* and other tree (*Eucalyptus* sp.) species. Similarly, neither nest hollows nor food resources were limiting in populations of Galahs and Long-billed Corellas in Western Australia (Smith and Saunders 1986). Rowley (1990) also concluded that the breeding core comprised a small proportion of the Galah flock (*ca* 25%) with the majority made up of unmated adults, immature birds and young from the previous spring. Similar results were found in this study in that bred birds (the "breeding core" of Beeton, 1977) were less numerous than unbred birds in southern summer flocks in two of three years.

Long-billed Corellas and Galahs reach sexual maturity at age 3 years although not all birds reaching sexual maturity actually form pairs and breed (GT Smith, 1991; Rowley, 1990). GT Smith (1991) reports that female Long-billed Corellas breed for the first time between age 3 and 5 and that males do not begin until age 5. In this study, one female banded in 1988 was shot three years later during routine collection of specimens. Her ovary was differentiated but, judging by the condition of her oviduct, she had not bred. Assuming she was between 3 months (i.e. young of the previous spring) and 3+ years old at the time of banding, she was between 3 and 6+ years old when shot.

Why the breeding core should remain small when unmated individuals of both sexes and of suitable age are present in the flock is an unanswered question. Neither nest hollows nor food availability are necessarily limiting and perhaps social factors related to dominance and hierarchy operate to prevent some birds from pairing and successfully mating i.e. most recruits come from a few very successful pairs (Rowley 1983b).

The productivity, or breeding success, of a population determines the number of animals recruited to that population. Other workers have attributed variations in the productivity of cockatoo populations to a number of seasonal and environmental factors including timing and quantity of winter rain and summer temperatures. Beeton (1977, 1985) concluded that breeding success in Little Corellas was determined by seasonal differences in forage quality and quantity. Similarly, Smith and Saunders (1986) and GT Smith (1991) suggested that timing and amount of winter rainfall could influence productivity in Galah and Long-billed Corella populations by determining the abundance of food early in the breeding season. Both related low productivity to below-average rainfall in the preceding winter.

Productivity in Little Corellas in the Flinders Ranges was also affected by seasonal conditions, albeit favourably. Results from this study showed a significant increase in the proportion of young birds in summer flocks in 1990 following above-average rainfall (40%-50% above average) in the preceding autumn and winter . Whether this represents "normal" productivity following poor seasons in the years prior to the study or increased (i.e. more than "normal") productivity in response to favourable conditions could not be determined. Pulses of increased productivity following favourable conditions may in fact be the usual pattern of recruitment in this species. Longer term studies would be required to clarify this further. Seasonal differences between 1989 and 1990 also appeared to influence ovum size in females and timing of rainfall affected timing of peak testis volumes in males. Birds in the southern study area maintained significantly higher levels of stored body fat than birds in the north, possibly due to the prevalence of wheat in the diet of the former. The majority of southern birds were sexually immature birds (including young of the previous year) and a nutritious diet may enhance the survival of juveniles and immatures at a time when normally, mortality rates are high (Rowley 1983a).

CHAPTER 4.

IMPACT OF LITTLE CORELLAS ON RIVER REDGUMS IN THE FLINDERS RANGES.

4.1. INTRODUCTION

Broadscale clearance of vegetation in Australia has caused soil erosion, soil and water salinisation and loss of wildlife habitat (Copley and Venning 1983, Oates 1983, Saunders *et al.* 1985, Bishop 1987). Retention of remnant vegetation is necessary to prevent further soil loss, to protect water catchments and to assist in the conservation of remaining wildlife species. Effective retention depends on the health of the standing population of trees and on tree regeneration. However, tree decline and dieback are widespread in forests, remnant woodlands and rural areas in Australia (Old *et al.* 1981, Kile 1981, Podger 1981, White 1986). Tree decline is defined as a reduction in the number of trees whereas dieback describes the deteriorating vigour in extant trees (Sullivan and Venning 1982). Prolonged dieback (loss of vigour) can result in tree death.

Many factors, both biotic and abiotic, have been proffered as causes of rural tree decline and dieback. Included among them are fungal disease (Podger 1981), root disturbance and soil compaction by stock (Kile 1981), water stress (White 1969, 1986), salinisation (Morris 1981, Wylie and Bevege 1981a, b) and the defoliation stress caused by insects (Landsberg 1988, 1990a, b, c) and other wildlife species (Martin 1985). Broadscale vegetation clearance that leaves scattered trees in paddocks has made those isolated remnants more susceptible to physical damage, salinisation and insect attack (Neumann *et al.* 1981). Several factors may operate concurrently and stresses may have cumulative effects on tree health and vigour such that one stress may predispose trees to suffer proportionally more under the influence of additional stresses. For example, salt tolerance in eucalypts is reduced if the tree is stressed by disease or insect attack (Morris 1981). Landsberg (1988) found that dieback of trees on the New England tableland was associated with increased herbivory by leaf chewing insects. Subsequent work (Landsberg 1990a, b, c) showed that leaf chewing insects preferentially attacked leaves with high foliar nitrogen and water content. Such conditions were often found in foliage that had regrown (epicormic growth) after an environmental stress such as drought, fire or herbivore grazing. Therefore any condition that promotes a flush of epicormic growth may predispose that tree to insect attack. The longer term implication of a cycle of defoliation and regrowth is a reduction in, and possible exhaustion of, starch reserves leading eventually to the death of the tree (Bamber and Humphries 1965).

In the southern Flinders Ranges of South Australia, Little Corellas form large post-breeding flocks during the summer months (see Chapter 2). During this time, Little Corellas roost in River Redgums along creeks, and defoliate the trees by pruning leafy sprays from the outer canopy. Communities in the southern Flinders Ranges are concerned about declining tree health in roost areas and possible loss of trees.

An investigation of pruning impact on canopy condition in roost trees asked the following questions:

1. **Does pruning by corellas affect condition of roost trees?**

2. **What factors affect the amount of damage done by the roosting flock?**

3. **What are the characteristics of Little Corella roosts?**

4. **Are there any special features of roosts such that some roost trees are affected more than others?**

5. **What other factors affect the health of trees in the southern Flinders Ranges?**

6. Do other factors influence the survival of the River Redgum population in the Flinders Ranges?

4.2. METHODS

4.2.1. Identification of Roosts.

Little Corella roosts were identified by the presence of large numbers of birds using the creek area as a night roost. Roosts were also identified by the presence of severed leafy sprays littering the ground, by the copious amounts of bird faeces under trees, and by the characteristic "stagged" appearance of trees that the birds had attacked i.e. loss of upper, outer canopy and inner canopy intact. The roost area was defined as a section of creekline containing trees showing evidence of pruning damage either presently or in the recent past. Where sections of undamaged trees were interspersed with sections of damaged trees, each section of damaged trees was considered a separate roost.

4.2.2. Assessment sites

Six roost sites at four locations were chosen for a closer examination of pruning damage to roost trees (Figure 4.1). The sites were selected on the basis that at least 1,000 Little Corellas had roosted at the site in most years in the recent past. Three sites were chosen in the Quorn area to provide some replication within the area where tree damage appeared worst. Other sites differed in rainfall (Richmans Valley, Melrose) and/or aspect (Baroota). Table 4.1 provides details of aspect, average annual rainfall, reliability of creek flow and groundwater salinity at each site. Tree height and breast height diameter (BHD-1.2m from ground) were measured using a clinometer and tape measure at Stoney Creek and Pichi Richi Creek in Quorn, at Capowie Creek in Richmans Valley and at Mount Remarkable Creek in Melrose.

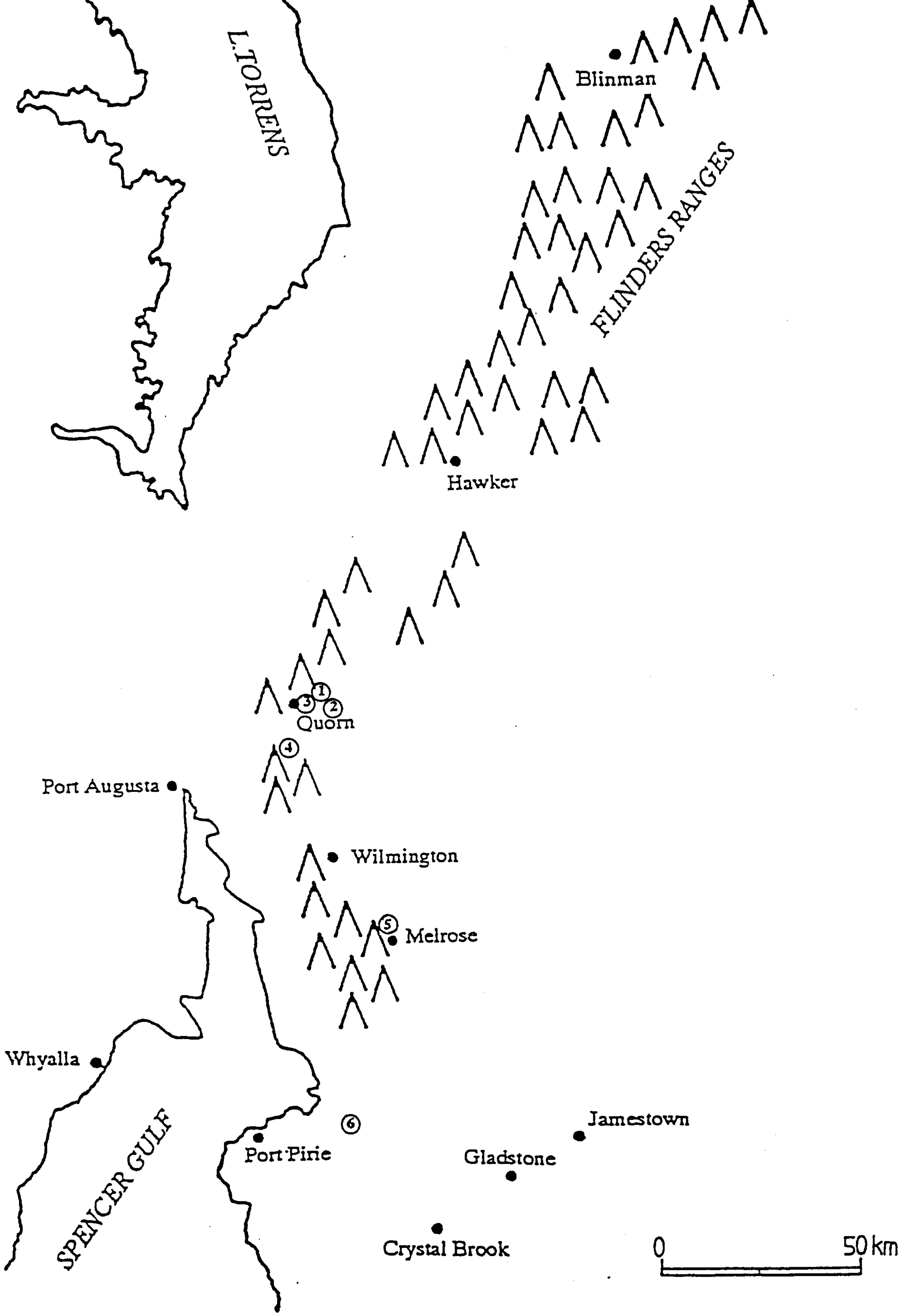


Figure 4.1

Location of the six roost sites chosen for assessment of change in canopy conditior during the study period. 1: Stoney Creek, Quorn. 2: Pichi Richi Creek, Quorn. 3: Pinkerton Creek, Quorn. 4: Capowie Creek, Richmans Valley. 5: Mount Remarkable Creek, Melrose. 6: Baroota Creek, Baroota.

Table 4.1

Differences in average annual rainfall, reliability of creek flow and groundwater salinity between all sites where visual assessments of canopy condition were made.

Site	Aspect (E or W of Flinders Ranges)	Average Annual Rainfall (mm)	Reliability of creek flow	Ground water salinity TDS* (mg/l)
Stoney Creek Quorn	East	330	Intermittent	1,400-19,000 (most 2,000 -6,000)
Pinkerton Creek Quorn	East	330	Intermittent	"
Pichi Richi Creek Quorn	East	330	Intermittent	"
Capowie Creek Richmans Valley	East	446	Intermittent	"
Mount Remarkable Creek, Melrose	East	586	Usually annual	500-1,200
Baroota Creek Baroota	West	379	Continual	600-1,000

* TDS=Total Dissolved Solids

Commonwealth Bureau of Meteorology provided rainfall data and South Australian Department of Mines and Energy provided salinity data (D. Clarke, Officer-in-Charge, Crystal Brook Regional Office). Information regarding creek flow was obtained from local landholders.

4.2.3. Bird numbers at assessment sites

Regular assessments of the sizes of the evening roosts were made at the six sites. The size of the evening roost was measured by counting either the number of Little Corellas flying into the roost in the period 2.5-3.0 hours before last light, or the number of Little Corellas flying out from the roost between dawn and 7.30 a.m. Roost persistence was defined as the number of days that more than 500 Little Corellas used a particular roost during the summer season expressed as percentage of the length of the summer season. The summer season was the period extending from the time that Little Corellas first arrived in the district (usually the first week in November) until seven days after significant rains fell in the following late summer or early autumn. Significant rainfall was defined as that sufficient to cause germination of fallen grain, the principal food of Little Corellas, in the stubble paddocks. Germination of fallen grain occurs following either rainfall greater than 50mm, or rainfall greater than 25mm followed by a further 25mm or more within the following three weeks (S. Jefferies pers. comm.). Once the fallen grain has germinated, this food source is no longer available to the birds and food resources become scarce. A general dispersal of Little Corellas and a reduction in flock size and roost persistence usually followed these rain events.

4.2.4. Assessment of roost tree condition

The condition of trees in the roosts was assessed using a visual technique and a photographic technique. The visual assessment technique was designed to assess the condition of all trees in the roost. The photographic assessment technique followed the fate of individual trees and provided verification for the visual assessment technique. Results from the visual technique described canopy condition while the photographic technique described canopy cover.

4.2.4.1. Visual Assessments

Visual assessments were made at the same six sites in April or May of each year at a time when bird damage was most obvious in roost trees, and before a flush of spring growth had obscured pruning damage done in the previous summer. Within the roost area, all trees greater than 2m in height were assessed and assigned to one of the following four categories:

1. Canopy largely intact, no epicormic growth, no twigging or stagging (see below), and little or no evidence of pruning by Little Corellas;

2. Some loss of very outer canopy (twigging-usually at the apex of the tree), some epicormic growth may be evident, and some evidence of pruning by Little Corellas;

3. Substantial loss of outer canopy, branches in upper, outer canopy bare (stagging), epicormic growth common on branches, and substantial evidence of pruning by Little Corellas;

4. No foliage, tree dead.

On each occasion, visual assessments of the roost were made three times by the same observer. Raw scores were averaged for the three counts and the number of trees falling into each category was expressed as a percentage of total number of trees in the roost. These percentage scores were used as a measure of canopy condition in the whole roost. Contingency tables and Chi-squared analysis were used to test for differences in canopy condition between roost sites and between years. The numbers of trees less than 2m tall were counted to measure the extent of tree regeneration in each of the roosts.

4.2.4.2. Photographic Assessments

At the start of the project, three of the six sites used for visual assessments were also used for photographic assessment of canopy cover. At two sites, five trees from each of the first three categories were chosen randomly and marked using a unique code (15 trees per site, Stoney Creek and Capowie Creek). At the third site (Mount Remarkable Creek), only 11 trees were chosen and marked because foliage from adjacent trees obscured a clear view of the target canopy. One site (Capowie Creek) included an additional five trees that showed no sign of recent attack. Photographic assessments were conducted in June in each of the three years. June was chosen as a time when bird damage was still obvious in roost trees prior to a flush of growth in spring.

A series of black and white photographs was taken of the outer canopy by an observer standing underneath the canopy of the target tree. A 35mm lens was used to photograph the canopy directly overhead. Usually, eight photographs were taken of each tree, one at each of the eight points of the compass (Figure 4.2). The distance between the trunk and the photograph varied according to the shape of the canopy (Figure 4.2). The same sections of canopy were photographed each year (Figure 4.3). The film was developed and individual photographs were mounted as slides. Each slide was then projected onto a dot matrix measuring 57cm by 86cm and containing 1230 dots (after Zohrer 1978). The number of dots falling on leaves and twigs were counted for four of the eight slides (usually north, south, east and west) and summed. The total number of dots (leaf plus bare twig) was used as a measure of total canopy cover. To test for differences in canopy cover between sites and between years, two-way Analyses of Variance were performed on raw scores (total number of dots) and transformed data ($\log_{10}$(total number of dots)). At each site, differences in canopy cover between years were investigated further using Tukey's Multiple Range tests (raw scores (total number of dots) and $\log_{10}$(total number of dots)). Differences in canopy cover between sites and between years was also tested using Kruskal-Wallis one-way Analysis of Variance (raw scores). Results from the two-way Analyses of Variance using raw scores and transformed data were similar, as were results of Kruskal-Wallis tests, and thus only results for two-way Analysis of Variance (raw scores) are presented.

4.2.5. Relationship between bird numbers and prunings

The relationship between bird numbers and prunings of roost trees was examined during the period November 1989 to April 1990. Five places covering occasional roosts (roost persistence<15%) and regular roosts (roost persistence>15%) along Capowie Creek (Figure 4.4) were chosen and, at each place, three groups of trees with similar canopies were identified. A single plastic sheet was laid on the ground underneath each group of trees at each place (fifteen "nappy" sheets at five sites). Each sheet measured 10m by 2m

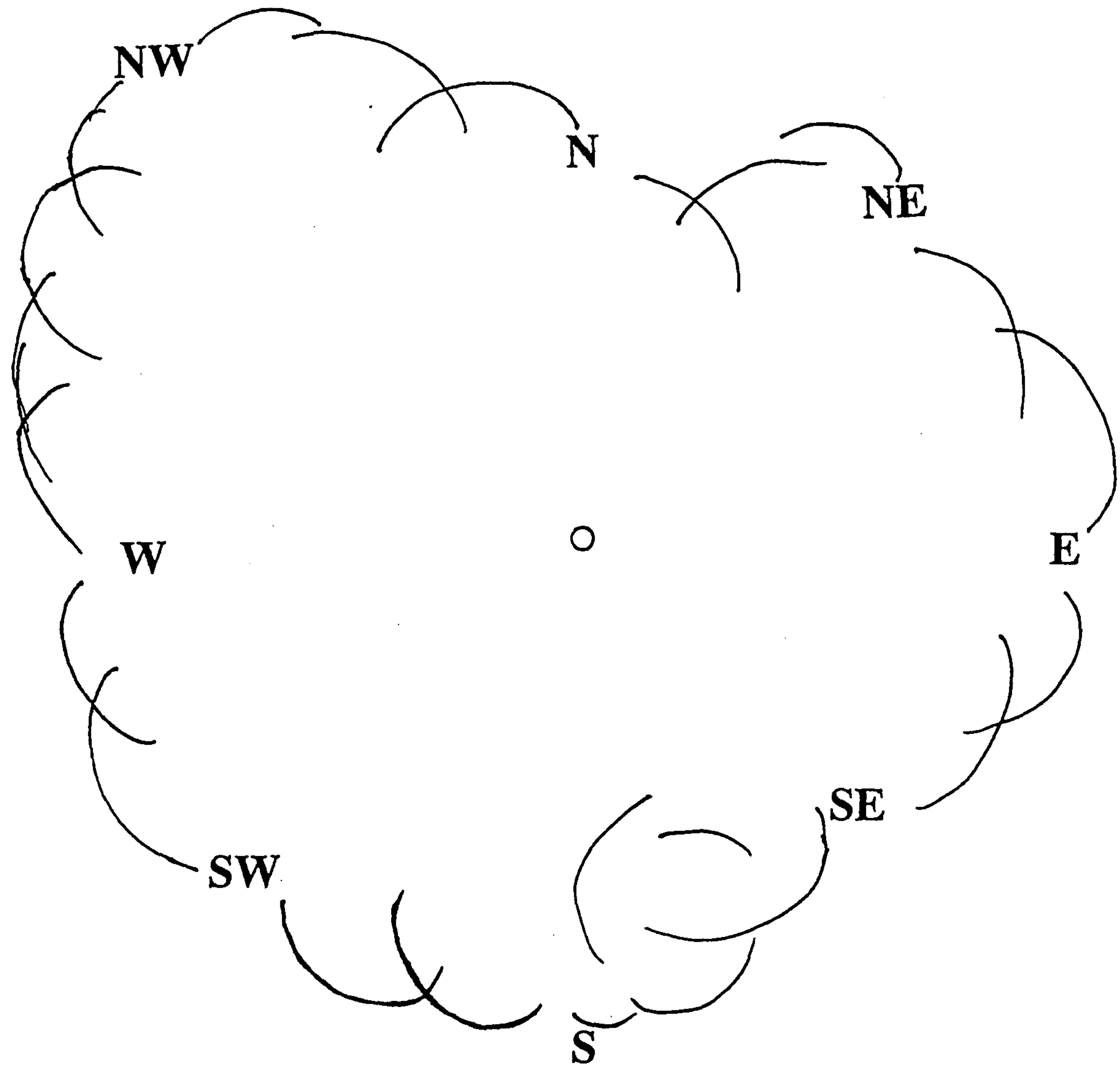


Figure 4.2

Aerial view of the tree canopy showing the position of the eight canopy photographs.

1989

1990

1991

Figure 4.3

Canopy negatives from tree B3, Richmans Valley for the years 1989-1991. Negatives were projected onto a dot matrix and all dots falling on leaf or twig were summed and used to assess canopy cover (prints of negatives presented).

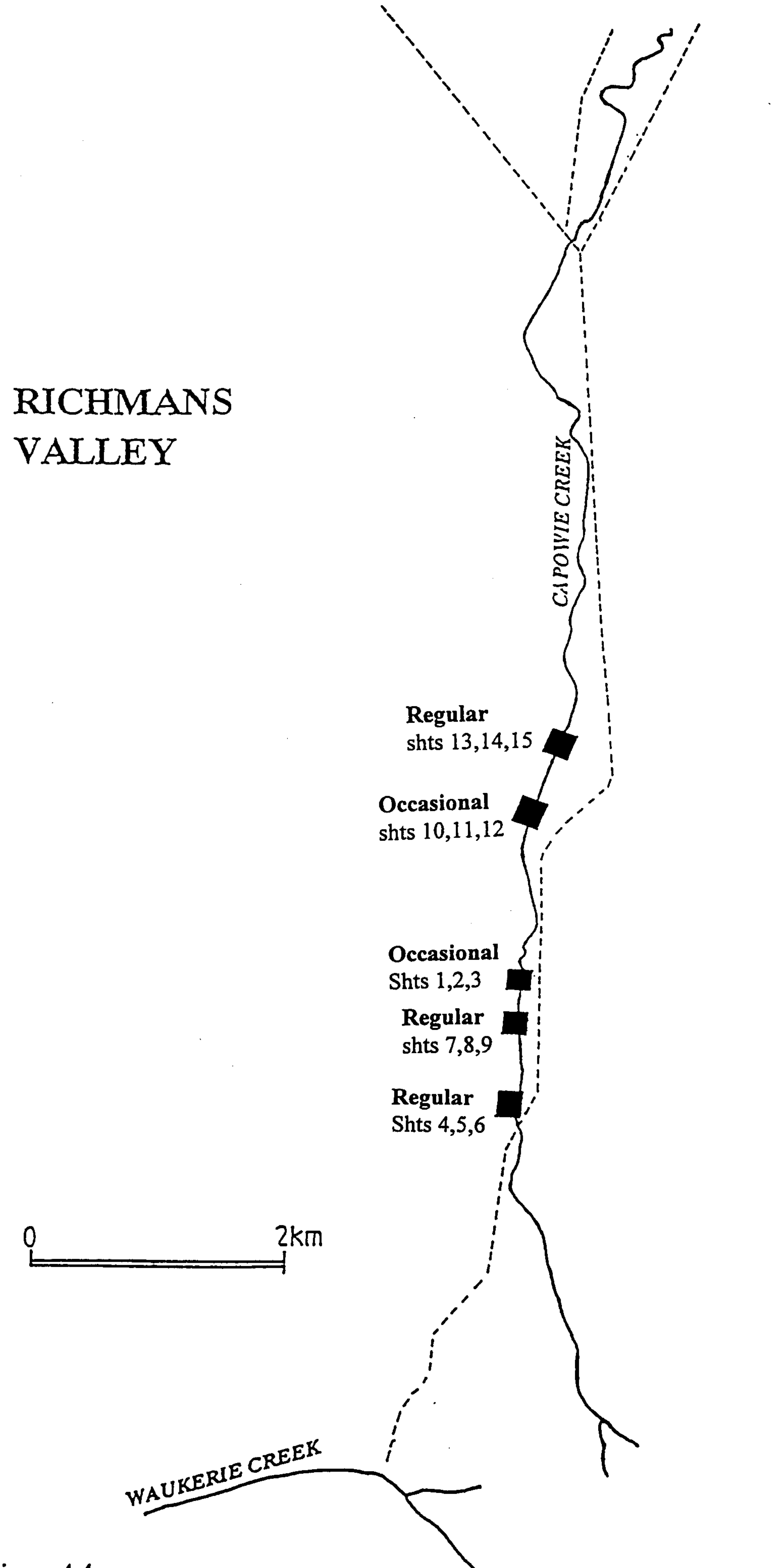


Figure 4.4
Location of the five groups of trees (and sheet numbers) used to measure the number of leafy sprays and leafless twigs falling in regular and occasional roosts (---- road).

($20m^2$). The number of leafy and leafless prunings, and the number of bird faecal events, falling onto each sheet was counted either daily or every 2-3 days.

4.2.6. Relationship between tree condition and distance from water.

In order to examine the relationship between tree condition and proximity of the roost to water, assessments of canopy condition in trees close to established watering points (stock troughs and dams) were made using both visual and photographic techniques (see above). In 1991, canopy condition in a sample of trees was assessed using the visual technique every 100m along a 3.2 km section of Capowie Creek Richmans Valley, south of Quorn. The position of all watering points in the creek was also noted. More detailed information was collected on ten trees using the photographic technique. These trees were situated on the border of a traditional roost in Capowie Creek at various distances from a farm dam used regularly by Little Corellas. Canopy cover was measured for each tree (1991 data set) and the relationship between tree condition (canopy cover) and distance from the dam was examined using Linear Regression.

4.3. RESULTS

4.3.1. Characteristics of Little Corella roosts

Little Corellas used the River Redgums of some of the creeklines in the southern study area as their day and night roosts during the summer. Roosts were identified by the characteristic stagged appearance of the trees where the majority of the upper and outer canopy had been lost due to the pruning activities of roosting Little Corellas. Compared to the whole creekline, roosts were generally confined areas centred around established watering points. The average length of creekline affected varied according to site and year but did not usually extend much beyond 3km (Table 4.2).

Table 4.2

Length of creekline affected by the pruning activities of roosting Little Corellas in the southern Flinders Ranges during 1989-1991. The affected area was defined as a section of creekline containing trees showing evidence of pruning damage, either presently or in the recent past. Where sections of undamaged trees were interspersed with sections of damaged trees, separate sections of damaged trees were considered separate roosts. The length of creekline occupied by each roost along one creek was summed and expressed as a percentage of the length of the entire creekline (values shown in brackets).

Site	Length of creekline surveyed (km)	Length of creekline affected (km)		
		1989	1990	1991
Stoney Creek Quorn	5	2.3 (46%)	0	0.4 (8%)
Pinkerton Creek Quorn	5.5	2.6 (47%)	2.6 (47%)	2.6 (47%)
Pichi Richi Creek Quorn	6	3.2 (52%)	1.3 (21%)	1.3 (21%)
Capowie Creek Richmans Valley	15	2.6 (17%)	2.5 (17%)	2.5 (17%)
Mount Remarkable Creek, Melrose	8	0.7 (9%)	0	1.2 (16%)
Baroota Creek Baroota	6	1.3 (21%)	0	1.2 (19%)

Little Corellas also used Northern Cypress Pine (*Callitris columellaris*), Peppermint Box (*Eucalyptus odorata*) and Long-leaved Box (*E. goniocalyx*) as roost trees (Badman 1989, pers. obs.). A list of tree species known to be pruned by Little Corellas is presented in Table 4.3.

Table 4.3

A list of tree species pruned by Little Corellas.

Common Name	Scientific name	Source
River Red Gum	*Eucalyptus camaldulensis*	Palmer (1991); Badman (1989); Pers. obs.
Peppermint Box	*E. odorata*	Pers. obs.
Long-leaved Box	*E. goniocalyx*	Badman (1989)
Red Mallee	*E. socialis*	Badman (1989)
Lemon scented Gum	*E. citriodora*	Badman (1989)
European Olive	*Olea europaea*	Badman (1989); Pers. obs.
Northern Cypress Pine	*Callitris columellaris*	Pers. obs.
Almond	*Prunus dulcis*	Pers. obs.
Norfolk Island Pine	*Araucaria heterophylla*	J Coombe (pers. comm.)
Moreton Bay Fig	*Ficus macrophylla*	J Coombe (pers. comm.)
Allepo Pine	*Pinus halepensis*	J Coombe (pers. comm.)
Candle Pine	*Cupressus sempervirens*	pers. obs.
Athel Pine	*Tamarisk aphylla*	Badman (1989); Pers. obs.

J. Coombe, District Clerk, District Council of Strathalbyn

4.3.2. Pruning behaviour

During the summer, Little Corellas showed a consistent pattern of daily behaviour. Included in this pattern were two periods of roosting: the day roost, where Little Corellas sought shelter from the sun in the canopy of trees during the middle of the day; and the nocturnal roost when birds congregated in the outer canopies of roost trees in the late afternoon (pers. obs.). Pruning took place during both roosting periods. Day roosts and night roosts often coincided but in cases where they did not, day roosts were often difficult to find. Therefore, events at the night roost were taken as a general model to describe the impact of Little Corellas on roost trees.

Roosting Little Corellas perched in the canopy and took the terminal leafy sprays in their beaks. The spray was usually severed from its branchlet, the severed end was often chewed and the spray was then allowed to fall to the ground. The birds then chewed and/or severed the remaining denuded twigs and thus pruning drop typically consisted of both leafy sprays and small chewed twigs (Figure 4.5). Pruning activity was usually confined to the upper, outer canopy whilst the inner canopy was left largely intact (Figure 4.6).

4.3.3. Site differences at assessment sites

Study sites differed from each other in several ways. There was a distinct north-south decline in average annual rainfall at sites on the eastern side of the Flinders Ranges i.e. average gaugings were highest at Melrose (586 mm pa) intermediate at Richmans Valley (446 mm pa) and least at Quorn (330 mm pa). Baroota, the only site located on the western side of the ranges, has an average annual rainfall of 379 mm (Table 4.1). Actual rainfall gaugings recorded during the study reflected the same north-south decline. At Quorn, Richmans Valley and Melrose rainfall was below average in 1988 (10%-23% below) and above average in 1989 (17%-57% above; Figure 4.7). Rainfall at the remaining study site, Baroota Creek, was close to the long term average in 1988 and 1989. Rainfalls at all sites were close to the long term average in 1990 and below average rainfalls were again recorded in 1991 (17%-24% below; Figure 4.7).

Creeks at the more northern sites, Quorn and Richmans Valley, did not necessarily flow each year. However, Mt Remarkable Creek at Melrose, due to its position at the base of Mt Remarkable and large catchment area, flowed in most years (Table 4.1). Similarly, Pichi Richi Creek at Quorn which is situated downstream of the confluence of three other creeks received comparatively high volume flows. Flow in Baroota Creek was continuous, although of low volume, due to leaking from the Baroota Reservoir upstream (R. Merrick

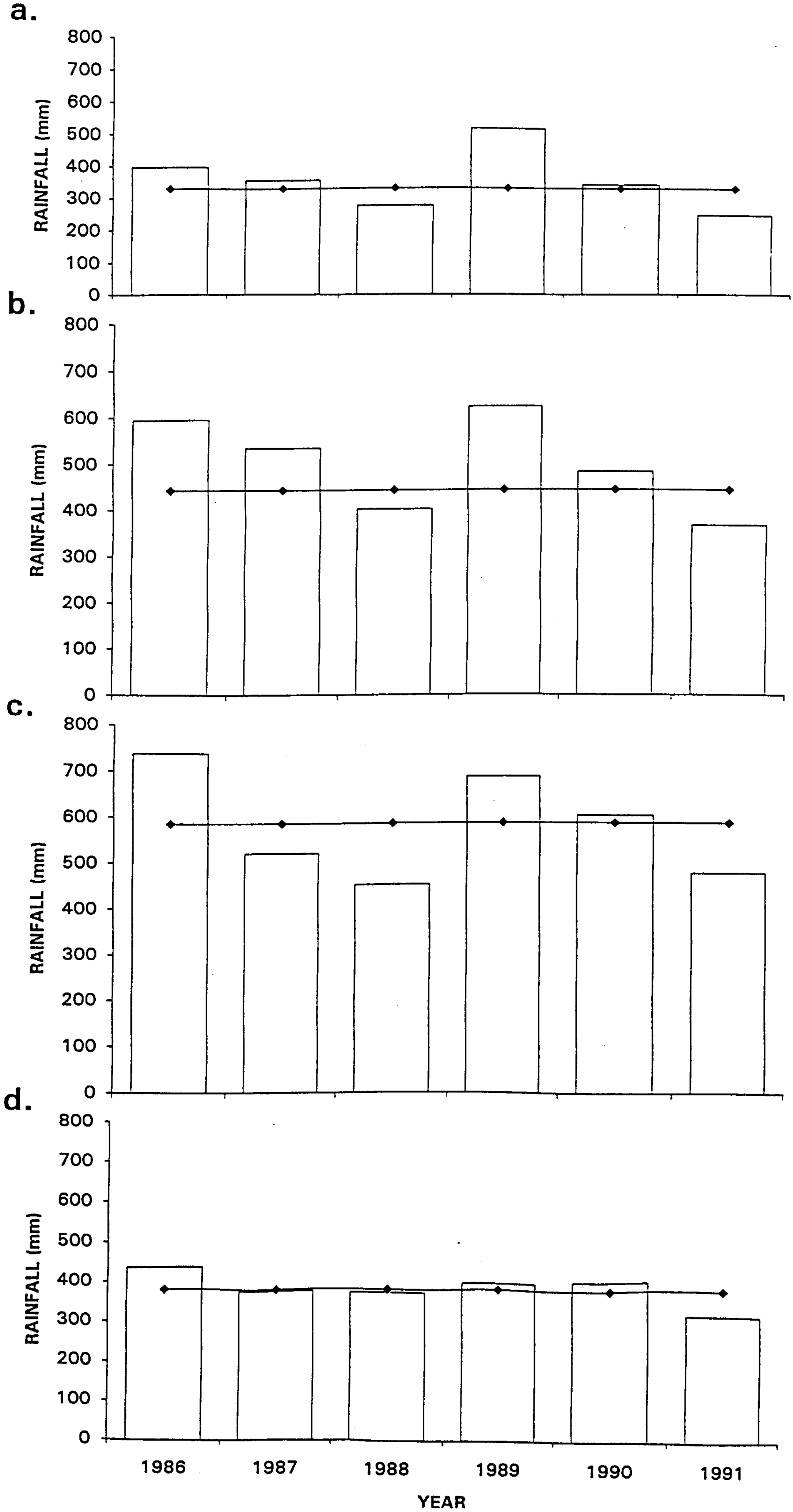
Figure 4.5

Leafy sprays and leafless twigs comprised the material falling onto the nappy sheets. Note chewed ends on the twigs.

Figure 4.6

Typical canopy configuration in roost trees that have been pruned by Little Corellas.

Figure 4.7 Annual rainfall recorded at a. Quorn Post Office, b. Olive Grove Homestead, Richmans Valley c. Melrose Post Office and d. Baroota Reservoir in the years 1986-1991. Average annual rainfall also shown (horizontal line).



pers. comm.[11]). Salinity in groundwater varied between sites with more northern sites experiencing higher salinities than southern sites (Table 4.1). Differences in average annual rainfall and creek flow were reflected in tree height and breast height diameter (Table 4.4). Heights and trunk diameters of roost trees differed significantly between sites (Kruskal-Wallis $H=31$; df 3; $p<0.001$ and $H=18$; df 3; $p<0.001$ respectively). Taller trees with greater girths were found at sites with high rainfall and reliable creek flow or at sites with high volume creek flow. Thus, roost trees in the Mt Remarkable Creek roost (Melrose) were the tallest, followed by roost trees at Pichi Richi Creek (Quorn), Stoney Creek (Quorn) and Capowie Creek (Richmans Valley) respectively (Table 4.4). Similarly, roost trees in the Mt Remarkable Creek and Pichi Richi Creek had larger girths than roost trees in either Stoney Creek or Capowie Creek (Table 4.4).

Table 4.4

Tree heights (m) and trunk diameters (m) for River Redgums at four sites in the southern Flinders Ranges. Trunk diameter were measured at breast height (1.2m) above ground.

Site	n	Tree Height (mean ∓ s.e.)	Trunk Diameter (mean ∓ s.e.)
Stoney Creek Quorn	15	13.5 ∓ 0.8	0.8 ∓ 0.1
Pichi Richi Creek Quorn	15	17.3 ∓ 0.8	1.3 ∓ 0.1
Capowie Creek Richmans Valley	15	13.1 ∓ 0.8	0.7 ∓ 0.1
Mt Remarkable Creek, Melrose	11	25.5 ∓ 1.8	1.6 ∓ 0.2

[11]Mr R. Merrick, Reservoir Keeper, Baroota Reservoir, South Australia.

Canopy condition in roost trees, as measured by visual assessment (number of trees in Category 1), differed significantly between roost sites in all years of the study (Table 4.5). However, the underlying reasons for differences in canopy condition were not clear as ranking roost sites according to canopy condition did not follow a clear pattern according to average rainfall regime (Table 4.6). Although trees in Mt Remarkable roost were ranked highest in each year, canopy condition was not significantly different to that recorded at sites receiving lower rainfall (e.g. Mount Remarkable Creek *vs* Pinkerton Creek 1989; χ^2=2; df 1; p=0.2: Mount Remarkable Creek *vs* Pichi Richi Creek 1991; χ^2=4; df 1; p=0.06).

Table 4.5

Canopy condition (number of trees in Category 1) in each of the six roosts in 1989, 1990 and 1991. Significant differences in canopy condition between the six roost sites were found in 1989, 1990 and 1991 ($\chi^2 = 313$, 119 and 86 respectively; df 5;$p<0.001$).

	Canopy Condition (number of trees in Category 1)					
	1989		1990		1991	
	Total no. of trees	No. in Cat. 1	Total no. of trees	No. in Cat. 1	Total no. of trees	No. in Cat. 1
Stoney Creek Quorn	281	52	285	135	294	173
Pinkerton Creek Quorn	332	202	248	171	251	154
Pichi Richi Creek Quorn	489	166	540	376	487	335
Capowie Creek Richmans Valley	279	58	295	207	293	148
Mount Remarkable Creek, Melrose	154	104	190	164	291	146
Baroota Creek Baroota	245	108	264	163	273	186

Table 4.6

Ranking of all roost sites in descending order of tree condition in each year of the study. Differences in canopy condition (number of trees in Category 1) between adjacent ranks were tested pairwise using Chi-squared analysis (see text).

		Rank		
Site	Average annual rainfall (mm)	1989	1990	1991
Mount Remarkable Creek, Melrose	586	1	1	1
Pinkerton Creek Quorn	330	2	4	4
Baroota Creek Baroota	379	3	5	3
Pichi Richi Creek Quorn	330	4	3	2
Capowie Creek Richmans Valley	446	5	2	6
Stoney Creek Quorn	330	6	6	5

In contrast, canopy cover in individual roost trees, as measured by photographic assessment, did not differ significantly between roost sites in any year of the study (Two-way Analysis of Variance F=2; df 2, 36; p=0.09; see also section 4.3.6.). Significant differences in tree height, tree girth and canopy condition between roost sites suggest that site differences influence tree condition and that higher rainfall sites generally supported bigger trees with better canopies. However, a closer examination of sites receiving lower rainfall showed that differences in canopy condition between roost sites did not always follow rainfall regime. This lack of agreement and the lack of significant difference in canopy cover between roost sites implies that site differences are not the only influences operating on roost trees. Thus results from whole roosts (canopy condition) and individual trees (canopy cover) imply that events occurring in each year, such as rainfall and/or the size and persistence of the Little Corella roost, may also exert an influence on tree condition.

4.3.4. Little Corella numbers at assessment sites

Little Corella numbers at the assessment sites fluctuated over the period of the study (Table 4.7). Flock use of a particular roost site varied in any one year and all sites experienced wide fluctuations in roost size (median roost size *cf* peak roost size, Table 4.7; see also Figure 2.16). Roost persistence also varied between years. Median roost size was strongly correlated with roost persistence (Spearman Rank correlation r_S=0.81; $p<0.001$).

4.3.4.1. Quorn roosts

Roost size and persistence were examined at three closely associated roosts in Quorn: Stoney Creek; Pichi Richi Creek; and Pinkerton Creek. Roost size and persistence were high at the Stoney Creek and Pichi Richi Creek roosts in 1989 (Table 4.7). In the following year, Little Corella numbers fell dramatically at Stoney Creek and no birds were observed in the roost during the 1990 season. However, Little Corellas were present at Pichi Richi Creek in 1990 where median roost size and peak roost size were similar to that of the preceding year although roost persistence was greater in 1990 than in 1989 (Table 4.7). In 1991, Little Corellas again used the roost trees at Stoney Creek although numbers were comparatively low and the flock was often absent (12% persistence, Table 4.7). At Pichi Richi Creek, median roost size increased in 1991 although the roost persistence in 1991 was less than half that of 1990 (30% 1991 *cf* 68% 1990).

Roost size and persistence at Pinkerton Creek were low in all years with median roosts of less than 1000 birds present for less than 20% of the time in all three years (Table 4.7).

Table 4.7

Length of summer season*, median roost size and roost persistence** for all sites at which canopy condition was assessed. The summer season was defined as the period extending from the time that Little Corellas first arrived in the district (usually the first week in November) until seven days after significant rain fell in the following late summer or early autumn (see text).

Site	Year	Length of of summer season (days)	Median Roost Size	Max. Roost Size	Date of Max. Roost Size	No. Days >500LC present	Roost persist-ence (%)
Stoney Creek	88-89	136	4000	8000	11 Mar 89	56	41
Quorn	89-90	205	0	0		0	0
	90-91	230	472	2200	22 Feb 91	27	12
Pinkerton Creek	88-89	136	285	1000	22 Feb 89	15	11
Quorn	89-90	205	700	1500	22 Mar 90	36	18
	90-91	230	210	800	15 Feb 91	11	5
Pichi Richi	88-89	136	4200	20000	16 Mar 89	76	56
Creek, Quorn	89-90	205	3700	21220	24 Jan 90	45	68
	90-91	230	5100	10910	22 Feb 91	69	30
Capowie Creek	88-89	136	6000	7500	23 Feb 89	73	54
Richmans Valley	89-90	205	7276	7300	24 Jan 90	45	22
	90-91	230	1910	9500	22 Feb 91	102	44
Mt Remarkable	88-89	136	nd	8000	24 Feb 89	70	51
Creek, Melrose	89-90	205	1779	2060	27 Feb 90	10	5
	90-91	230	4200	5300	5 Feb 91	64	29
Baroota Creek	88-89	136	nd			70	51
Baroota	89-90	205	200			1	0.5
	90-91	230	75	2240	25 Jan 91	14	6

* The summer season was the period extending from the time that Little Corellas first arrived in the district (usually the first week in November) until seven days after significant rains fell in the following late summer or early autumn.

**Bird presence in roosts around Quorn was usually assessed daily, in Richmans Valley weekly and at the more distant roosts (Melrose and Baroota) monthly. Information about bird presence at more distant roosts was supplemented every week by information obtained from local landholders.

Roost persistence was calculated thus;

$$\frac{\text{no. days} > 500 \text{ corellas present}}{\text{total no. days on which observations were made}} \times \frac{100}{1}$$

4.3.4.2. Richmans Valley roost

Roost size and roost persistence were both high at the Capowie Creek roost in 1989 (Table 4.7) with a large roost present for more than 50% of the time. Median roost size was higher in 1990 compared to the previous year although roost persistence was approximately half that of 1989. In 1991, median roost size declined although roost persistence doubled (Table 4.7).

4.3.4.3. Melrose roost

Insufficient data were collected at the Mt Remarkable Creek roost to calculate median roost size in 1989 although a flock of 5000-8000 birds was present for about half the summer season (N. Bailey pers. comm.[12]). In 1990, Little Corella numbers were relatively low and their roost was not persistent. Median roost size increased markedly in 1991 as did roost persistence (Table 4.7).

4.3.4.4. Baroota roost

No data concerning roost size were collected in 1989 although Little Corellas were present in the Baroota Creek roost for approximately half the summer season (R. Merrick pers. comm.). In the following year, a small flock of Little Corellas made only a fleeting visit to this roost. In 1991, Little Corellas again used the roost trees in Baroota Creek although median roost size was small and roost persistence was low (Table 4.7).

4.3.5. Visual assessment of canopy condition in roosts.

4.3.5.1. Quorn roosts

At the start of the study in 1989, canopy condition in the standing population of River Redgums at Stoney Creek and Pichi Richi Creek was generally poor with less than 50% of all trees bearing intact canopies (19% and 33%, respectively, see Figures 4.8 and 4.9). Most trees in the Stoney Creek roost were severely defoliated (>50% of all trees in

[12]Mr N. Bailey, Senior Wildlife Protection Ranger, South Australian National Parks and Wildlife Service, Port Augusta.

Figure 4.8 Visual assessment of canopy condition* in roost trees in Stoney Creek, Quorn for the years 1989-1991. Sample sizes (number of trees assessed in each year) are shown above columns.

*Poor canopy condition is shown by a high proportion of trees in Category 3 and good canopy condition is shown by a high proportion of trees in Category 1.

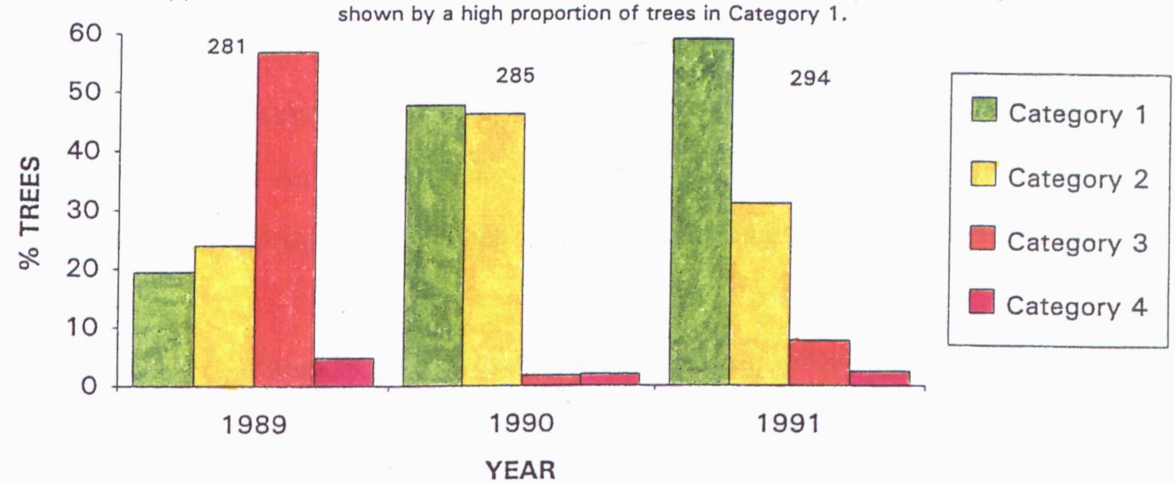
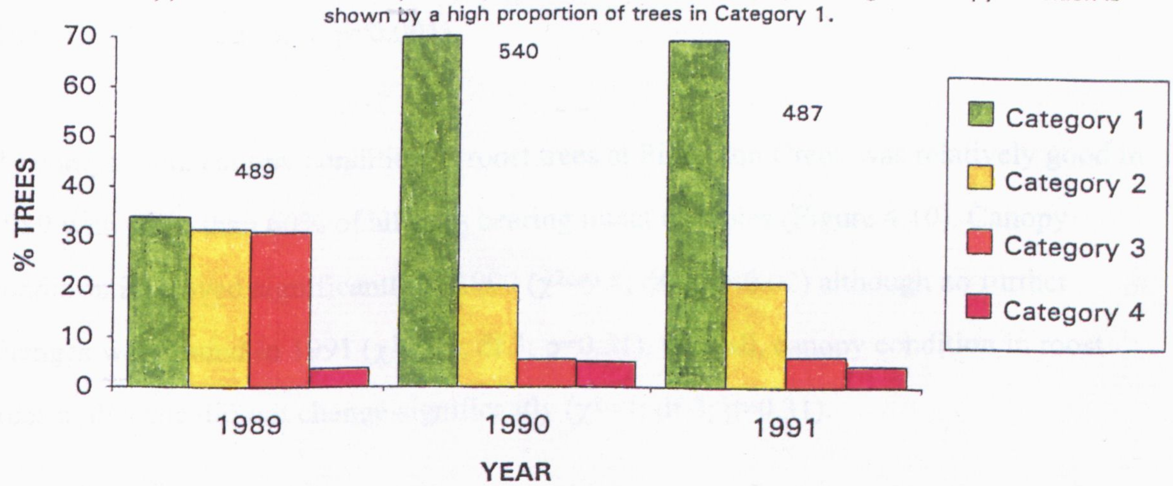


Figure 4.9 Visual assessment of canopy condition* in roost trees in Pichi Richi Creek, near Quorn for the years 1989-1991. Sample sizes (number of trees assessed in each year) are shown above columns.

*Poor canopy condition is shown by a high proportion of trees in Category 3 and good canopy condition is shown by a high proportion of trees in Category 1.



Category 3, Figure 4.8) whereas a mix of partially and severely defoliated trees comprised the majority of roost trees in Pichi Richi Creek (Figure 4.9).

In Stoney Creek canopy condition in roost trees improved significantly in 1990 (χ^2=197; df 3; p<0.001). The number of severely defoliated trees fell markedly while the number of partially defoliated trees increased as did the number of trees with intact canopies. In Pichi Richi Creek, canopy condition in roost trees in 1990 had also improved significantly (χ^2 =171; df 3; p<0.001). An increase in the number of trees bearing intact canopies was recorded as were declines in the number of both partially and severely defoliated trees.

In 1991, canopy condition in roost trees in Stoney Creek improved significantly when compared to 1990 (χ^2=26; df 3; p<0.001). A further increase in the number of trees bearing intact canopies was recorded as was a continuing decline in the number of partially defoliated trees. In Pichi Richi Creek, no significant change in canopy condition was detected between 1990 and 1991 (χ^2=1; df 3; p=0.89).

Overall, canopy condition in roost trees at both sites in 1991 was significantly better than that recorded at the start of the study in 1989 (Stoney Creek χ^2=166; df 3; p<0.001: Pichi Richi Creek χ^2=148; df 3; p<0.001).

By comparison, canopy condition in roost trees at Pinkerton Creek was relatively good in 1989 with more than 60% of all trees bearing intact canopies (Figure 4.10). Canopy condition improved significantly in 1990 (χ^2=9.8; df 3; p<0.02) although no further changes were found in 1991 (χ^2=3.6; df 3; p=0.31). Overall, canopy condition in roost trees at this site did not change significantly (χ^2=4; df 3; p=0.31).

4.3.5.2. Richmans Valley roost

Canopy condition in the Capowie Creek roost trees was poor in 1989 with most trees in a severely defoliated state (Figure 4.11). Tree condition improved significantly in 1990 with

Figure 4.10 Visual assessment of canopy condition* in roost trees in Pinkerton Creek, Quorn for the years 1989-1991. Sample sizes (number of trees assessed in each year) are shown above columns.

* Poor canopy condition is shown by a high proportion of trees in Category 3 and good canopy condition is shown by a high proportion of trees in Category 1.

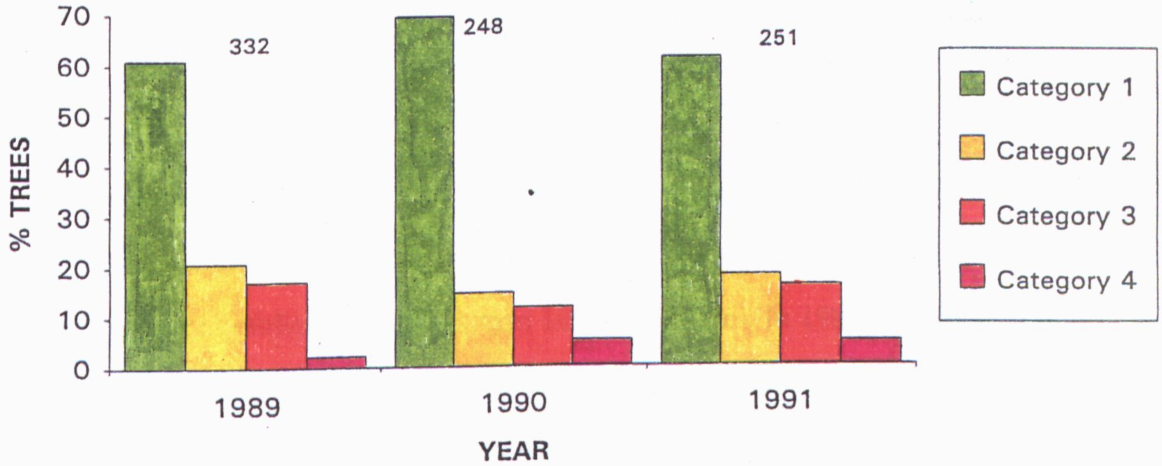
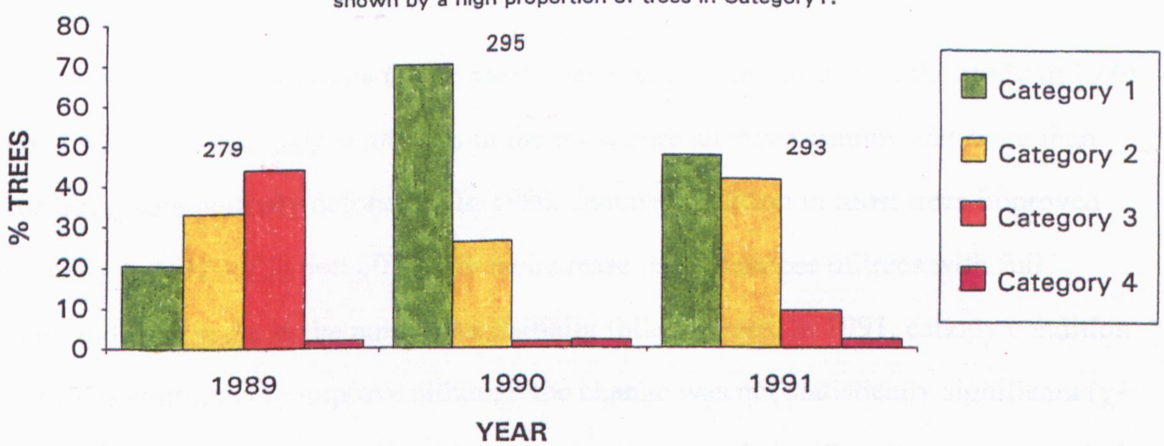


Figure 4.11 Visual assessment of canopy condition* in roost trees in Capowie Creek, Richmans Valley for the years 1989-1991. Sample sizes (number of trees assessed in each year) are shown above columns.

*Poor canopy condition is shown by a high proportion of trees in Category 3 and good canopy condition is shown by a high proportion of trees in Category1.



70% of all trees bearing intact canopies (χ^2=194; df 3; p<0.001). Concurrently, the number of severely defoliated trees fell steeply. Tree condition declined significantly in 1991 (χ^2 =31; df 3; p<0.001) with the proportion of trees bearing intact canopies declining from 70% in 1990 to 46% in 1991. Nevertheless, canopy condition in roost trees at the end of the study was significantly better than that recorded at the start (χ^2=104; df 3; p<0.001).

4.3.5.3. Melrose roost

Canopy condition in the Mount Remarkable Creek roost was generally good throughout the study with most trees bearing intact canopies in all years (Figure 4.12). The proportion of trees with severe defoliation was less than 10% in all years. In 1989, nearly 70% of all trees bore intact canopies and only 25% were partially defoliated. Canopy condition in roost trees improved significantly in 1990 (χ^2=25; df 3; p<0.001) with an increase in the proportion of trees bearing intact canopies and a decline in the proportion of partially defoliated trees (Figure 4.12). Canopy condition declined significantly in 1991 (χ^2=7.9; df 3; p=0.05) wherein the proportion of trees with full canopies fell and the proportion of trees with partial canopies increased (Figure 4.12). At the end of the study, canopy condition in roost trees was significantly better than at the start (χ^2=9; df 3; p=0.03).

4.3.5.4. Baroota roost

Canopy condition in the Baroota Creek roost trees was poor at the start of the study in 1989 (Figure 4.13). Less than half of all trees in the roost bore an intact canopy and more than 30% of trees were partially defoliated. In 1990, canopy condition in roost trees improved significantly (χ^2=32; df 3; p<0.001) with an increase in the number of trees with full canopies and a decrease in the number of partially foliated trees. In 1991, canopy condition in roost trees continued to improve although the change was not statistically significant (χ^2 =7.9; df 3; p=0.06). Canopy condition in roost trees improved significantly over the period of the study (χ^2=34; df 3; p<0.001).

Figure 4.12 Visual assessment of canopy condition* in roost trees in Mount Remarkable Creek, Melrose for the years 1989-1991. Sample sizes (number of trees assessed in each year) are shown above columns.

* Poor canopy condition is shown by a high proportion of trees in Category 3 and good canopy condition is shown by a high proportion of trees in Category 1.

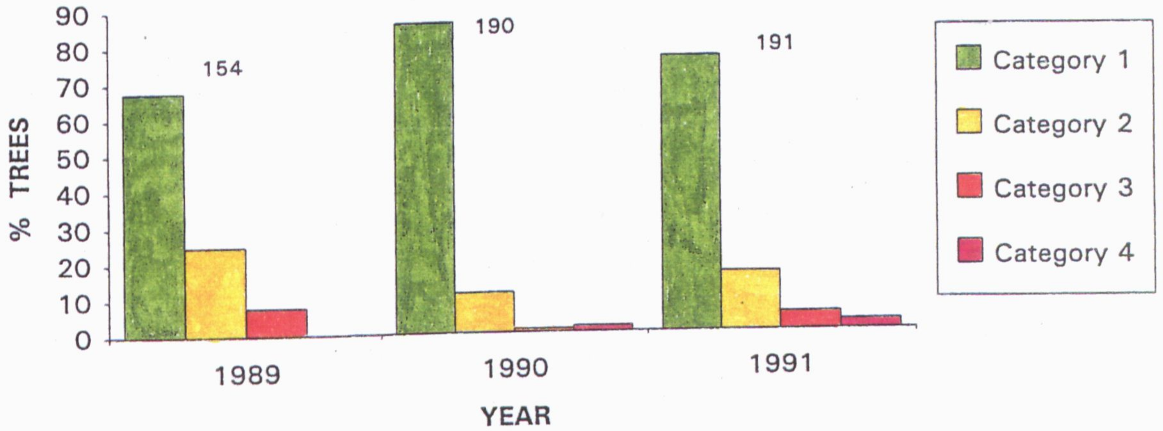
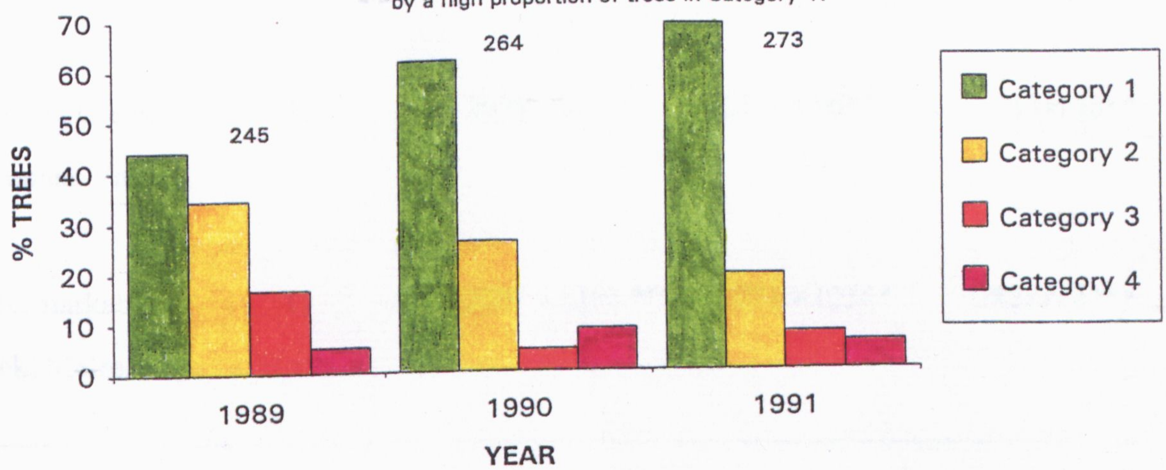


Figure 4.13 Visual assessment of canopy condition* in roost trees in Baroota Creek, near Barootta for the years 1989-1991. Sample sizes (number of trees assessed in each year) are shown above columns.

*Poor canopy conditon is shown by a high proportion of trees in Category 3 and good canopy condition is shown by a high proportion of trees in Category 1.



4.3.6. Photographic assessment of canopy cover in roosts.

Canopy cover in roost trees did not differ significantly between the three roost sites in any one year of the study (Two-way Analysis of Variance F=2; df 2, 36; p=0.09), nor was there a significant interaction between sites and years (Two-way Analysis of Variance F=1; df 4, 34; p=0.6). However, canopy cover in individual roost trees was significantly different between years (Two-way Analysis of Variance F=29; df 2, 36; p<0.001; Table 4.8) and most of the variance was attributable to a significant change in canopy cover at two of the three sites in 1990. Canopy cover in non roost trees did not change during the period of the study (Analysis of Variance F=0.04; df 2, 15; p=0.9).

Table 4.8

Differences in canopy cover in roost trees at all sites where photographic assessments were made in each year of the study. Data were analysed using Two-way Analysis of Variance. * and ** indicate where no significant differences in canopy cover between sites were detected (Tukey's HSD Multiple Range Test p>0.3).

		Canopy Cover (total dots) mean ∓ s.e.		
Site	n	1989	1990	1991
Stoney Creek Quorn	15	2020 ∓ 98*	2665 ∓ 82**	2719∓110**
Capowie Creek Richmans Valley	13	2079 ∓ 61*	2811 ∓ 96**	2743∓130**
Mt Remarkable Creek, Melrose	11	2397 ∓ 130* **	2771 ∓ 125**	2828∓147**

Canopy cover at two roost sites (Stoney Creek, Quorn and Capowie Creek, Richmans Valley) improved between 1989 and 1990 (Tukeys HSD $p<0.001$ for both). All measured trees at both sites recorded significant improvements in canopy cover. No further improvements were recorded at either of these sites between 1990 and 1991 (Tukeys HSD $p=1$ for both) and measured trees showed both improvements and declines in canopy cover. At both sites, canopy cover increased significantly over the period of the study (1989-1991; Tukeys HSD $p<0.001$ for both).

Canopy cover in roost trees at the third site, Mount Remarkable Creek, Melrose did not change significantly between 1989 and 1990 (Tukeys HSD $p=0.4$), nor between 1990 and 1991 (Tukeys HSD $p=1$). In each year, measured trees showed both improvements and declines in canopy cover.

4.3.7. Comparison of roost and non roost trees

A comparison of change in canopy cover in roost and non roost areas was made using Two-way Analysis of Variance (raw scores) and investigated further using Tukey's HSD Multiple Range tests. The roost and non roost sites were situated within 500m of each other in the same creekline and under the same rainfall and creekflow regime. There were no significant differences in tree height between the two sites (Student's $t=0.013$; df 21; $p=0.99$) and no Little Corellas were observed in the non roost area at any time during the study.

Canopy cover in roost and non roost trees differed significantly according to both location and year (Two-way Analysis of Variance $F=12$; df 1, 17; $p=0.001$ and $F=9$; df 2, 16; $p<0.001$ respectively). There was also a significant interaction between site and year ($F=3$; df 2, 16; $p=0.04$). In 1989, canopy cover in roost and non roost trees was significantly different (Tukey's HSD $p=0.001$). However, in the following two years, canopy cover in roost and non roost trees was not significantly different (1990; Tukey's HSD $p= 0.97$ and 1991; Tukey's HSD $p=0.94$). Furthermore, canopy cover in roost trees in 1990 was not significantly different from canopy cover in non roost trees in either the previous year (Tukey's HSD p= 0.99) or in subsequent years (1990; Tukey's HSD p=0.96 and 1991; Tukey's HSD p=1.0; Table 4.9). This indicates that roost trees could, given favourable conditions, restore canopies to the level observed in non roost trees.

Table 4.9

Differences in canopy cover in roost and non roost trees in Capowie Creek, Richmans Valley. Data were analysed using Two-way Analysis of Variance. * indicates where no significant differences in canopy cover were detected (Tukey's HSD Multiple Range tests p>0.9).

		Canopy Cover (total dots) mean ∓ s.e.		
Site	n	1989	1990	1991
Roost	15	2397 ∓ 130	2771 ∓ 125*	2828 ∓ 147*
Non roost	13	2918 ∓ 225*	2993 ∓ 209*	2933 ∓ 198*

4.3.8. Comparison of visual and photographic assessments

Both visual and photographic assessment techniques detected significant improvement in tree condition between 1989 and 1990 at all sites. Similarly, both techniques showed significant improvements at most sites between the start and finish of the project (Table 4.10). However, whereas visual assessments showed significant improvements and declines in canopy condition between 1990 and 1991, photographic assessments detected no significant change in canopy cover for the same period (Table 4.10).

Table 4.10

Direction of change in canopy condition (visual assessments) and canopy cover (photographic assessments) in roost trees at all sites between each year of the study (1989 to 1990 and 1990 to 1991) and between the start and the finish of the project (1989 to 1991). NS denotes that change was not significant.

Site	1989 to 1990	1990 to 1991	1989 to 1991
Stoney Creek, Quorn			
Visual	+ve	+ve	+ve
Photographic	+ve	NS	+ve
Pinkerton Creek, Quorn			
Visual	+ve	NS	NS
Pichi Richi Creek, Quorn			
Visual	+ve	NS	+ve
Capowie Creek, Richmans Valley			
Visual	+ve	-ve	+ve
Photographic	+ve	NS	+ve
Mt Remarkable Creek, Melrose			
Visual	+ve	-ve	+ve
Photographic	+ve	NS	NS
Baroota Creek			
Visual	+ve	NS	+ve

The results obtained using the two techniques were broadly similar indicating that both techniques were capable of detecting change in the canopies of roost trees. Visual assessments were considered more robust indicators of tree health given the large variation in the use of trees by Little Corellas. For example, individually monitored trees situated within a roost area may receive considerable pruning attention in one year and little in the following years. Therefore, estimates of canopy cover from a few trees would not accurately reflect the effects of the roosting birds on all trees in the roost. Photographic estimates were found to be suitable for a more detailed understanding of pruning in cases where pruning had taken place (as seen by severed sprays) but had been insufficient to cause a visual change in canopy condition; for example, where the amount of pruning varied as a function of tree height or distance from water, or in the comparison of roost and non roost areas.

4.3.9. Relationship between bird numbers and prunings

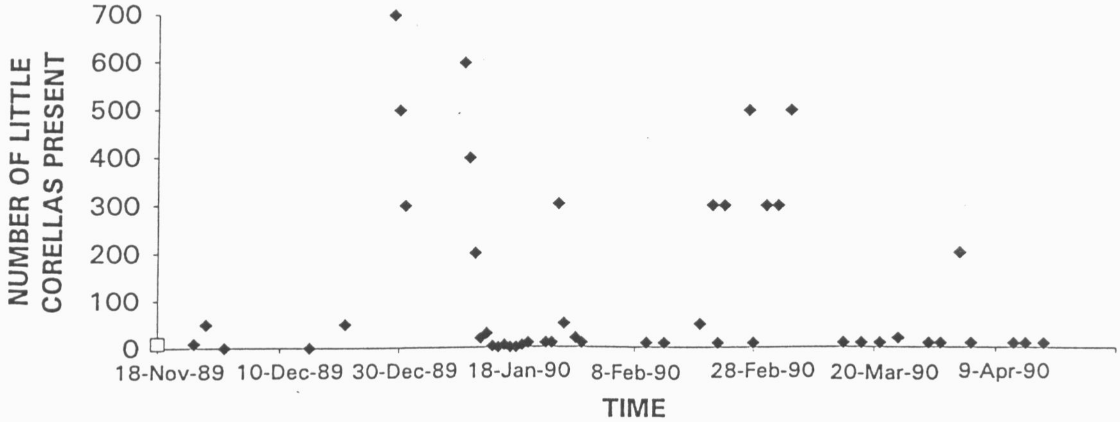
Both Little Corellas and Galahs were present in the Quorn and Richmans Valley area at the time of this experiment. Both flocked in large numbers and both pruned trees. Although regular counts of the number of Little Corellas and Galahs in the experimental plot were made, it was difficult to obtain an accurate picture of the daily fluctuations in bird number, flock location and the pattern of tree use by the flock. The number of faecal events was taken as a more accurate indicator of bird dwell time (a combination of flock size and time spent in roost trees) in target trees than bird counts *per se.*

As both Little Corellas and Galahs were present in the experimental plot, the question arises as to whether Little Corellas or Galahs were responsible for the pruning drop collected from the nappy sheets. The patterns of Little Corella presence, Galah presence and of faecal events over the entire experiment are shown in Figure 4.14. Galah numbers were initially high and then fell to a low level whereas Little Corella numbers fluctuated as did the pattern of faecal drop. As the pattern of faecal events more closely resembled the pattern of Little Corella presence, faecal drop was taken as a direct measure of Little Corella dwell time in roost trees.

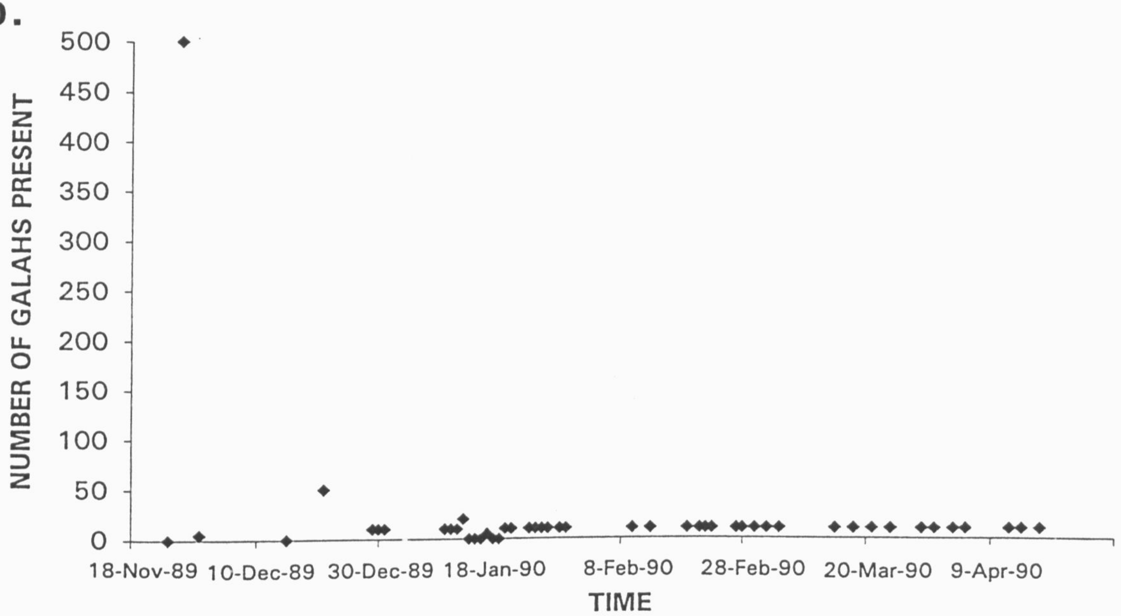
Pruning of roost trees began as soon as Little Corellas arrived in the area, occurred whenever they were present in the roost and continued for the entire summer season (Figure 4.15). At any one roost site, pruning rate varied widely on a daily basis (Figure 4.16a) and appeared to follow the variation in the number of faecal events (Figure 4.16b).

Figure 4.14 Relationship between time and the number of a. Little Corellas and b. Galahs present in the experimental plot and c. faecal events falling on the nappy sheets during the period November 1989-April 1990.

a.



b.



c.

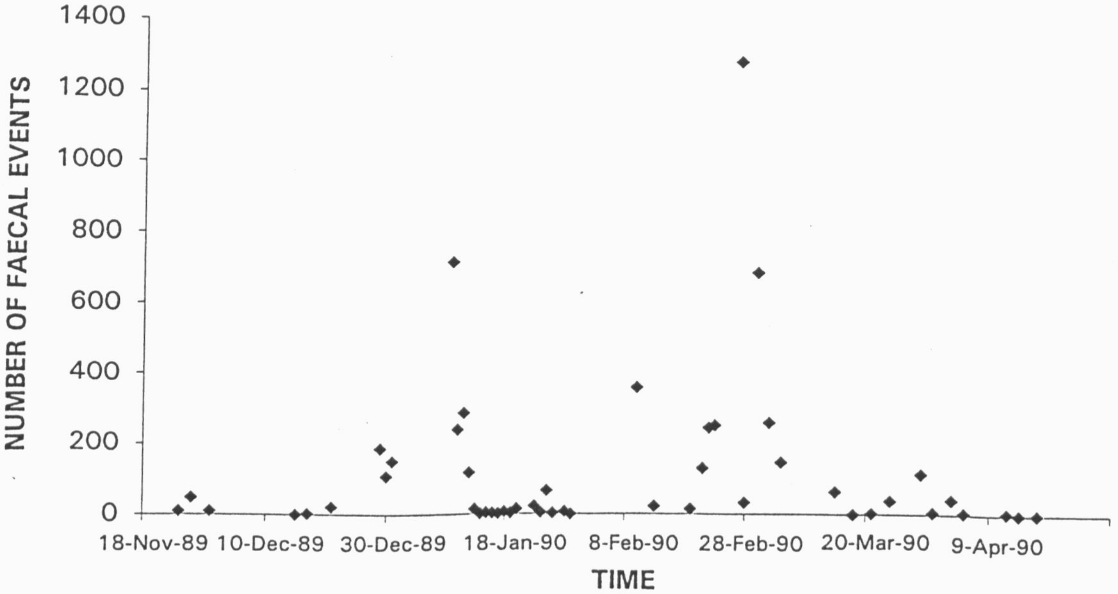


Figure 4.15 Seasonal pattern of pruning by Little Corellas at five sites (combined) in Richmans Valley between November 1989 and April 1990. Blanks on the graph represent days on which prunings were not collected from the nappy sheets.

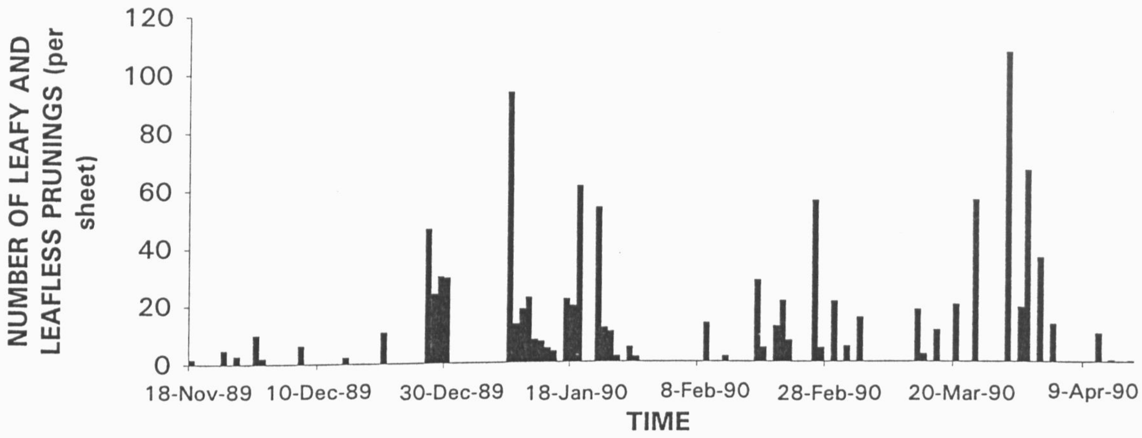
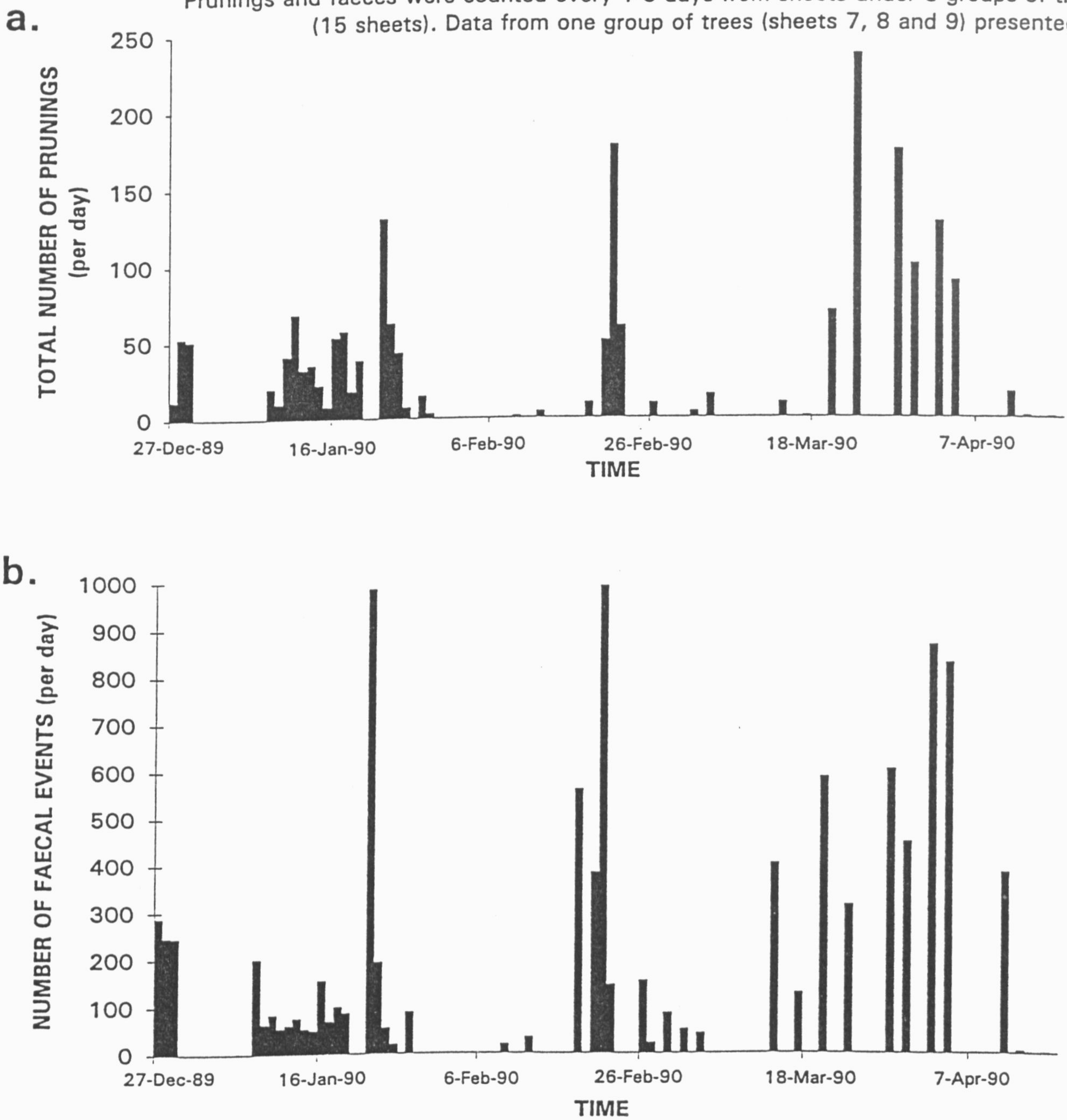


Figure 4.16 Variation in a. daily pruning rate and b. faecal deposits in Capowie Creek, Richmans Valley between December 1989 and April 1990.
Prunings and faeces were counted every 1-3 days from sheets under 3 groups of trees (15 sheets). Data from one group of trees (sheets 7, 8 and 9) presented.



Visual assessments of canopy condition were made at each of the fifteen sheets at five sites before and after the experiment (Table 4.11). Total pruning drop collected on each sheet for the November-April period was also measured. Trees in both occasional and regular roosts lost leafy sprays from their canopies (Table 4.11). Roost trees that received persistent attention from Little Corellas (e.g. site 3; mean (total faecal deposits)=2921, s.e. 537) lost more canopy than either trees in regular roosts that were visited less often (e.g. site 5; mean (total faecal deposits)=2036, s.e. 123) or trees in occasional roosts (e.g. site 4; mean (total faecal deposits)=179, s.e. 88). The amount of pruning was related to the number of faecal events falling on the nappy sheets (Spearman rank correlation $r_S=0.9$; $p<0.001$) and to roost persistence and median roost size (Spearman rank correlation $r_S=0.57$; $p<0.05$ and $r_S=0.69$; $p<0.005$ respectively). No trees were pruned to the extent of complete defoliation and there was no instance in which pruning was sufficient for a group of trees to decline in canopy condition to the extent that a visual change was noticeable (i.e. no change in visual assessment category before and after pruning; Table 4.11).

The relationship between Little Corella dwell time (mean number of faecal events/sheet) and pruning by Little Corellas (mean number of leafy and leafless prunings/sheet) is shown in Figure 4.17. Dwell time was strongly correlated with the amount of pruning (Spearman Rank correlation $r_S=0.85$; $p<0.001$) and implies that the higher the dwell time, the more pruning took place. It also infers that substantial pruning damage could be incurred by the extended presence of a small flock of Little Corellas, or by the occasional visit of a large flock. A reduction in dwell time should also reduce the amount of pruning.

Figure 4.17 Relationship between bird dwell time and amount of pruning. Data for both variables were transformed using log (x+1).

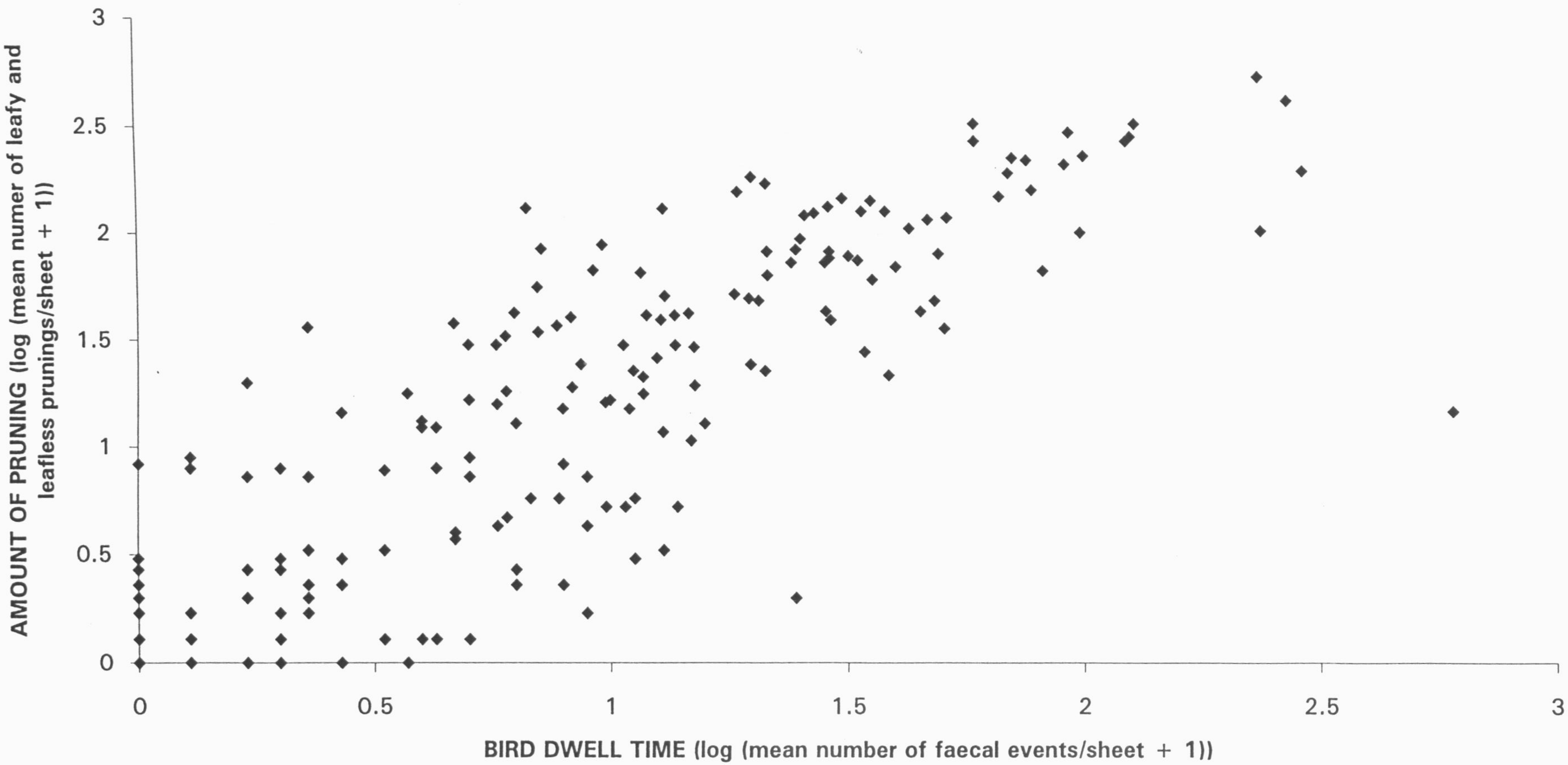


Table 4.11

Total prunings, total faecal deposits and visual assessments of canopy condition before and after pruning by Little Corellas for each of 15 trees at five sites where pruning and dwell time were measured .

Site	Sheet	Roost use	Canopy Condition by category		Total no. prunings	Total no. faecal deposits
			Before Nov 89	after April 90		
1	1	Occasional	1	1	224	430
	2		1	1	293	818
	3		1	1	598	1971
2	4	Regular	3	3	746	2312
	5		2	2	878	1197
	6		2	2	432	1074
3	7	Regular	2	2	1,429	2297
	8		2	2	1,296	2476
	9		2	2	1,383	3989
4	10	Occasional	1	1	87	352
	11		1	1	45	62
	12		1	1	94	122
5	13	Regular	1	1	827	2260
	14		1	1	587	1836
	15		1	1	808	2011

4.3.10. Relationship between tree condition and distance from water.

Canopy condition (visual assessments) in trees along Capowie Creek was generally poor within traditional roost areas, particularly near established watering points (Figure 4.18). Canopy condition improved with increasing distance from watering points. Similarly, canopy cover (photographic assessments) in roost trees improved with increasing distance from a farm dam (correlation coefficient r=0.82; df 9; p=0.004; Figure 4.19). Although taller trees were preferentially attacked by Little Corellas (see section 4.4.3.5), canopy cover was not correlated with tree height in this instance (correlation coefficient r=0.11; df 9; p=0.8).

Figure 4.18 Change in canopy condition (visual assessments) in relation to watering points along a 3.2 km section of Capowie Creek, Richmans Valley.

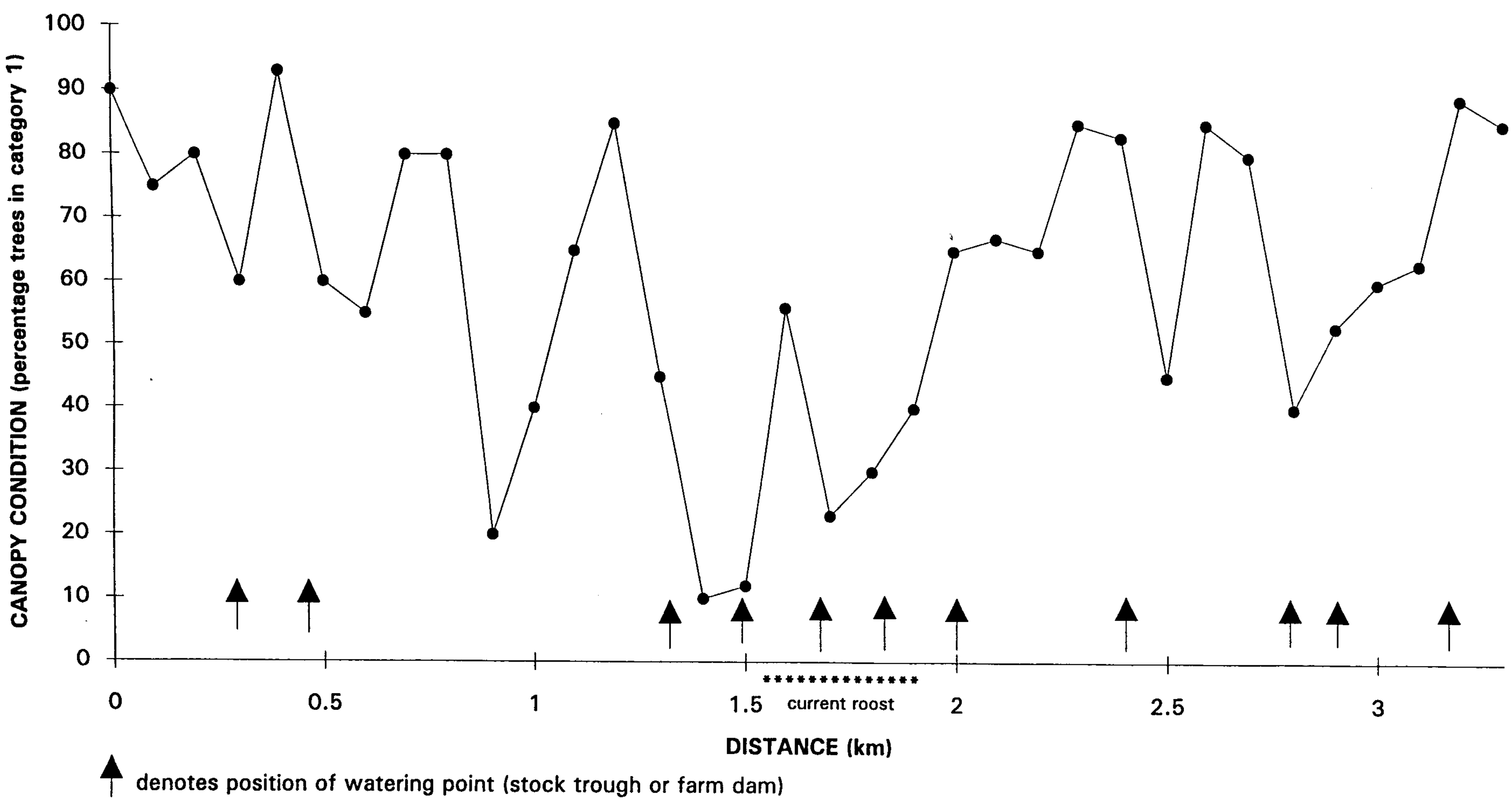
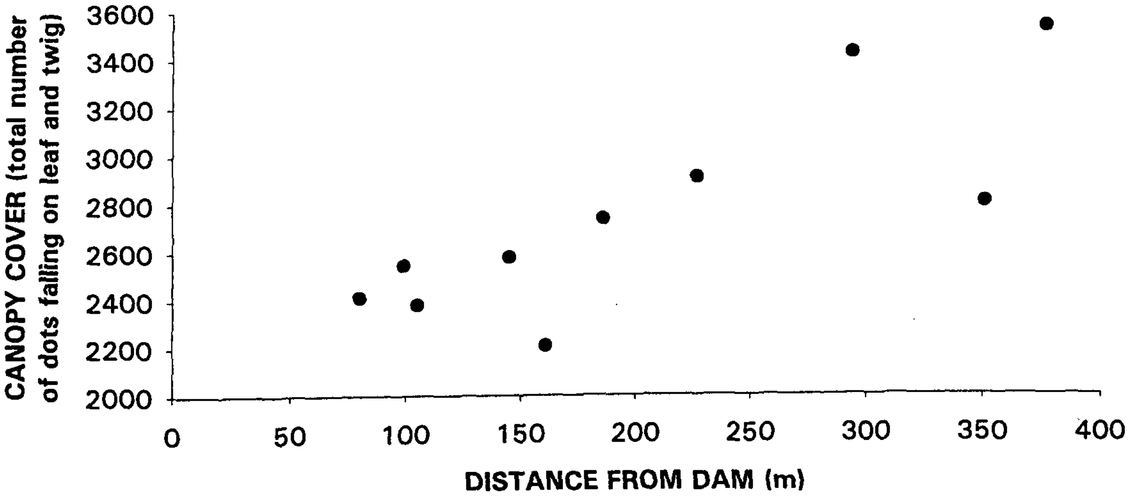


Figure 4.19 Change in canopy cover (photographic assessments) with distance from water (a farm dam).



4.3.11. Recruitment of roost trees.

At all visual assessment sites, the majority of the standing population of River Redgums comprised mature and senescent trees and there was a noticeable lack of small to medium sized trees. Only Pinkerton Creek and Pichi Richi Creek showed any significant recruitment of River Redgums (627 and 160 young trees in 1991 respectively, Table 4.12). The former site is situated within the township of Quorn and experiences at worst light grazing from stock (usually horses). The latter site is situated on a cattle and sheep property downstream of the confluence of the Pinkerton, Stoney and Capowie Creeks. There is light to moderate grazing of the creek line in this area. Extra flow in the Pichi Richi branch of the creek from the three water courses upstream may also help promote tree regeneration at this site. There was little or no recruitment of River Redgums at the other four sites (Table 4.12).

Table 4.12

Extent of recruitment of River Redgums at all sites where visual assessments of canopy condition were made. Declines in the number of young trees at Pinkerton Creek and Pichi Richi Creek were recorded between 1990 and 1991. These declines were due to some trees growing above 2m in height and do not represent a loss of trees.

Site	Number of Redgums less than 2m in height	
	1990	1991
Stony Creek, Quorn	0	0
Pinkerton Creek, Quorn	937	627
Pichi Richi Creek, Quorn	212	160
Capowie Creek, Richmans Valley	0	0
Mt Remarkable Creek, Melrose	0	0
Baroota Creek, Baroota	5	5

4.4. DISCUSSION

Canopy condition in the River Redgums in the study area can be affected by a number of abiotic factors such as rainfall, creek flow and groundwater salinity as well as biotic factors such as insect attack and pruning by Little Corellas. Any one of these factors can put Redgums under stress. Under such conditions, Redgums display a typical response that consists of a generalised thinning of the canopy and is associated with loss of leaves (Davidson and Reid 1989), terminal leafy sprays and even branches. Alleviation of stress consists of a flush of epicormic growth (Davidson and Reid 1989). Thus, stress responses can be similar despite a variety of causative agents and attributing canopy condition to any one of the above-mentioned factors can be difficult.

According to both visual and photographic assessments, canopy condition of River Redgums in the study area did vary during the period of the study and an attempt to distinguish between the influence of the different factors was made.

4.4.1. Change in tree condition during the study

In non roost areas, neither canopy condition nor canopy cover changed significantly during the period of the study. In contrast, canopy condition of roost trees did change and improved significantly between 1989 and 1990. Improved canopy condition was sustained at one site only (Stoney Creek) in 1991. Of the five remaining sites, declines were recorded at two sites in 1991 and at three sites there was no statistically significant change. However, there was a significant improvement in canopy condition at all sites except one (Pichi Richi Creek) between the start and the finish of the project (Table 4.10). Canopy cover in roost trees in 1990 was not significantly different to canopy cover in non roost trees. This indicates that canopy restoration in roost trees was possible in the short term given favourable conditions.

4.4.2. Factors affecting condition of roost trees

Average rainfall and creek flow regimes differed between sites with higher rainfalls and more reliable creekflow recorded for more southerly sites situated on the eastern side of the Flinders Ranges. Although groundwater salinity also varied between sites, rising saline groundwater has been discounted as a factor causing declining tree health in the study area (Jolly *et al.* 1992). Tree condition was best at Mt Remarkable Creek roost, the site receiving the highest rainfall, in all years of the study. However, at sites receiving lower rainfall, tree condition did not follow the pattern of average annual rainfall. For example, canopy condition in the Quorn roosts varied between roost areas within each year of the study whilst average rainfall did not. Nor did tree condition follow the pattern of actual annual rainfall within any year of the study; roost trees in Capowie Creek were ranked the lowest of all sites in 1991 despite receiving twice the annual rainfall (482mm) of sites around Quorn (248mm) (Table 4.6). Stochastic events in one year, such as above average rainfall, also affected tree condition in roost areas. Significant improvements were detected at all roost sites in 1990 following above average rainfall in 1989. In contrast, tree condition in non roost areas did not vary significantly during the study period and did not show a response to rainfall.

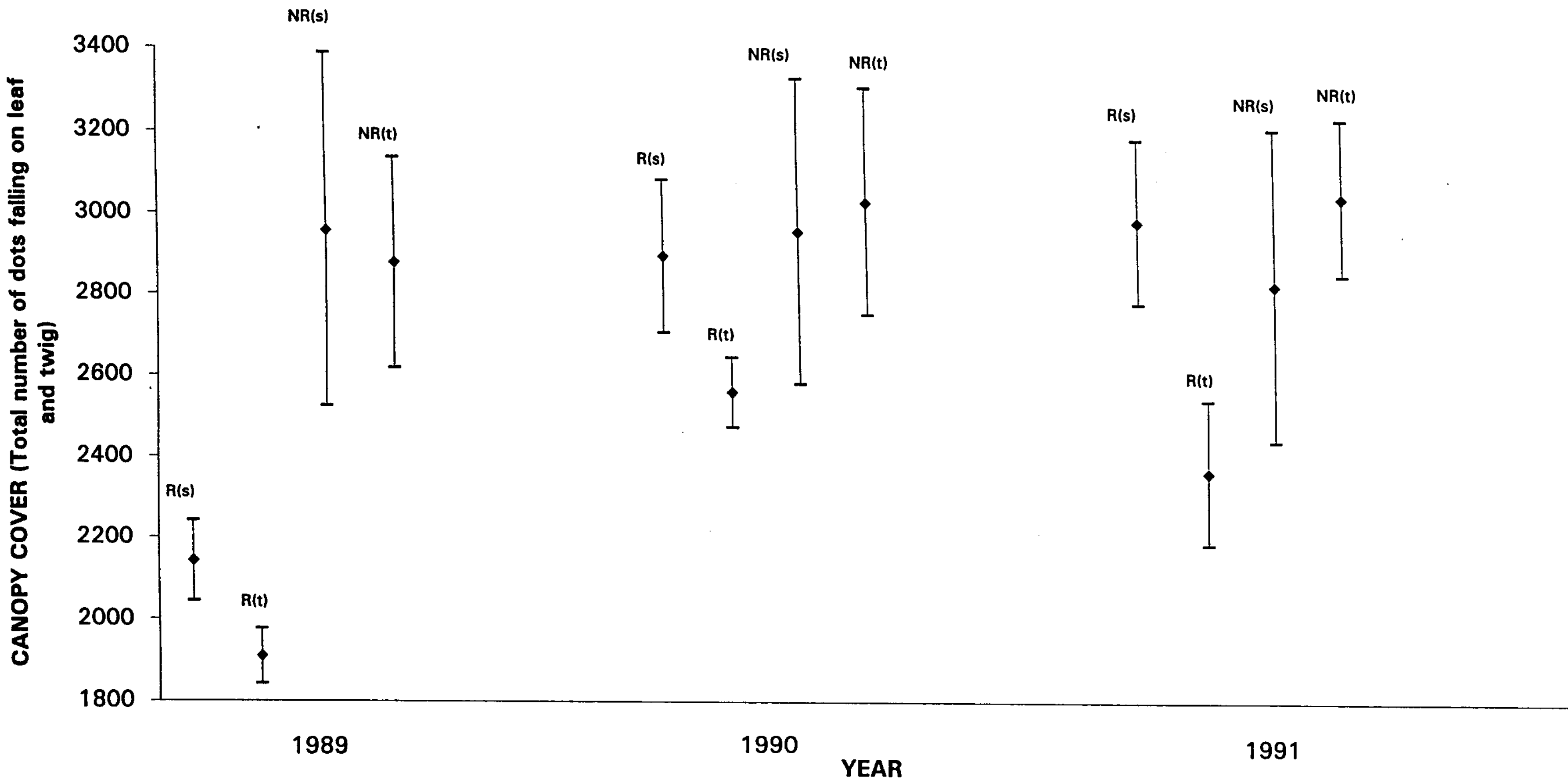
The disparities in tree response between firstly, rainfall regime (average annual and actual annual) and tree condition at low rainfall sites and secondly, roost and non roost areas suggest that pruning imposes some level of stress on roost trees.

The pruning activities of roosting Little Corellas caused loss of tree canopy, as seen by the leafy sprays littering the ground underneath roost trees. Pruning began when the birds first arrived in the area and continued for the entire time the birds were present. The duration of the summer roost depended on the quantity and the timing of autumn rains, and birds remained in the southern area longer if the seasonal rains were delayed (Table 4.7). During the life of the summer roost, there was a direct relationship between the amount of pruning and bird dwell time. Bird dwell time is a combination of flock size and the amount of time spent in the roost trees - increases in either parameter could cause increases in the amount of pruning.

Roost size and persistence were generally high at most sites in 1989 and tree condition was uniformly poor. Tree condition improved significantly at all sites in 1990 and improvements coincided with both a reduction of pruning pressure at some sites (Stoney Creek, Capowie Creek, Mt Remarkable Creek) and an increase in pruning pressure at other sites (Pichi Richi Creek, Pinkerton Creek). Similarly, in 1991, trees responded to pruning pressure in several ways. Increased pruning pressure was associated with either declines in tree condition (Capowie Creek, Mt Remarkable Creek) or continued improvement (Stoney Creek) whilst decreased pruning pressure failed to elicit a response from roost trees at the remaining sites.

The Little Corella roost was often established at a site used in previous years and usually within easy access of water (troughs, dams and open tanks) and food. Flocking behaviour in the period before the evening watering session was a regular component of the birds daily behaviour pattern. At this time, Little Corellas chose to perch in the upper, outer canopy of the taller roost trees near a favoured watering point. These aspects of Little Corella behaviour subjected particular trees to increased rates of pruning attack e.g. trees close to watering points maintained less canopy cover than did trees in neighbouring non roost areas. Taller trees at all sites tended to sustain a greater level of pruning damage than did short trees (pers. obs.). This is illustrated by comparing the responses of the shortest and the tallest trees within a roost area and an adjacent non roost area (Figure 4.20). Canopy cover in non roost trees did not vary significantly as a function of tree height in any year of the study. In contrast, taller trees within the roost area maintained less canopy cover than did shorter trees in all years even though both tall and short trees responded to favourable conditions in 1990. In 1991, canopy cover in taller roost trees declined significantly (Student's $t=2.3$; df 8; $p=0.05$) while canopy cover in shorter trees did not. This coincides with a substantial increase in roost persistence (double that of the previous

Figure 4.20 Differences in canopy cover between the 5 tallest (R(t)) & 5 shortest (R(s)) trees from a roost area and the 3 tallest (NR(t)) & 3 shortest (NR(s)) trees in an adjacent non roost area in 1989, 1990 and 1991. Values plotted as means ± s.e.



year) even though median roost size decreased. Caution is required in the statistical interpretation of these data since the same trees were measured in each year. However, these data and data collected by Palmer (1991) do suggest that the taller trees in roost areas are preferentially attacked by Little Corellas.

Clearly, the duration of the summer roost, roost size and roost persistence determine the amount of pruning damage sustained by roost trees in any one year. Small, persistent roosts are capable of as much pruning activity as larger, transient roosts. The importance of pruning damage to tree health depends firstly, on the location of the roost area and secondly, on the position and size of the individual tree within the roost. Thus, trees at high rainfall sites suffered comparatively less than trees at low rainfall sites under pruning pressure from Little Corellas. Taller trees situated near the watering point in a favoured roost area sustained more pruning damage than did other trees in the same roost. The variation in tree response to pruning pressure suggests that stochastic events may also play an important part in determining condition of roost trees. In particular, events affecting trees in 1990, such as rainfall in 1989, may have overridden the deleterious effects of canopy pruning and possibly extended a beneficial influence in subsequent years. This suggests that favourable conditions may mask pruning impact and conversely, that unfavourable conditions may enhance the impact of Little Corellas on roost trees.

4.4.3. Effects on roost trees in the long term

Accurate historical data on tree condition and Little Corella numbers were not available and an assessment of Little Corella impact on River Redgums over extended periods can only be inferred. Health of roost trees can be affected directly and indirectly by pruning damage. These effects are most likely to affect taller individuals situated close to the favoured watering point within the roost area as these trees are preferentially attacked.

Eucalypt trees respond to the removal of foliage by producing epicormic growth from buds under the bark (Pryor 1976). Pruning by Little Corellas, by removing foliage, provides the stimulus for epicormic bud burst. The amount of growth that takes place subsequently probably depends on environmental conditions with growth of epicormic foliage continuing only if moisture is sufficient (R. Sinclair pers. comm.[13]). Re-establishment of the crown depletes starch reserves in the sapwood (Bamber and Humphreys 1965). Trees die when (1) starch reserves are exhausted during chronic cycles of defoliation and regrowth, and (2) photosynthetic area falls below that needed to support respiration (Bamber and Humphreys 1965, Martin 1985). Thus, exhaustion of starch reserves may have caused the fatal decline noted in trees continually defoliated by koalas *Phascolarctos cinereus* (Martin 1985).

In the case of pruning by Little Corellas, defoliation occurs mainly during the summer when birds are congregated in large roosts. During the winter, Little Corellas are largely absent from summer roost sites and, provided winter rainfall is sufficient, roost trees are able to produce epicormic growth. Bamber and Humphreys (1965) examined seasonal variation in sapwood starch levels in defoliated and intact *Angophora costata* trees in Cumberland National Forest, N.S.W. They found peak levels occurred in both defoliated and intact trees in late spring prior to a flush of foliage growth. However, total starch content was less in defoliated trees than in intact trees. Thus, roost trees defoliated in the preceding summer may be able to partially restore starch reserves during the winter when birds are absent from roosts although total starch content may be less in defoliated trees than in undefoliated trees. Therefore, the rapid deterioration in koala browse trees noted by Martin (1985) may not occur in trees defoliated by Little Corellas. Improved canopy condition in roost trees following above average rainfall indicates that current starch reserves in defoliated trees in the study area are sufficient not only to support canopy growth but also to restore canopies to a level comparable with non roost trees. Therefore a lack of foliage growth during the times when birds are absent may be related to insufficient rainfall rather than insufficient starch reserves.

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[13]Dr R. Sinclair, Botany Department, University of Adelaide, South Australia.

The long term, debilitating effect of repeated seasonal defoliation on total energy reserves in roost trees cannot be dismissed. Starch reserves in trees defoliated in this way may decline progressively and inhibit the trees ability to produce epicormic growth and thus to accumulate further starch reserves. Tree deaths resulting from defoliation by Little Corellas may be delayed but not necessarily avoided and in this sense, pruning damage more closely resembles the chronic insect damage noted in dieback trees by Landsberg and Wylie (1983). Further clarification of the effect of pruning on starch reserves in roost trees, especially during a variety of seasonal conditions, is needed but was beyond the scope of this study.

Pruning by Little Corellas also exerts indirect effects on tree condition. Defoliated trees throw a flush of epicormic growth which produces leaves high in nitrogen. Leaf damaging insects such as members of the order Psyllidae and Pergidae prefer foliage of high nutritional status (Landsberg and Wylie 1983, Landsberg 1990a) and thus trees defoliated by Little Corellas are comparatively more susceptible to attack from these insects. Furthermore, once insect populations have become established, continued herbivory is self-perpetuating via a positive feedback between continued defoliation and enhanced dietary quality (Landsberg 1990b). Dense infestations of psyllids were recorded on leaves in roost trees in the Quorn area in 1986 (Palmer 1991) although none were detected during the present study.

Large, persistent roosts of Little Corellas may directly and indirectly influence tree health in the study area. The relative importance of pruning as a debilitating agent will probably vary as a function of rainfall and may be more significant in a series of dry years.

4.4.4. Recruitment

The decline in the rural tree population is associated with a lack of recruitment as much with the dieback of the standing mature individuals (Boardman 1981, Palmer 1991). Lack of tree recruitment is associated with competition from annual grasses and heavy grazing from herbivores such as rabbits, kangaroos, sheep, cattle and goats (Dexter 1967, Venning and Croft 1983, Kiddle 1987). In the Flinders Ranges, lack of recruitment is more widespread than the localised damage associated with Little Corella roosts and the survival of the River Redgum population in this area is jeopardised.

During the period of this study, widespread germination of seedlings would have been possible following high rainfall in March 1989 when soil temperature and soil moisture conditions were favourable (Dexter 1967). Some regeneration of River Redgums has occurred in the study area and is more common in areas such as creeklines in townships where grazing pressure and weed competition are minimal.

CHAPTER 5.

CONTROL OF LITTLE CORELLA DAMAGE.

5.1. INTRODUCTION

The literature suggests that there are two main avenues available for the control of pest birds namely, the reduction of the population by culling individuals, and the modification of feeding, watering and/or roosting habitat to deter flocks from sensitive areas. A wide variety of techniques have been used to destroy pest birds including shooting, trapping, drugs and poisons. A range of non destructive techniques aimed at reducing bird damage have also been tested. Most try to make the feeding, watering, roosting or loafing habitat unattractive to the pest bird and thus often exploit some aspect of the birds behaviour such as aversion to certain chemicals, to sudden noise, to obstructed views whilst feeding or drinking. A review of techniques used to control pest birds is presented in Appendix 1 (page 101).

Little Corellas feed, water and roost communally in the non breeding season. The social nature of daily life contributes to the problem (pruning damage to roost trees by large flocks) but also suggests a number of possible solutions. Reliance on easy access to food and, in particular, water makes the flock vulnerable to manipulation of these resources. The communal nature of feeding and watering also makes large numbers of Little Corellas vulnerable to population reduction via poisons or drugs administered in either food or water.

The effects of firstly, reduction of southern summer flocks of Little Corellas and secondly, modification of habitat on bird numbers at roosts was evaluated in this study and in doing so the following questions were posed:

1. **Do culls have any lasting effect on population size of Little Corellas in the southern Flinders Ranges during the summer?**
2. **Can roosting habitats be modified to make them less attractive to Little Corellas during the summer?**

5.2. METHODS

5.2.1. Population reduction using aqueous administration of alphachloralose.

5.2.1.1. Dose Response Trials

The effect of alphachloralose on Little Corellas was tested by exposing captive wild caught birds to varying concentrations of the drug. Prior to drug trials, Little Corellas were kept at the South Australian National Parks and Wildlife Service Fauna Complex at Monarto, South Australia for a minimum quarantine period of two months. Birds were housed in flight aviaries and food and water were allowed *ad libitum*. Qualified animal attendants provided daily care and maintenance.

For drug trials, twenty Little Corellas (one hand reared and 19 wild caught Little Corellas) were housed singly in banks of cages set up in a small laboratory. Partitions between the cages prevented individuals from seeing each other although birds were not isolated audibly. The captive birds vocalised often especially when left undisturbed. The presence of the observer in the room usually caused an alert watchful response from the birds. Therefore all observations were made through a port in the laboratory door. Food and water were allowed *ad libitum* and ambient temperatures (13^{o}C night;25^{o}C day) prevailed. The birds were subjected to 14 hours light and 10 hours dark, similar to prevailing light conditions at the time of the experiment (February). The Little Corellas were allowed 24 hours in which to become accustomed to their new surroundings before alphachloralose was administered.

Prior to drug administration, drinking behaviour of each bird was observed and water intake of each bird was determined. Little Corellas drank by dipping the beak into water, filling the lower mandible and raising the head to allow the water to run down the gullet. The birds often spilled water from their drinkers. Occasionally head shaking with the bill full also accompanied drinking, resulting in further minor spills. The ambient temperature in the laboratory was then increased to approximately 37^{o}C in order to mimic summer temperatures experienced by the birds in the wild. Food and water were supplied *ad libitum* for one more day and thereafter access to water was restricted to a single 30 minute drinking session in the morning. Once the ambient temperature was increased and access to water restricted, drinking behaviour changed. Although water was still spilt from the drinker (birds perched on the drinker), head shaking with a full bill ceased. The number of dips taken by a bird during the drinking session, rather than the residual volume in the drinker, was used as a measure of consumption.

Little Corellas were assigned to one of five groups and groups consisted of four birds. Each group was exposed to solutions containing 0, 1.0, 2.0, 4.0 or 8.0 g alphachloralose/litre presented as an aqueous solution in the drinker. In order to achieve a range of drug intakes, the level of exposure for each bird was chosen according to its drinking rate as measured in the pre-drug exposure drinking sessions. As before, birds were allowed a 30 minute drinking session during which time drug intake was noted as the number of dips the birds made in their drinkers. Drug exposure was staggered for each group such that a single observer could count dips made by the individuals in that group. The following observations were made on birds exposed to the drug:

1. drinking rate;
2. time taken to coma;
3. time taken to death; or
4. time taken to partial recovery (alert, but ataxic), and
5. time taken to full recovery (capable of co-ordinated movement).

Following the experiment, all Little Corellas were killed using a lethal dose of phenobarbitone. Birds were weighed and sexed. Measurements of the volume of the lower mandible of each individual were taken and used to calculate approximate drug intake.

5.2.1.2. Field trials

Field trials using alphachloralose to cull Little Corellas were conducted on 21 and 22 January and 9-12 February 1991 on the property of Jim and Rita Britza, Richmans Valley, 10 km south of Quorn. The area designated for the cull was the roost area around the homestead (called the "target roost"). Alternative roosts were available in the immediate area and were used by the birds on some occasions in 1991.

Observations of bird behaviour prior to administration of the drug included (1) noting which troughs were favoured by the birds for each of the morning and evening drinking sessions, (2) counting of the number of Little Corellas alighting on the target trough, and (3) estimating individual drinking rates (dips/bird alight at the target trough).

The drug (6.0g alphachloralose/l) was administered via a stock trough where Little Corellas had been observed to drink. The trough was ballasted with rocks to reduce the volume of drug solution required to fill it. Birds were allowed access to the trough during daylight hours only and the trough was covered each night to preclude other animals. During the period of drug administration, the following were recorded;

1. Little Corella preference for watering points in the immediate vicinity, in particular any change in preference,

2. the number of drugged birds that were dead when first found, and

3. distance of drugged Little Corellas from drug trough when first found.

Counting the number of alights at the drug trough was not always possible, nor were counts of individual drinking rate. Birds that were alive upon encounter were dealt a fatal blow to the head. Most carcasses were buried although some were retained for measurements of weight, bill dimensions, moult pattern and gonad condition (see Chapter 3).

In order to assess the value of culls as a method to reduce population size, estimates of roost size at the target roost were made before, during and after the culls. Observations of roost size at other roost sites nearby were also made to determine any change in roost site preference. Counts of roost size at all preferred locations were conducted daily before, during and after culls. Thereafter weekly counts were made and this information was supplemented by regular reports from local landholders.

5.2.2. Habitat Modification

The feasibility and success of three types of habitat modification were considered. These modifications consisted of (1) restricting access to troughs, tanks and dams, (2) restricting access to grain installations such as grain bunkers, field bins and silos, and (3) deterrents, specifically the persistent and timely use of scareguns reinforced by shotguns.
Only methods of water management (restricting access to troughs and tanks) were tested in the field as part of this study. Experiments to investigate the effect of manipulating food supply on bird roosting behaviour could not be performed. However, anecdotal evidence and regular observations were used to determine some aspects of roosting pattern in response to food availability. Similarly, experiments to investigate the effect of deterrents such as scareguns and shooting on the roosting behaviour were not conducted. However, several landholders in the Quorn area used a combination of scareguns and shooting to deter Little Corellas from roosting in trees on their properties. Accounts of their experiences, combined with observations of bird behaviour, were used to establish roosting behaviour in response to deterrents.

5.2.2.1 Water management

Trough modifications that restricted bird access to water whilst allowing access by stock were developed by Mr Ray Cox of *Uonhill*, Quorn. The trough modifications consisted of six droppers cut in half and placed at each corner and halfway along the trough. A pair of wires was then strung at 80mm and 145mm above the trough lip and along the entire edge of the trough through the droppers. Lengths (50mm) of black poly pipe were threaded on the upper wire. All wires were kept taut by means of turnbuckles that connected the wire to the droppers.

Little Corellas were able to land on the upper wire but were unable to balance sufficiently to drink. The bottom wire prevented birds from alighting on the trough lip. With all the wires taut, Little Corellas were effectively excluded from the modified trough. The modifications are shown in Figure 5.1. Mr Cox reported that the modifications were successful in preventing Galahs and Little Corellas from drinking at his stock trough.

Modifications were installed on three more troughs around Quorn where Little Corellas had been observed to drink. The effect of restricted access to water on roost size, and thus bird dwell time, was assessed by observing drinking and marshalling behaviour of Little Corellas before and after the installation of trough modifications. Drinking behaviour was measured by counting the number of alights at one trough before and after trough modifications. Marshalling behaviour was measured as the number of birds assembling at or near the troughs and as the number of birds using the nearby roost site before and after the installation of modifications. Limited resources and difficulties in matching sites (in particular, finding sites where roost sizes and distances between water points and roosts were similar) prevented replication of this experiment with other modified, and unmodified, troughs.

5.3. RESULTS

5.3.1. Dose Response Trials

Observations of the drinking behaviour of wild Little Corellas showed that water intake varied considerably between individuals (range 1-13 dips per session) and that water intake did not vary with increasing ambient temperature (Spearman Rank r_S=-0.04; $p>0.05$; n=235). Water intake in captive Little Corellas also varied considerably between individuals (range 1-14 dips per session) and increased significantly with increasing

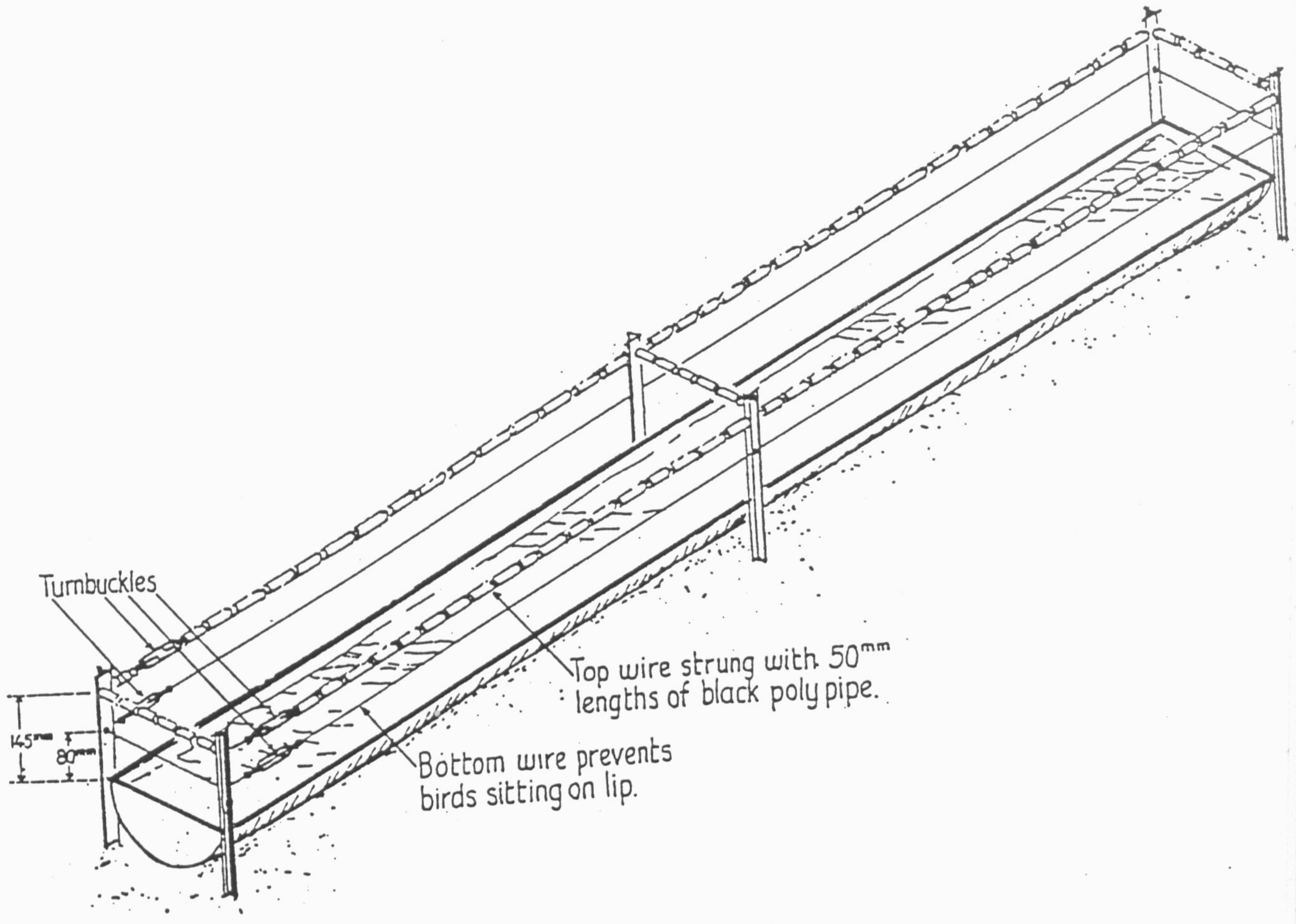


Figure 5.1

Diagram of trough modifications used to prevent Little Corellas from drinking from the trough (original design from Mr R Cox, "Uonhill" Quorn).

ambient temperatures (Spearman Rank r_S=0.4; p<0.001; n=85). Water intake in free flying Little Corellas at all temperatures and captive Little Corellas held at high temperatures (daily maxima 37°C) were not significantly different (Student's t=-0.05; df 19; p=0.9). In order to mimic the drinking rate of free flying Little Corellas, ambient temperatures were raised to 37°C during the dose response trials.

Drinking rate varied between individual birds (range 3 dips-16 dips per session) and thus individual drug intake also varied (range 7.7 mg/kg-338.6 mg/kg, Table 5.1). Average volume of the lower mandible was 0.96 mls (s.e. 0.03; n=20). Little Corellas exposed to varying concentrations of alphachloralose varied in their responses (Table 5.1). All birds exposed to the drug became comatose. Higher concentrations produced a more rapid onset of symptoms. For example, when exposed to a drug concentration of 8.0 g/l Little Corellas became comatose in 0.2h (s.e. 0.03h; n=4) whilst, at 1.0g g/l, the mean time taken for symptoms to appear was 0.7h (s.e. 0.1h; n=4). The length of coma varied with higher doses generally, but not always, producing a more extended coma (Spearman rank correlation r_S = 0.44; 0.2>p>0.1, n=12). All birds exposed to the highest concentration of the drug (8.0g alphachloralose/litre) died. Three of the four Little Corellas exposed to the highest dose received in excess of 225mg alphachloralose/kg and died within 3 hours. The remaining bird received approximately 69mg alphachloralose/kg and died some eight hours later. Two Little Corellas exposed at a concentration of 4.0g/l received doses greater than 69mg/kg but did not die, suggesting that there may be some toxic effect associated with the intake of high concentrations of this drug.

Table 5.1

Effects of increasing concentration of alphachloralose on time taken to coma, length of coma and time taken to death in captive Little Corellas exposed to the drug.

Bird	Sex	Weight (g)	Drug intake (mg/kg)	Onset of coma (h)	Death (h)	Recovery (h)	Length of coma (h)
Control 0g alphachloralose/litre							
1	F	415	0				
2	F	410	0				
3	F	355	0				
4	M	410	0				
1.0g alphachloralose/litre							
1	F	350	25.1	0.40	na	16.4	15.3
2	F	370	12.9	0.83	na	15.7	14.7
3	F	360	21.4	0.55	na	14.9	14.0
4	M	390	7.7	0.92	na	7.6	6.9
2.0g alphachloralose/litre							
1	F	405	35.6	0.08	na	8.6	8.3
2	M	400	40.0	0.25	na	9.8	9.4
3	F	410	32.2	0.42	na	8.4	7.8
4	M	430	30.7	0.33	na	3.9	13.5
4.0g alphachloralose/litre							
1	M	375	106.7	0.32	na	22.1	21.4
2	F	400	50.0	0.33	na	49.8	49.3
3	M	420	45.7	0.22	na	35.4	34.9
4	M	410	78.1	0.15	na	13.9	13.8
8.0g alphachloralose/litre							
1	F	430	225.1	0.17	2.5		
2	F	340	258.8	0.27	2.4		
3	M	375	338.6	0.17	2.0		
4	M	420	68.6	0.15	8.5		

Once the symptoms of coma had passed, the Little Corellas recovered quickly and were capable of co-ordinated movement, vocalisation, feeding and drinking within one hour of regaining consciousness (mean=0.6h; s.e. 0.09h; n=12).

These results suggest that low concentrations of alphachloralose could be used to capture Little Corellas for banding and release and that higher concentrations could be used to cull Little Corellas. The concentration for capture and release was set at 1.5g/l. Since the effects of high concentrations of alphachloralose (8g/l) on off target species were not known, the drug was not used at concentrations greater than 6g/l in field trials.

5.3.2. Field trials

The target roost was a large flock of Little Corellas (*ca* 9000) using the trees adjacent to the homestead and sheds belonging to Jim and Rita Britza, Richmans Valley (Figure 5.2). The target roost, alternative roosts and the watering points associated with both are shown in Figure 5.2. The target roost contained the majority of the Little Corellas roosting in the immediate area for most of the period January-March 1991 (Figure 5.3).

This flock followed a regular daily routine of dawn marshalling, mass departure from the night roost and a feeding session in nearby stubble paddocks. From approximately 8.30 am onwards, a proportion of the flock then returned to the target roost drinking at the target trough on the way (Figure 5.2). The birds then roosted in the trees for most of the day, emerging in the late afternoon for a repeat of the morning routine. Observations indicated that the drug trough was the preferred watering point for the day roosting flock for a period of at least 10 days prior to the cull. Several dams in the immediate area also attracted a number of birds.

The birds were allowed access to the drug solution on two occasions. On the first occasion (21 and 22 Jan), Little Corellas were permitted access to the drug trough over two

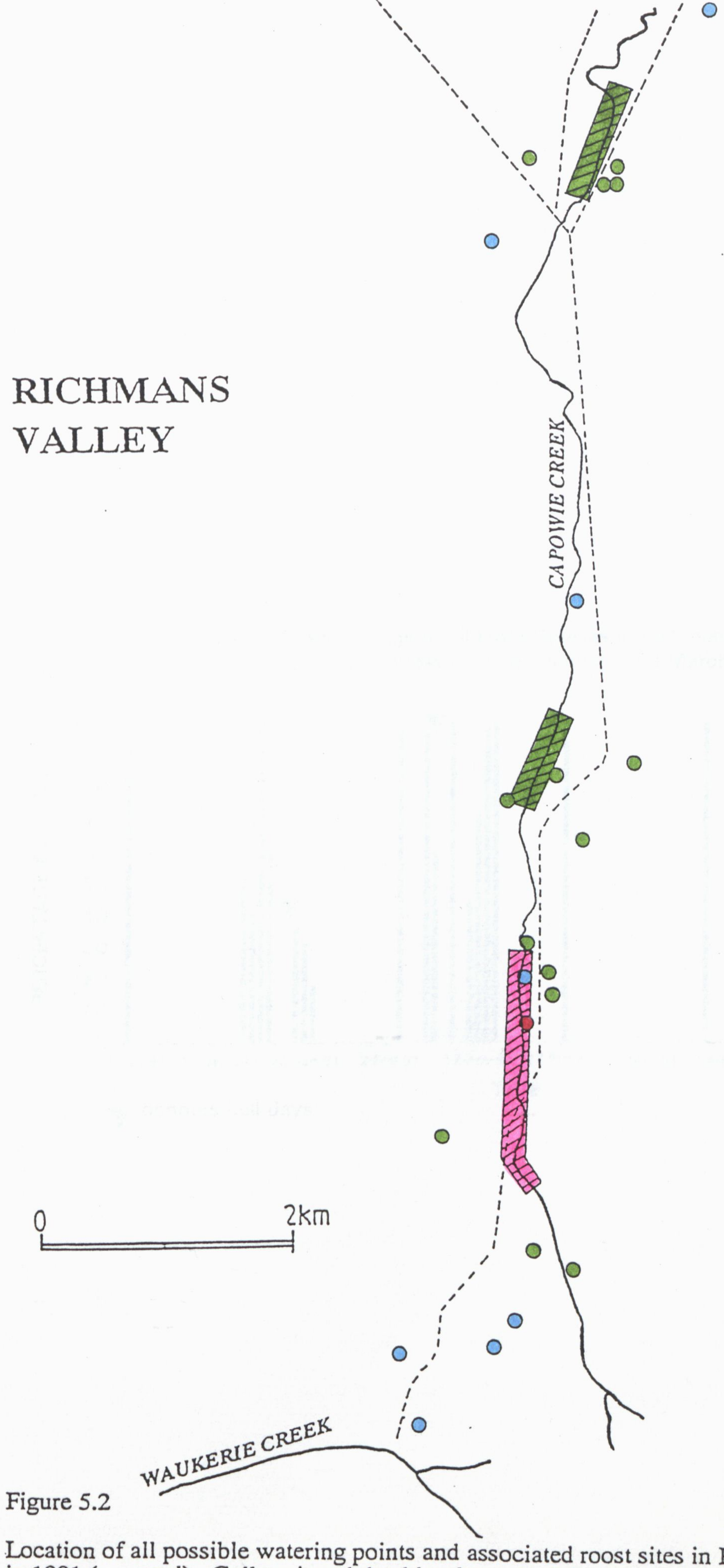
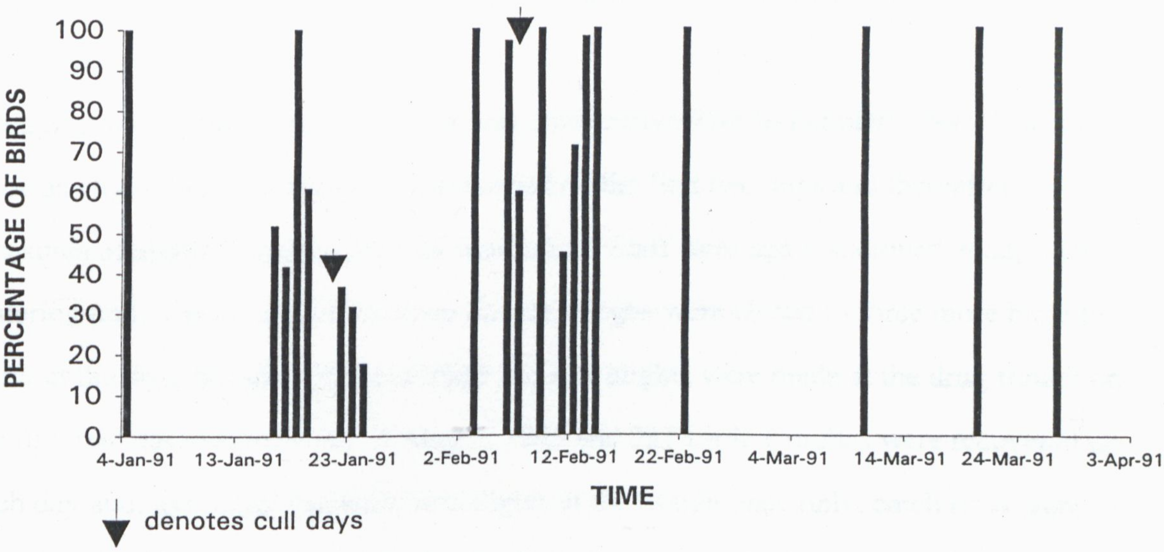


Figure 5.2

Location of all possible watering points and associated roost sites in Richmans Valley in 1991 (---road). Culls using alphachloralose administered in the stock trough where Little Corellas drank were conducted in January and February 1991. The target roost and target trough are marked in red and the alternative roosts and alternative watering points (troughs, tanks and dams) used by the birds are marked in green. Other (unused) watering points are marked in blue.

Figure 5.3 Percentage of all Little Corellas in Richmans Valley that used the target roost between January and March 1991.



consecutive days. The drug trough had attracted an average of 1024 (s.e. 140, n=3) alights during the evening drinking sessions on each of the three days prior to drug administration. Average water intake was 6.0 dips/bird (s.e. 0.7, n=24) indicating a drug intake of 35 mg alphachloralose/bird (equivalent to approximately 79 mg/kg) could be expected.

Staff were stationed at watering points adjacent to the drug trough to prevent the Little Corellas from using these alternative waters. Little Corellas drank freely at the drug trough on their way to the day roost following the morning feed. Coma was evident in those that drank within 30 minutes of the first arrivals at the drug trough. Daily culls were 702 and 368 respectively and a total of 1070 were culled from the roost in January 1991. Rain and cooler conditions prevented further drugging. The drug solution was removed from the drug trough and Little Corellas were allowed access to undrugged water.

Drugging was again attempted during four consecutive days in February 1991. The number of birds alighting at the trough was measured on the first two days and thereafter no measures of alights nor drinking rate were taken. Staff were again stationed at adjacent watering points and some of the more distant troughs were closed to force more birds to drink at the drug trough. A total of 2926 and 601 alights were made at the drug trough on the first two days respectively. A total of 1066 and 227 Little Corellas were recovered on each day and, assuming that each bird alights at the trough once only, catch rates were 36.4% and 37.8% respectively. Catch numbers declined markedly between day 1 (1066) and day 2 (227) when more Little Corellas were observed attempting to drink at alternative watering points. Decoys (dead Little Corellas) appeared to enhance the acceptability of the drug trough, probably by attracting birds on the wing. When decoys were strewn around the trough and more staff were deployed to discourage drinking at alternative waters, catch numbers again increased (day 3; 628) although this was not sustained (day 4; 59). A total of 1980 birds were culled from the roost in February 1991. The flock then split into smaller groups which used a number of distant (>3km) alternative sources of water. Further drugging was not attempted. The majority of comatose Little Corellas were found within 300m of the drug trough and 50-60% of these were alive when found.

Overall, a total of 3050 Little Corellas were removed from the flock using roosts in Richmans Valley in the summer of 1991, approximately one third of the original roosting flock.

Changes in roost size were monitored during the period before, during and after the culls. Roost size fluctuated considerably during this time, both at the target roost (Figure 5.4) and in the whole valley (Figure 5.5). Following each cull, the size of the target roost declined in excess of the number of Little Corellas removed from the flock. This was followed by a further decline in the number of Little Corellas using this roost despite the absence of further culling. Little Corellas began using alternative roosts nearby. After the January cull, the birds joined a roosting mob at a site approximately 4 km north of the target roost (property of John Finlay, Figure 5.6a). After the February cull, Little Corella numbers at the target roost dropped and the birds made use of trees situated 3 km north (Pine Glen Figure 5.6b). Birds were observed shifting between the roost trees at Pine Glen and the target roost. Thereafter the Little Corella numbers in the valley continued to decline as birds chose more distant roosts. However, within seven weeks of the last cull, Little Corellas had returned to the valley and were again using the trees in the target roost as a favoured location (information from regular counts and from landholders). Numbers observed at the target roost in March (peak 8115, 28/03/91) were similar to those observed in January (peak 8500, 20/01/91) and February (peak 9500, 07/02/91).

Off target captures included one Laughing Kookaburra (*Dacelo novaeguineae*), eight Ravens (*Corvus* sp), eight Australian Magpies (*Gymnorhina tibicen*) and four Galahs. Of these, only one raven was found alive and it was confined, allowed to recover and later released. Two Adelaide Rosellas (*Platycercus elegans*) were observed to drink at the drug trough but were not found. One Wedge-tailed Eagle was found dozing in a paddock near

Figure 5.4 Change in the number of Little Corellas using the target roost between January and March 1991.

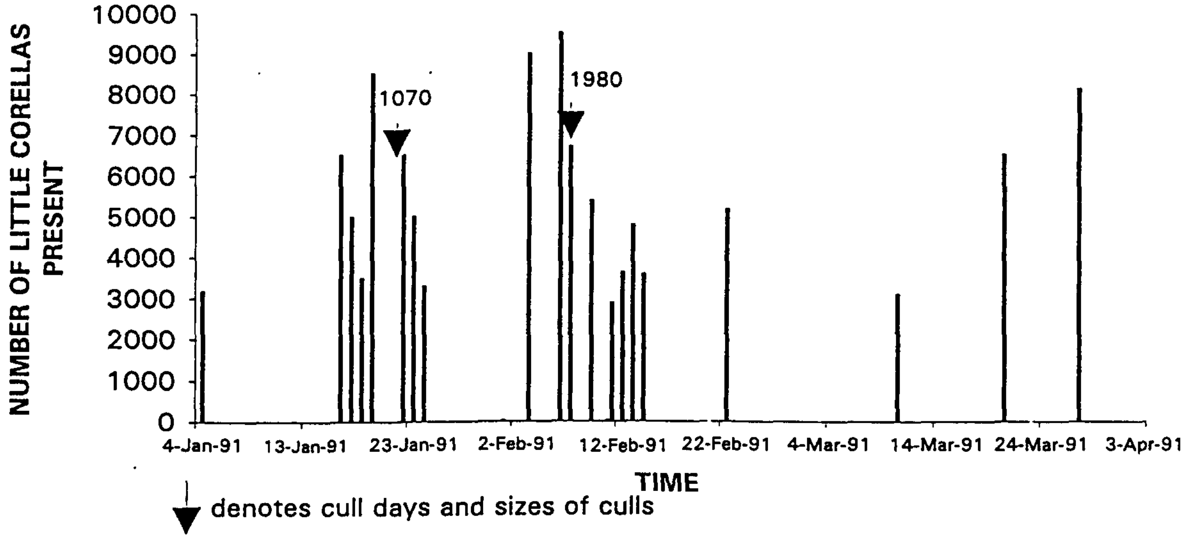


Figure 5.5 Changes in the numbers of Little Corellas using all roost sites in Richmans Valley during and after culling conducted at the target roost.

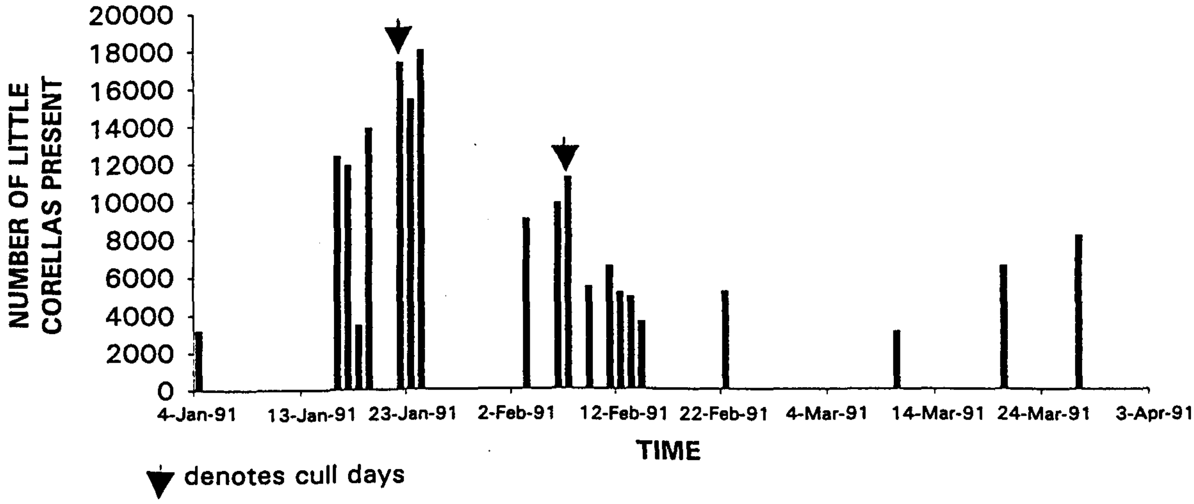
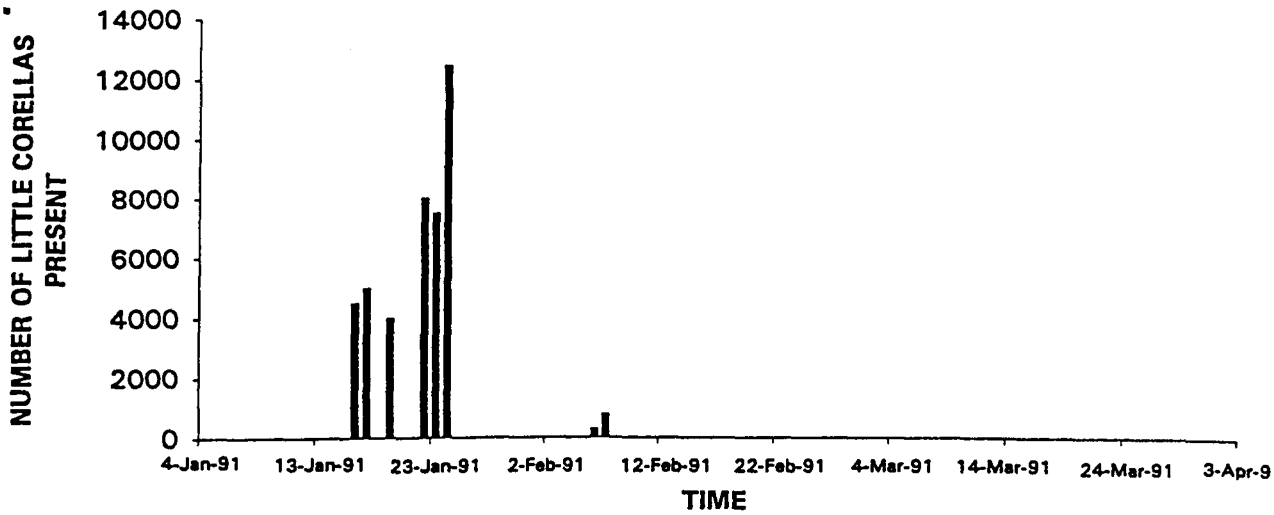


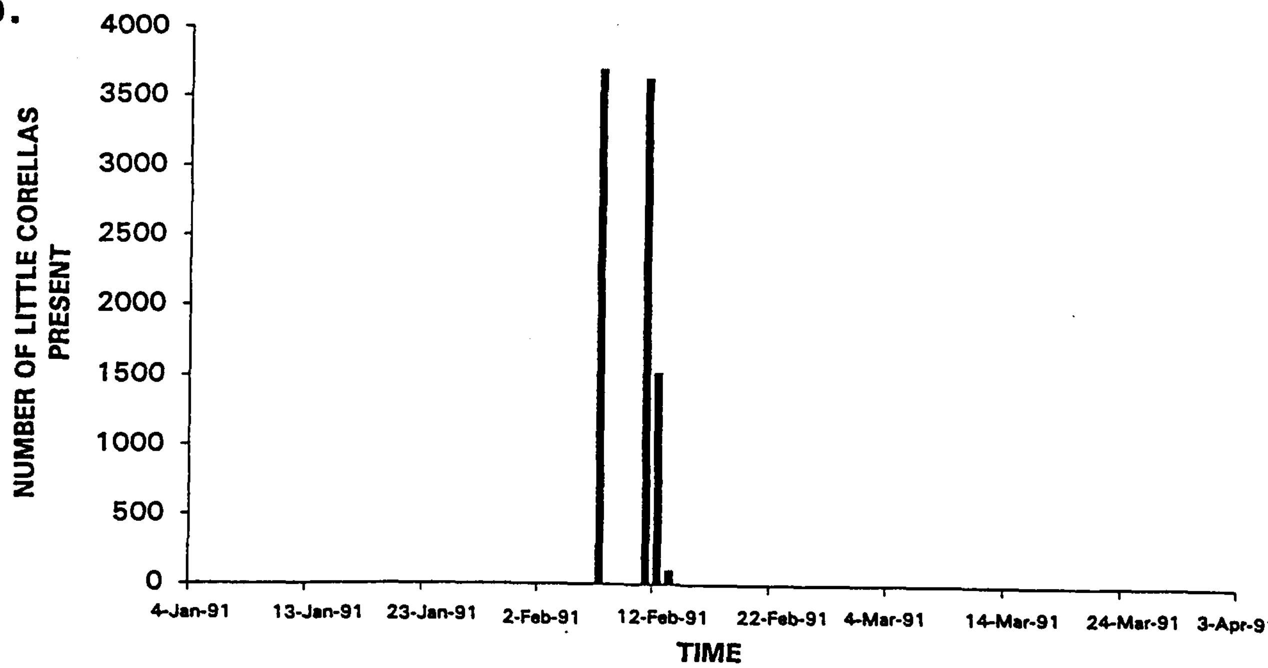
Figure 5.6 Change in the number of Little Corellas using alternative roosts following culls. a. property of J Finlay before and after January cull and b. "Pine Glen" before and after February cull*.

*Little Corellas were not observed at these sites at any other time during the summer of 1991.

a.



b.



the drug trough. Several comatose Little Corellas were found in the immediate area. The eagle was not capable of co-ordinated movement (flew awkwardly) and it was left undisturbed. It was observed approximately five hours later in the company of another Wedge-tailed Eagle and appeared to be flying strongly. Although the eagle was not observed actually eating a Little Corella carcass, it presumably had consumed one of the comatose Little Corellas lying close by.

5.3.3. Habitat modification

5.3.3.1. Characteristics of favoured watering points

Little Corellas and Galahs preferred watering points and feeding sites where they could obtain a clear, all-round view. Little Corellas were observed drinking from farm dams, stock troughs, open tanks and the puddles left after rain. They appeared to avoid dams with steep sides and tall surrounding vegetation (e.g. the railway dam in Quorn). Observations made during the cull indicated that Little Corellas also avoided troughs where one or both sides are screened by vegetation. For example, one alternative watering point for Little Corellas during the cull was a trough situated approximately 150m north of the drug trough. The alternative trough was screened along one side by a dense row of Peppercorn trees (*Schoenus areira*). At no time did Little Corellas use this trough either during the cull or at any other time (see Figure 5.2). However they made persistent attempts to use several other alternatives (one trough and two dams) also situated close to the drug trough.

5.3.3.2. Modifications to existing troughs.

In February 1990, modifications were fitted to the three troughs situated close to a night roost used regularly by 5,000-7,000 Little Corellas (troughs labelled A, B and C; Figure 5.7). Little Corellas returning to the roost following the afternoon feed usually chose either trough A or trough B for the evening drinking session. Birds also drank at an open tank and overflowing bore situated alongside trough B. Trough C was sometimes used by Little Corellas returning to the roost from the north-west.

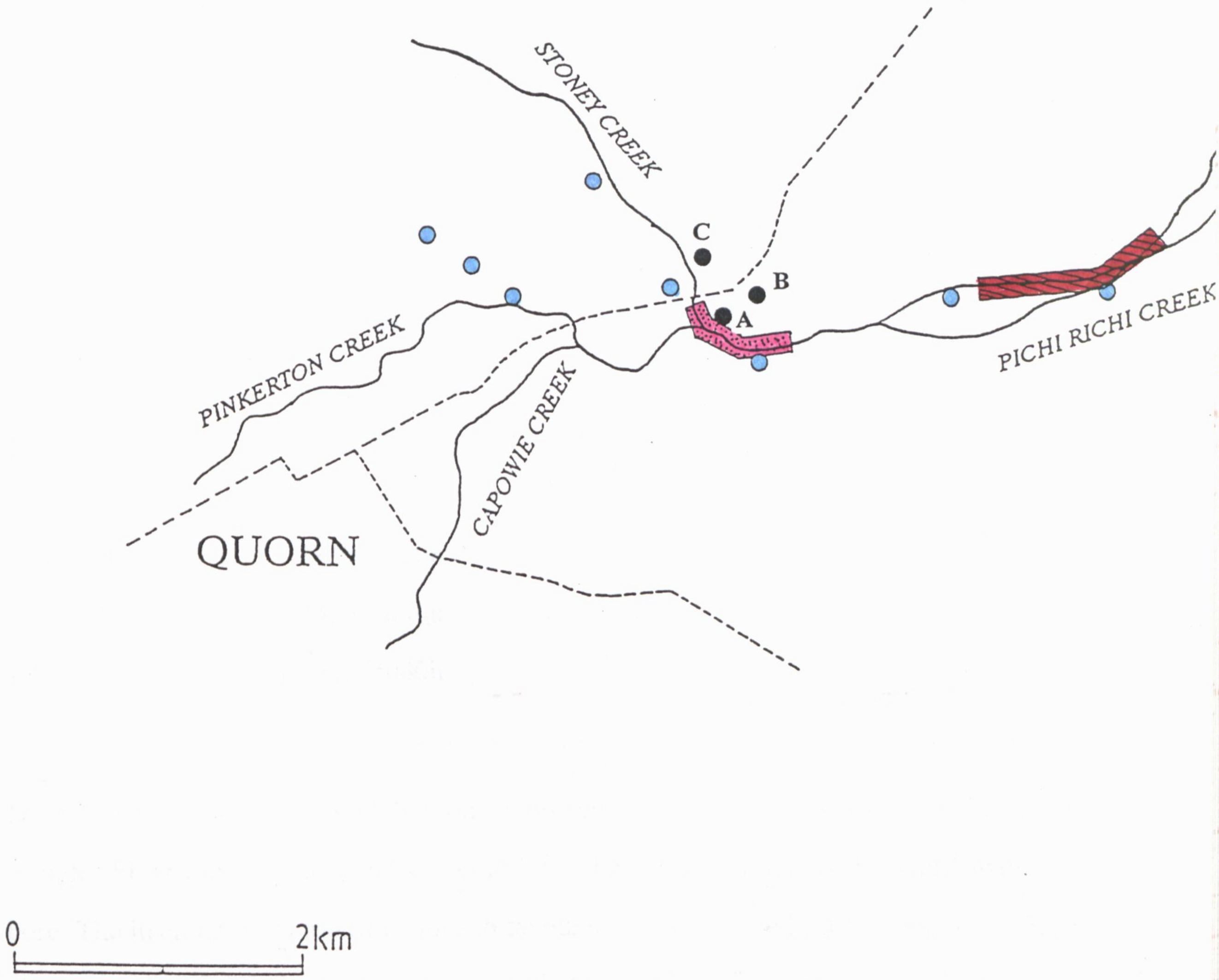


Figure 5.7

Location of marshalling area (▬), modified troughs (●) and alternative (unmodified) watering points (○) associated with the Pichi Richi Creek roost (▬) in 1990 (---road).

Modifications were first fitted to trough A. The birds abandoned trough A in favour of trough B (Table 5.2). Modifications were then fitted to troughs B and C and the open tank alongside trough B was covered. Due to a lack of observers, no record of bird attendance was made at trough C. With modifications fitted to troughs A and B, Little Corellas were unable to drink successfully at either of these favoured watering points (Table 5.2).

Table 5.2

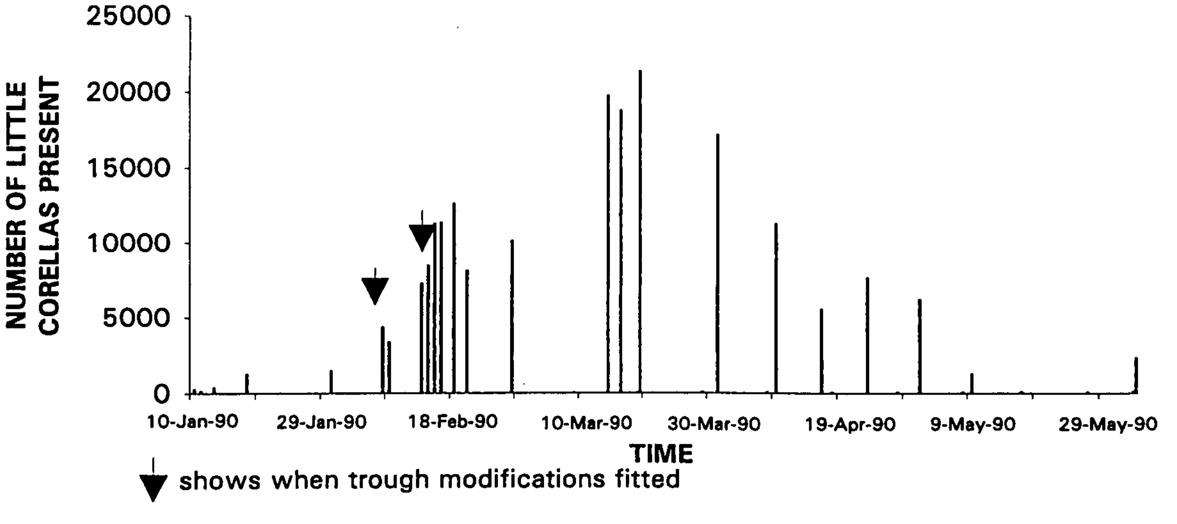
Effect of trough modifications on Little Corella use of two troughs (A and B), at Quorn.

Date	Time interval	Alights at trough **A**	Alights at trough **B**
08/02/90	1625-2035h	950	107
09/02/90	1800-2035h	0 (modified)	1250
10/02/90	1625-2015h	0	1395
11/02/90	1715-2025h	0	2759
12/02/90	1800-2020h	0	2975
13/02/90	1825-2020h	0	1207
14/02/90	1825-2040h	0	847
15/02/90	1825-2040h	0	0 (modified)

Despite the success of the modifications in preventing Little Corellas from drinking at the troughs, birds were able to drink successfully at the puddle created by the overflowing bore. The installation of modifications to favoured troughs caused Little Corellas to shift to alternative, unmodified troughs in the immediate area to obtain water (Figure 5.7).

Whilst restricted access to water caused a shift in water point preference, it appeared to have little effect on marshalling and roosting behaviour. Little Corellas continued to congregate in large numbers in the trees close to the modified troughs and to use the nearby roost (Figure 5.8). Two factors were considered to be important in determining the birds

Figure 5.8 Changes in the numbers of Little Corellas using the marshalling area before and after the installation of modifications to troughs used by the birds.



continued use of the area, firstly, the close proximity of several alternative watering points that were not modified, and secondly, a set pattern of marshalling and roosting behaviour established before the installation of the trough modifications.

5.4. DISCUSSION.

5.4.1. Dose response study

The laboratory-based dose response study also showed that drinking rate in captive Little Corellas was related to ambient temperature. Confined to cages, Little Corellas are relatively inactive irrespective of ambient temperature and their water turnover (as measured by water intake) increased when temperature was increased. However, water intake in free flying Little Corellas did not vary with increasing ambient temperature suggesting that water turnover was similar at all temperatures encountered in the Flinders Ranges during the summer. Free flying Little Corellas were more active in cooler weather (flying, foraging and display) than in hot weather. On hot days, they spent most of the day inactive in the canopies of trees. At higher temperatures, water intake was probably related to ambient temperature. At cooler temperatures, increased levels of activity in free flying birds may have been the factor determining water intake.

Exposure to alphachloralose at a concentration of 8.0 g/l was lethal to Little Corellas either by the action of the drug itself or by the toxic effects associated with ingesting high doses. All birds exposed to lower concentrations survived.

One advantage of using alphachloralose to cull Little Corellas was the ability to capture and confine off target species for later release. However, due to limited time, no off target species were subjected to dose response studies similar to those performed on Little Corellas. Therefore, to err conservatively, alphachloralose was not used at concentrations greater than 6.0 g/l during field trials.

5.4.2. Population reduction using alphachloralose

The culls conducted during January and February 1991 showed that efforts to reduce the population of Little Corellas in Richmans Valley had a two fold effect, both of which resulted in a temporary reduction in bird numbers at the target roost. Firstly, large numbers of birds were captured as a result of baiting one of their favoured watering points with alphachloralose. A comparison of the number of alights at the drug trough and the number of Little Corellas found comatose indicates that only 35-40% of Little Corellas alighting on the trough actually succumbed. This suggests that not all birds alighting on the trough actually drank or that some drank insufficient drug solution to become comatose. Alternatively, some birds may have alighted and drunk more than once. Similar capture rates were found during tagging and banding studies (results not shown). Approximately one third of the flock using the target roost was destroyed and thus the number of Little Corellas at the target roost was reduced.

Secondly, within 24 hours of initial exposure to the drug, Little Corellas showed a wariness of the drug trough. This was reflected in catch sizes which were initially high and then declined. The birds consistently tried to water at nearby, and then distant, watering points. Although acceptance of the drug trough could be temporarily enhanced by the use of decoys, the effect was not sustained. After each cull, numbers of birds at the target roost declined in excess of the number of birds actually removed. The final result was desertion of the target roost for a period of some weeks and thus bird numbers at the target roost were (temporarily) reduced. Wariness of the drug trough could be attributed to the Little Corellas developing an aversion to the drug; an association with either the taste of the drug or, possibly, linking the site of the drug trough with unpleasant experiences such as subclinical effects of the drug or loss of mate, siblings or parents. The level of wariness was sufficient to cause Little Corellas to temporarily alter their roosting behaviour. Thus the drug had a deterrent effect on bird behaviour. Other studies where alphachloralose had been used to cull pest birds report results similar to those reported here. For example, taste aversion to alphachloralose was observed by Statham and Medlock (1987) in Tasmanian

Native Hens (*Tribonyx mortierii*). A deterrent effect of repeated exposure to the drug was observed by Morris (1969) in Domestic Pigeons (*Columba livia*) and House Sparrows (*Passer domesticus*) and by Sinclair (R. Sinclair pers. comm.[14]) in Starlings (*Sturnus vulgaris*).

Neither reduction in number nor the change in roost site preference had a lasting effect on bird numbers at the target roost. The number of birds using the target roost seven weeks after the cull was similar to that observed before culling began.

The use of alphachloralose may target immature birds. The proportion of immature birds captured increased over successive days of drugging (see section 3.3.5.1., Chapter 3) and this suggests that the drug trough remained attractive to the younger, inexperienced birds even though older, more experienced birds were attempting to drink elsewhere. Age bias in capture has also been reported for Red-winged Blackbirds when attempts were made to reduce populations by trapping (Weatherhead 1982). Mortality rates in parrots are highest within the first year of life (Galahs; Rowley 1990) and therefore, the use of alphachloralose to cull Little Corellas may be expending a disproportionate amount of catch effort on those birds most likely to die anyway.

Overall, the number of off target birds captured was considerably less than the number of Little Corellas captured due to the tendency of Little Corellas to drink in exclusive groups. Most off target birds and approximately 50% of Little Corellas were dead on encounter. The high mortality rate amongst Little Corellas and off target species was not predicted by the dose response studies and was attributed to extended exposure to elevated temperatures whilst under the influence of the drug (Lees 1972, Arnold *et al.* 1986).

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[14]Dr R.G. Sinclair, Senior Research Officer, Animal and Plant Control Commission, Department of Primary Industries, South Australia.

Whilst the present study may attract criticism for being a one-off effort to reduce the numbers of Little Corellas in the lower Flinders Ranges, other studies show that sustained and/or repeated culling has had little effect on population sizes of pest birds e.g. Blackbirds (Icteridae) and Starlings (*Sturnus vulgaris*, Tahon 1980, White *et al.* 1985), Herring Gulls (*Larus argentatus*, Woronecki *et al.* 1989), Grackles (*Quiscalus quiscula*, Tipton 1989a). No control programme is more conspicuous in its failure than the 20 years of control effort expended on the Red-billed Quelea (*Quelea quelea*) in Africa (e.g. Ward 1979). Similarly, repeated and sustained efforts to remove individuals from Little Corella flocks in the Flinders Ranges, by whatever method, may not achieve a reduced population size in the longer term. As demonstrated during tagging studies, Little Corellas are extremely mobile and the removal of birds from one location could easily be countered by an influx of birds from neighbouring flocks. Given the widespread distribution of the Little Corella in South Australia, replacements could come from some considerable distance (at least 200 km, see section 2.3.2.2.) from the target population.

Members of the parrot family generally form strong pair bonds and one outcome of population reduction may be the disruption of the pair bond with subsequent effects on breeding performance. Studies on the Galah (Rowley 1990) and Western Long-billed Corella (GT Smith 1991) have shown that re-mating can occur after loss of a partner or divorce. Removal of one member of the pair may not necessarily affect breeding performance in future years provided the survivor can find a suitable replacement. GT Smith (1991) has also shown that while breeding success of the re-mated pair may be adversely affected in the short term especially if loss of one member occurs during the breeding season, re-mating does not necessarily affect performance in the long term. Analysis of the age structure of summer flocks in the Flinders Ranges indicated that there may be a large pool of non breeding birds available to fill any gaps made by the death of one member of a pair. Thus, the culls conducted in this study may not have affected the breeding performance of the population. Whilst occasional or accidental loss of a partner may not affect subsequent breeding, the effects of continual disruption of the pair bond by say, culls directed only at breeding birds are less clear and may well have longer term effects on breeding performance.

5.4.4. Habitat Modification.

During the summer period, Little Corellas relied on the fallen grain in stubble paddocks and grain spilt around silos, field bins and temporary grain bunkers (see Chapter 3). They watered at farm dams, open tanks and stock troughs. The birds chose roost sites within easy access to water and food although not all potential roost sites with these features were used. Once established at a site that met their food, water and roosting requirements, Little Corellas were consistent and regular in their daily behaviour. Alterations to habitat directly (use of deterrents) or indirectly (restrictions to water and food) affected flocking and roosting behaviour.

Anecdotal evidence from landholders in the Quorn area suggested that shooting, combined with conservative use of a gas operated scare gun, disrupted cohesive flocking behaviour and was successful in discouraging Little Corellas from a variety of feeding and roosting sites. For example, a vehicle-mounted scaregun combined with a shotgun was used successfully to deter Little Corellas from feeding at the grain bunkers at Gladstone (D. Cooper pers. comm.[15]). Similarly, a shotgun and scaregun were used to deter Little Corellas from roosting in and around Quorn Caravan Park. Roost trees in this area have recovered from pruning pressure and now bear full canopies.

Two landholders in the Stoney Creek area, Quorn have used the scaregun/shotgun combination to successfully discourage Little Corellas from roosting in their section of the creek. As a result, canopy condition in the trees has improved (B. Powell pers. comm.[16], R. Cox pers. comm.[17]). All users of this method reported that the success of the method relied on timing of use and on vigilance. Either technique used alone was less effective i.e. birds

[15]Mr D. Cooper, South Australian Co-operative Bulk Handling Pty Ltd, Gladstone.
[16]Mr B Powell, *Endilloe*, via Quorn.
[17]Mr R. Cox, *Uonhill*, via Quorn

habituated to the sound of the scaregun and relying on the shotgun involved a prohibitive amount of time. Best results were obtained if the scaregun/shotgun programme was started as early as possible in the summer season to prevent any persistent pattern of roosting from becoming established. Daily patterns, once established, were more difficult to break.

Observations of feeding flocks during the summer indicated that Little Corellas, once established at a successful site, were persistent and regular in their behaviour. A reduction in available food supply after a feeding pattern was established caused the feeding flock to move elsewhere although the flock continued to visit the previously successful site regularly. For example, in late 1989, South Australian Co-operative Bulk Handling (SACBH) established a temporary grain bunker at Quorn. A considerable amount of grain was spilt alongside the bunker during loading. In January 1990, Little Corellas were observed feeding in the adjacent stubble paddock. Some birds discovered the spilt grain and then the bunker. A small feeding flock became established and flock size rapidly increased to about 6000. Birds attacked and breached the tarpaulin, leaving the grain exposed to further bird depredations, faecal contamination and moisture. SACBH made considerable efforts to discourage birds from the bunker and installed a gas-operated scare gun on the stack and employed a person part-time to shoot Little Corellas and Galahs. Despite early off-loading of the grain from the bunker, and a concentrated clean-up, Little Corellas continued to visit the empty bunker in search of food.

A reduction in available food supply before a feeding pattern was established (specifically, improved hygiene around grain installations) prevented problems with bird attack to grain bunkers. Thus in 1991, when the Quorn bunker was again used to store grain, bunker hygiene was vastly improved and little grain was spilt during loading. On several occasions, a few Galahs and Little Corellas were observed feeding in the adjacent stubble but none attacked the tarpaulin protecting the stored grain.

Similarly, when trough modifications to exclude Little Corellas from water were fitted to three favoured troughs in Quorn, the birds were forced to find alternative watering points. Whilst trough modifications installed after roost establishment did not necessarily affect roost size, modifications installed before birds establish roosts could influence choice of roost site and size of roosts. Abandonment of a roost area following water restrictions was observed in only one instance when Little Corellas vacated roost trees near a farm dam that dried up in January 1991. In this case, the flock shifted to an adjacent roost where other birds were already present.

5.4.5. Comparison of population reduction and habitat modification

Where problems with pest birds are experienced, amelioration of bird damage has taken one of two approaches namely, population reduction or habitat modification. This study has investigated both population reduction and habitat modification in order to find a solution to the problems associated with large summer flocks of Little Corellas in the southern Flinders Ranges.

Attempts to reduce the population of Little Corellas in the Quorn area were ineffective due to the mobility of flocks and individuals. Population reduction was an expensive option with the average cost of destruction using aqueous administration of alphachloralose estimated at $0.99 per bird (Table 5.3). All costs were recurrent as either consumable items (alphachloralose), vehicle running costs or labour. Other workers also conclude that population reduction is costly (White *et al.* 1985, Ward 1979).

Population reduction also had a deterrent effect that lasted some weeks. The cost of deterring birds from the target roost (Richmans Valley 1991) for say, 10 of a possible 20 weeks from 9,000 Little Corellas was $0.33 per bird. Unit costs ($/bird) would presumably increase if culls were to be used to deter birds from the target roost for the entire summer e.g. if two culls were conducted (one cull at the start of the season and one cull 10 weeks later), combined costs would be $6020 or $0.67 per bird. If roost size at the start of the season was less than 9,000 Little Corellas, unit costs would increase for the same cull effort.

Table 5.3

Costs associated with the reduction of the Little Corella roost at Richmans Valley in January and February 1991. A total of 3050 corellas were destroyed during the culls and the costs were $0.99 per bird.

Materials	Number required	Unit Cost ($)	Cost ($)
Alphachloralose solution (6.0g/l) technical grade 1kg $430	100 litres	430/kg	260
Vehicle	500 km	0.50/km	250
Labour bird scaring & pick up, attending drug trough.	250 hours	10/hr	2500
		TOTAL	**$3010**

This study has established that habitat modification techniques such as food and water management and the use of deterrents can, operating independently, affect the behaviour of Little Corella flocks in summer. Thus a reduction in food supply decreased bird damage and depredations to the temporary grain bunker, and modification of troughs caused birds to drink elsewhere. The scaregun/shotgun combination shifted roosting flocks. If all vulnerable aspects of bird behaviour were manipulated simultaneously by combining all of these techniques in a coordinated fashion, flocks could be discouraged from traditional roosts and pruning damage at these sites could be reduced.

The cost of habitat modification depends on the size of the area to be protected e.g. the number of troughs to be modified, the spacing of scareguns and labour costs to operate the scareguns and shotgun. The trough modifications as described above cost approximately $50 per trough using all new materials. Modifications would be required only in cases where stock needed access to water. In cases where stock were absent, such as parklands within the townships, troughs could be covered to exclude birds. Minimising grain spills has advantages other than restricting food supply to Little Corellas namely, less waste and less potential food for rodents. The costs associated with protecting the Pichi Richi roost, the largest roost at Quorn (peak roost size *ca* 20,000 birds, Table 4.7) for the entire summer have been calculated at $0.36 per bird (Table 5.4). Approximately 40% of the costs are capital costs and the remaining 60% are consumable items, such as shot gun shells, vehicle running costs and labour. With no further capital expenditure required, the cost of protecting trees would be reduced in subsequent years.

Although less capital expenditure would be required to protect smaller roost areas from Little Corellas (e.g. fewer scareguns), unit costs may be greater as recurrent costs (shotgun shells, labour, vehicle running costs) are similar. For example, costs associated with protecting the target roost in Richmans Valley from 9,000 Little Corellas would be $0.51/bird assuming that two troughs required modifications and that one new scaregun was purchased.

Therefore as roost size decreases, the deterrent effects of population reduction and habitat modification may become economically comparable. Without further testing e.g. actual unit costs for protecting small and large roost areas from Little Corellas using both techniques, threshold roost size (the point at which culls are cheaper than habitat modification) could not be determined.

Table 5.4

Approximate costs associated with the protection of the traditional roost area in the Pichi Richi Creek, Quorn from Little Corellas. These costings assume that Pichi Richi Creek roost attracts a maximum of 20,000 corellas, that all equipment would be needed and most vigilance would be required. All materials costs are for new equipment and quoted as 1993 prices. The cost of protecting the roost area is $0.36 per bird.

	Number required	Unit ($)	Cost ($)
Materials			
trough modifications	6	50/trough	300
Scareguns (double shot) 2 fixed, 1 trailer mounted	3	490 each	1470
Gas cylinders	3	60 each	180
Trailer (commercial)	1	1300	1300
Shot gun shells	15 pkts	10/pkt	150
Vehicle	400 km	0.50/km	200
Labour			
Shooter's time			
1. start of season 4 hrs/day each day for 4 wks (November)	120 hours	10/hr	1200
2. remainder of season 4 hrs/day, 3 times/wk (December-April)	240 hours	10/hr	2400
		TOTAL	**$7200**

The disadvantage in shifting roosts is that Little Corellas will re-assemble at another site and continue damaging trees. However, if the flock could be shifted around the area on a rotating basis and encouraged to roost in previously unused trees, pruning damage could be spread over a larger area. Shifting the roost would allow individual trees a chance to recover in the years when not subjected to pruning attack. A programme of shifting Little Corellas could be achieved by a combination of water and food management and deterrents at traditional sites, particularly with mobile equipment and the co-operation of landholders.

CHAPTER 6

GENERAL DISCUSSION

In many parts of Australia, Little Corellas (and Galahs) have increased in range and abundance following the conversion of native vegetation to agriculture e.g. grain growing, the provision of water for sheep and the introduction of weeds. Little Corella numbers in South Australia generally, and in the Flinders Ranges in particular, appear to have increased since the 1950s.

Local communities in the southern Flinders Ranges experience problems with Little Corellas during the summer period when the birds congregate in large, noisy flocks. Little Corellas defoliate roost trees, usually River Redgums, causing community concern that tree health and survival are adversely affected. Communities are also concerned that Little Corella numbers are increasing rapidly and that, without some reduction in bird numbers, problems of pruning damage to roost trees will spread. In addressing these problems, this study examined the population structure of summer flocks and seasonal movement patterns of Little Corellas as well as their pruning and roosting behaviour and the impact of pruning on trees. All aspects were needed for the purpose of devising management strategies and actions to reduce bird damage to roost trees.

Movements of the Little Corella in the Flinders Ranges followed a distinct seasonal pattern. The birds dispersed over the entire Flinders Ranges in winter, mainly as small flocks, and congregated in large flocks in the southern section during summer. Estimates of population size in summer indicated that Little Corella numbers in the southern study area varied annually and were not increasing rapidly. Variation in the number of birds returning each summer suggested that seasonal conditions may affect summer flock sizes and that poor seasons may attract more birds to the south. The same individuals returned to the southern study area each year (although not necessarily to the same roost site) suggesting that Little Corella movements follow a pattern of congregation and dispersal within a defined area rather than a "flow through" pattern in which all birds pass through summer feeding grounds on their way elsewhere. However, range expansion to other areas of the state has been documented and suggests that some birds at least must disperse from natal areas and not return. The environmental cue for longer range dispersal in this species may have been related to drought events in the 1920s and 1950s when large numbers of Little Corellas and other "northern" species were observed outside their previous ranges. Problems with large flocks of Little Corellas also date from the 1950s. Exploitation of an abundant but seasonal food supply (fallen grain) in the south may have initiated and encouraged a pattern of seasonal movements based on food availability. Although difficult to verify, this argument suggests that Little Corellas discovered new areas when forced to disperse outside their range and their population size increased when they used existing food resources in those areas. Seasonal movements within an area which are tied to seasonal food availability are not precluded. Thus, drought-mediated dispersal of the Little Corella followed by local population increases supported by the easy availability of cereals may explain high bird numbers in the study area and is not inconsistent with the seasonal movements that have been observed.

Flocks of Little Corellas dispersed in the autumn after seasonal rains had caused germination of the fallen grain in the paddocks. Loss of this food supply was followed by a decline in body condition and an increase in the variety of food items in the diet. If rains were delayed, Little Corellas remained in the southern part of the study area longer and came into conflict with farmers by taking seed grain in newly sown paddocks. Bird distribution in the study area during winter was determined by reproductive status of the individual bird with breeding birds common in the northern section and non breeding birds common in the south. The relative lack of breeding birds in the southern study area during winter and spring indicates that little, if any, breeding takes place there. Breeding activity was confined to the north. This study could not determine whether seasonal partitioning based on breeding status would continue in the future. Given that neither food nor nest hollows were necessarily limiting and that Little Corellas have actively expanded their range and increased in abundance in recent years, continued expansion of the population, perhaps based on breeding activity in the south, is a distinct possibility. Population expansion combined with the concentrating effects of poor seasons predicts a continuation of the problems associated with destructive flocks in summer.

In summer Little Corellas roosted communally, often at sites used in previous years. These traditional roosts were always situated near water and usually within easy access of food. Despite cohesive flocking and roosting behaviour, tagging studies showed that individual Little Corellas were highly mobile and that the exchange of individuals between flocks was rapid. The mobility of individual birds or flocks often resulted in changes in the size and location of roosts.

Not all creeklines in the study area were used by roosting Little Corellas and thus most trees in most creeks were not affected by the pruning activities of these birds. Pruning damage to roost trees was a localised problem that focused on traditional roosts and, in particular, tall trees situated close to favoured watering points were most affected. The problem was worst in areas receiving pruning attack in consecutive seasons. The extent to which pruning by Little Corellas caused significant damage to roost trees depended on several key factors including bird dwell time (a combination of flock size and the amount of time the birds spent in the trees), roost location and rainfall in the previous year. Tree condition was deleteriously affected by the pruning activities of Little Corellas and pruning took place whenever birds were present in the roost. Larger flocks tended to be more persistent in their roosting behaviour and were capable of defoliating roost trees in a relatively short time. Therefore, trees in traditional roosts were at most risk from these flocks. Poor seasons may exacerbate pruning damage, first by concentrating birds in the southern study area and, second by extending the life of the summer roost and increasing the amount of time over which pruning may take place.

Trees in traditional roosts in low rainfall areas suffered more under pruning attack than did their counterparts in higher rainfall areas. In the former, environmental factors, such as low or unreliable winter rainfall, may constrain recovery and thus pruning damage may be a proportionally more important influence on tree health. Improvements in tree condition did occur in the years following above average rainfall and these improvements persisted thereafter, indicating that starch reserves in roost trees were sufficient to restore canopies.

Given the relationship between bird dwell time and pruning damage, the most appropriate way to reduce pruning impact at traditional roosts would be to reduce bird dwell time, either by reducing bird number or by reducing the amount of time birds spend in a roost. The reduction of the Little Corella population to control tree damage was a popular option amongst the local community (D. Knox pers. comm.[18]). As predicted by the studies of bird movements, attempts to reduce bird dwell time by reducing the Little Corella population were thwarted by the influx of replacements following culls. Moreover the cull method, a water-based drug bait, appeared biased towards the younger birds in the flock. Other studies have shown that mortality rates in birds are highest in the first and second year of life. There was a high incidence of the contagious avian disease, psittacosis amongst young Little Corellas in summer flocks. Therefore population reduction that focuses on summer flocks containing a surfeit of young birds may expend cull effort on birds likely to die anyway. Further, a predominance of young birds in summer flocks implies that any cull effort would remove younger (non-breeding) birds rather than older birds of breeding status. In this case, culling would not significantly reduce the reproductive potential of the population and young birds culled during summer could be replaced in the following year.

However, management options need not necessarily preclude population reduction if cull efforts are (1) directed against small populations (<2,000) which are relatively isolated from other flocks (e.g. Little Corella flocks on Kangaroo Island) or (2) made when there is most likelihood of maximum impact on the breeding portion of a population e.g. restricting cull activities to those years when large flocks comprise mostly adults. The cull technique used in this study would require further refinement, such as single-day drugging and

[18]Mr D. Knox, District Clerk, District Council of Kanyaka-Quorn, Quorn.

mobile bait stations, to improve catch sizes. Alphachloralose administered as a grain bait may also be suitable for culling Little Corellas. Grain baits would be most attractive at the time when birds were establishing their summer feeding pattern i.e. soon after arrival, and in autumn when grain in the stubble paddocks has germinated. Early culls may be more efficacious in that adults supporting dependent juveniles would be killed, and that birds would be culled before exerting defoliation pressure on roost trees. Although dispersal in autumn is based on breeding status of the individual bird, the timing of the dispersal of breeding and non breeding birds is not known. If breeding birds leave the southern Flinders Ranges in late summer, autumn culls with grain baits may target young birds as did the water baits in summer. Even if low bird numbers could be achieved through culling, without additional input to manipulate bird behaviour, favoured roost trees would continue to sustain pruning damage.

Rather than attempting a generalised control of bird damage by reducing bird numbers, habitat modification addresses the localised nature of pruning damage and manipulates vulnerable aspects of the birds roosting habitat to reduce bird dwell time. Little Corellas arriving in the southern study area each summer must search for a suitable roosting site - a process involving choice. This study has shown that roosting behaviour is plastic and that birds alter their roost preference regularly. This study has also established that manipulation of either food or water resources or the persistent use of deterrents does affect roosting and/or feeding behaviour especially if bird control measures are implemented before birds arrived (food and water restrictions) or as the first arrivals were observed (scaregun/shotgun). These measures exploit the birds natural tendency to shift roost and, if implemented in a co-ordinated fashion, could reduce pruning damage at traditional sites.

In discussing tree damage by Little Corellas and the fate of River Redgums in the study area, two points are worthy of consideration. First, canopy condition in the standing population of trees was only one aspect of the population dynamics of River Redgums in the study area. There was a widespread lack of River Redgum recruitment in many of the creeklines probably as a result of grazing impact and competition from weeds. Second, whilst shifting roosts may provide a temporary relief for severely pruned trees at traditional roosts, pruning damage at any new roost sites established by the Little Corella flock will continue. Thus, a regional strategy to ensure the survival of River Redgums in the southern Flinders Ranges should emphasise both the health of the standing population and oncoming generations of trees. To this end, a programme of shifting roosts, monitoring bird numbers and monitoring tree condition is required to alleviate pruning damage and a programme of restricting grazing in creeklines is needed to assist recruitment. Both these aspects must be considered by any community in the southern Flinders Ranges seeking to reduce Little Corella damage to roost trees and to secure River Redgum populations in the future.

CHAPTER 7

MANAGEMENT IMPLICATIONS

Management of River Redgums in the Flinders Ranges requires firstly, active manipulation of pruning pressure to reduce damage to the trees at traditional roosts and secondly, recruitment of young trees to ensure survival of the population in the long term.

7.1. Trees at traditional roosts

Habitat modification by altering bird choice and use of roosts offers the most promise of reducing dwell time, thus diffusing the pruning load and spelling damaged trees. Roost trees in low rainfall areas suffered more under pruning attack than did their counterparts in higher rainfall areas. Active management should therefore concentrate initially on roosts in lower rainfall areas in years when rainfall has encouraged good canopy growth. Reduced pruning pressure at this time should allow trees to produce epicormic growth and to re-establish the canopy crown and starch reserves. Insect populations on epicormic foliage should be monitored and the use of insecticides should be considered if an outbreak appears likely (Morgan 1984).

The Little Corella roost comprises three elements: access to water; access to food; and trees in which to roost. Thus, birds should be excluded from watering points near the roost, grain spills must be minimised and a deterrent should be used to discourage birds from roosting in trees. First efforts should be directed at traditional roosts i.e. those roost sites showing signs of severe damage in the past. Roost sites to be protected should be identified before Little Corellas arrive in the early summer and all troughs in the immediate area should be modified. All other equipment (scareguns, shotgun) should be assembled and one worker's time should be dedicated to the task of bird scaring.

The first priority should be to reduce flock size and bird dwell time by splitting large flocks into smaller units and preventing flocks from settling in the trees. Bird management must begin when birds first arrive and continue until the seasonal rains in the following autumn. Where epicormic growth is evident in roost trees, additional moisture (flooding, watering) may assist recovery of the canopy only if Little Corellas can be effectively and consistently prevented from using that site.

Protected trees should be monitored annually using visual assessments (see Chapter 3) to determine the level of recovery. Severely damaged roost trees may require more than one year free of Little Corellas for the crowns to recover fully, especially if winter rainfall is low.

Reduction of pruning pressure at traditional roosts involves spreading the pruning load over a wide area. Potentially suitable sites containing undamaged trees and watering points are available in the study area. A reduction of pruning damage at one site without a reduction in total bird numbers implies that total pruning pressure is re-located to previously unused trees (a sacrifice area) but remains unchanged. Therefore the aim of the management programme should be to diffuse the pruning load over as wide an area as possible thus, spelling damaged trees and minimising extensive pruning damage to other trees in sacrifice areas. Sacrifice areas could be made more attractive to Little Corellas if free food and water are provided, at least initially. As stipulated for traditional roosts, tree condition in sacrifice roosts should be monitored annually. This information could be used to determine siting of new sacrifice areas and the length of the rotation cycle needed to spell trees at both traditional and sacrifice roosts.

The provision of extra resources (food and water) at sacrifice areas may be criticised as favouring the survival of Little Corellas. However, free food should only be necessary to attract birds to a sacrifice area where, without further inducement, they will continue to roost provided they left undisturbed. Furthermore, sacrifice areas are intended to operate only during the summer when Little Corellas are congregated i.e. at a time when abundant food resources are also available in the stubble paddocks. Thus the provision of free food does not necessarily represent an increase in the birds food resources during summer.

Results from experimental culls conducted in this study showed that bird numbers at roosts could be temporarily reduced using alphachloralose water baits. Alphachloralose water baits had a two fold effect in that birds were removed from the roosting flock and birds were deterred from the roost site for a period of weeks. No long term effects on population size could be expected from this cull since most individuals captured were young and/or non breeding birds. However, if cull efforts could be refined and directed so as to affect the breeding potential of Little Corellas, then culls may reduce the size of the summer population in subsequent years. Culls should not be introduced unless such selective techniques are available. Furthermore, the implementation of culls requires an on-going commitment to population reduction and monitoring its effects. The relative age (see chapter 3) of all birds culled should be assessed to determine possible effects on breeding potential of the population. Bird numbers at target roosts and neighbouring roosts should be assessed to determine the effect of culls on bird behaviour and use of roosts. Monitoring of total bird numbers in the southern Flinders Ranges must also be conducted in order to determine the effects of culls on population size.

Habitat modification strategies to protect trees damaged by Little Corellas should be implemented in the townships of Quorn, Wilmington and Melrose as soon as possible. Population reduction should not implemented, at least initially, until some results from the habitat modification programme are available. Population reduction should never be regarded as an alternative to habitat modification nor, at this stage, as a necessary adjunct.

7.2. Recruitment of River Redgums

Recruitment of River Redgums in the study area is needed to ensure their survival. Natural regeneration is less costly than, and thus preferable to, replanting either from tubestock or from direct seeding. This species does regenerate freely from seedlings after flooding

(Dexter 1967) and above average rainfall in summer (Venning and Croft 1983, Bishop 1987) provided the seedbed has been suitably prepared and grazing pressure is low (Kiddle 1987). Best results have been obtained by burning and scarifying the ground around vigorous parent trees and allowing light grazing to reduce weed competition during seedling establishment (Dexter 1967). All landholders in the study area should be encouraged to provide conditions suitable for the natural regeneration of River Redgums including at the least, reduced grazing pressure in creeklines in the two years following high rainfall events in summer and at most, active efforts (e.g. seedbed preparation) to ensure seedling survival.

7.3. Directions for future research

Several aspects of the biology and ecology of Little Corellas were not addressed in the intensive study of summer flocks and their influence on tree health. The following require further investigation.

1. Variation in reproductive success of Little Corellas, especially in relation to variations in seasonal conditions (information on this topic may determine the rate of increase in the Little Corella population, and thus the size of the pruning and related problems in the future);

2. Factors affecting bird congregation and dispersal, in particular seasonal effects on congregation and the timing of dispersal in autumn (more data on these topics may clarify issues relating to culls e.g. which years and at what time in the season culls will affect adults rather than juveniles); and,

3. Incidence of psittacosis (and other avian diseases) in free living Little Corellas to determine the relative importance of natural influences in limiting population size as opposed to say, culls.

Further work on the influence of pruning damage on tree health is also required, particularly the effect of pruning on starch reserves in trees at traditional roosts and in sacrifice areas. Information on this topic should clarify the relative importance of pruning and of variation in seasonal conditions on tree health and help determine rotation cycles for traditional and sacrifice roost areas.

Appendix 1

A review of techniques used to control pest birds

An examination of the literature shows that a variety of techniques and substances have been employed in order to deter, capture and/or cull birds from situations in which they are perceived as a pest. The object is to reduce damage by either reducing the population of pest birds or by manipulating the feeding, roosting or loafing habitat so that it is no longer attractive to the birds.

Population reduction.

Techniques used to destroy pest birds include shooting, trapping, destruction of the roost using explosives (Tahon 1980) and poisoning using various chemicals (Dolbeer 1989). The principal effect of shooting is to deter birds from a site rather than achieving a lasting effect on population number. Despite its ineffectiveness, shooting has been the most commonly employed solution to the problem of pest birds (Fleming 1990). Also, birds (especially the parrots) come to learn to avoid areas where they are continually harassed. Shooting is an expensive and time consuming method of deterring birds. However the combination of shooting and the use of scareguns has proved more effective in that the scaregun produces a noise similar to that of a shotgun but takes over from the shooter (Davis 1974).

Substances registered for use against pest birds include a range of poisons and drugs. Poisons are administered either orally or as a topical application from the air or via the perch (e.g. Rid-a Bird perches containing endrin or fenthion, Jackson 1978). Ingested poisons include strychnine and *Starlicide* (DRC-1339[19]; Schafer 1984). Poisons that can be applied aerially to pest birds include PA-14[20], a surfactant applied to roosting birds to lower body temperature to a lethal level (Lefebvre and Seubert 1970), CPT[21] and fenthion which are contact toxicants (Douville de Franssu *et al.* 1988, Heisterberg *et al.* 1990,

[19]DRC-1339 is 3-chloro-p-toluidine hydrochloride and is related to CPT.
[20]PA-14 is α-alkyl-omega-hydroxypoly (oxyethylene)
[21]CPT is 3-chloro-4-methylbenzenamide

Dolbeer 1989). In North America, strychnine and toxic perches have been used against House Sparrows (*Passer domesticus*) and Domestic Pigeons (*Columba livia*) (Courtsal 1983). *Starlicide* is used to control starlings at feedlots and gulls on breeding islands used by terns (Schafer 1984). PA-14 has been used on Starlings (*Sturnus vulgaris*) and Red-winged blackbirds (*Agelaius phoeniceus*) (Johnson & Glahn 1983, Dolbeer 1983). CPT and fenthion have been used in France to control Starlings (Douville de Franssu *et al.* 1988) and in Africa to control Quelea (*Quelea quelea*) respectively (Dolbeer 1989).

Organophosphorus and carbamate insecticides are widely used agricultural chemicals. Although less persistent in the environment than the organochlorine insecticides, both have been implicated in the deaths of off target organisms through primary and secondary exposure (Balcomb 1983, Blus *et al.* 1989, Bruggers *et al.* 1989). Deliberate and accidental misuses of organophosphorus insecticides are known to be the cause of death in several bird species (Blus *et al.* 1989, Busby *et al.* 1990, Du Guesclin *et al.* 1983). Acute poisoning can occur when birds receive a topical application of an insecticide during aerial spraying, or through ingesting food items that have been sprayed. Long term effects include lower reproductive capacity due to reduced brain acetylcholinesterase activity in birds receiving sublethal doses (Hart 1990, e.g. Bairlein 1990).

Stupefying drugs such as alphachloralose have also been used to capture and/or destroy pest birds. Alphachloralose has been presented either alone or in combination with barbiturates such as sodium phenobarbitone (Dolbeer 1989). Mode of administration is usually as a solid bait (whole grains, cracked grains, legumes, bread and margarine sandwiches) although aqueous administration has also been used (Arnold *et al.* 1986). Alphachloralose is the condensation product of glucose and chloral (Lees 1972). It exists as two isomers only one of which, the alpha isomer, is pharmacologically active (Ridpath *et al.* 1961). Alphachloralose acts as a depressant on the central nervous system. In the body it is rapidly metabolised to trichloroethanol (the active metabolite) which combines with glucuronic acid in the liver to form urochloralic acid. Urochloralic acid is pharmacologically inactive and is excreted in the urine. Alphachloralose produces symptoms of anaesthesia within 30 minutes of administration independent of the mode of bait presentation (Morris 1969, Ridpath *et al.* 1961, Caithness 1968, Statham & Medlock 1987, Woronecki *et al.* 1989, this study). The drug apparently depresses body temperature (Lees 1972) although effects on thermoregulation in general have also been observed (Arnold *et al.* 1986). There are several advantages in using alphachloralose as a capture/cull agent for birds, namely:

1. quick onset of symptoms;
2. the majority of birds succumb to the effects of the drug close to the bait station;
3. off target birds consuming the bait can be captured and confined for later release;
4. high bait acceptance, at least initially; and
5. rapid metabolism of the drug to pharmacologically inactive metabolites which reduces the chances of secondary poisoning (Statham & Medlock 1987).

The disadvantages of alphachloralose include:

1. the Therapeutic Index (the ratio of LD50:ED50, a measure of drug safety) is low for some bird species (this implies that the dose required to produce symptoms is close to lethal dose and could make overdosing during field trials more likely, Loibl *et al.* 1988);
2. the Effective dose (ED50) and lethal dose (LD50) appear to vary considerably between bird species (Loibl *et al.* 1988); and
3. target animals develop an aversive response to the bait over successive drugging occasions (Arnold *et al.* 1986, Statham & Medlock 1987, this study).

A summary of pest birds in which alphachloralose has been used to capture or cull birds is presented in Table A.

Table A

Summary of pest bird situations in which alphachloralose has been used to capture and/or cull birds.

Common name	Scientific name	Problem	Mode of bait administration	Source
Rooks	*Corvus* sp	Crop damage	Solid	Giban 1950 (in Ridpath *et al.* 1961)
Pigeons	*Columba livia*	Faecal contamination	Solid	Ridpath *et al.*
Pigeons	*Columba livia*	Taking grain in feedlot	Solid	Morris (1969)
Wood-pigeons	*Columba palumbus*	Crop damage	Solid	Murton *et al.* (1963)
Sparrows	*Passer* sp	Faecal contamination	Solid	Cornwall (1966)
Black Backed gulls	*Larus dominicanus*	Hazard at airport	Solid	Caithness (1968)
Tasmanian Native Hen	*Tribonyx mortierii*	Crop damage	Solid	Statham & Medlock (1987)
Herring Gull	*Larus argentatus*	Power outages	Solid	Woronecki *et al.* (1989)
Ravens, Crows	*Corvus sp*	Competition with Ptarmigan for habitat	Solid	Parker (1991)
Magpies	*Pica pica*	Competition with Ptarmigan for habitat	Solid	Parker (1991)
Starlings	*Sturnus vulgaris*	Bait trials	Solid	Bomford (pers. comm.)

Dr M Bomford, Bureau of Rural Resources, Canberra.

Up until the present time, individual states in Australia have registered and controlled the use of chemicals to be used against pest birds. Although no one substance is registered for use as an avicide in all states, various substances are registered in some states. Thus, in Victoria, toxic perches containing fenthion methyl are used against introduced bird species (e.g. Domestic Pigeons) causing faecal contamination in buildings. Toxic perches are available for use in buildings and structures only and may not be used against native birds species. In Western Australia, alphachloralose is registered for use against Domestic Pigeons and Sulphur-crested Cockatoos although strict conditions control its use in the latter case. No substance is registered for use as an avicide in South Australia. Laws governing the registration and use of all chemicals, including pesticides, are under review and federal legislation is pending (A. Westley pers. comm.[22]). Under the proposed legislation, the National Registration Authority will oversee registration and determine general guidelines for the use of the substance. State authorities will then control specific conditions of use within their respective states. Rentokill Pty Ltd are interested in pursuing registration of alphachloralose for use against a variety of pest birds including both introduced and native species provided state wildlife and vertebrate pest authorities concur.

Habitat modification.

A wide range of non destructive techniques aimed at reducing bird damage have been tested. Most try to make the feeding, watering, roosting or loafing habitat unattractive to the pest bird and thus often exploit some aspect of the birds' behaviour e.g. aversion to certain chemicals, to sudden noise, to obstructed views whilst feeding or drinking. Techniques include shooting, physical exclusion from food, water and roosts using nets (Jarman & McKenzie 1983, Sinclair 1990) or lines strung in trees (Tipton 1989b) and buildings (Woronecki *et al.* 1989). Nest destruction has also been used (Rappole 1989). Some techniques use deterrent devices such as scareguns, *Bird-frite* cartridges (a gun-fired projectile containing a delayed explosive), effigies of predators (e.g. hawk kites etc.,

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[22]Ms A. Westley, Project Officer (Legislation), Farm Chemicals, Department of Primary Industries, South Australia.

Conover 1984) and effigies of conspecifics either singly or combined (Davis 1984, Montague 1985) to deter pest birds. Decoy feeding, that is the provision of an alternative food source, has proved successful in reducing Long-billed Corella damage to germinating winter cereals in the South Australia (P. Alexander pers. comm.[23]). Roosts are located and birds are provided with free feed in the immediate roost area for the period when the target crop is most vulnerable i.e. from sowing to germination.

Bomford and O'Brien (1990a) reviewed the use of sonic deterrents for the control of animal damage and found that efficacy was limited to short term control. Best results were obtained if the sound was presented at random intervals, if the sound source was moved frequently and if the sound was reinforced with a shotgun. Habituation to the aversive sound was universal. They concluded that sonic deterrents using biologically meaningful sounds such as specific communication signals had the most potential for use in the control of bird pests.

Substances used to discourage pest birds from feeding sites include a range of repellents such as 4-aminopyridine *Avitrol*, methiocarb *Mesurol* and methyl anthranilate. Repellents are presented either on the crop to be protected or as baits for ingestion. The repellent 4-aminopyridine is used as a frightening agent whereby individuals ingesting baited food become distressed and deter other individuals from the same site. Although employed as a deterrent, avitrol can cause considerable mortalities (Dolbeer 1989). Techniques designed to reduce the amount of repellent used whilst maintaining protection of the crop have been investigated e.g. by treating only half the crop (Avery 1989) and by combining repellents with other substances to enhance repellency (Avery 1984, Mason 1989). Avery (1984) found that visual cues enhanced repellency of methiocarb-treated oats in finches (*Carpodacus mexicanus*). Mason (1989) found that chemical (methyl anthranilate) and visual (calcium carbonate) cues increased the repellency of methiocarb-treated apples to

[23]Mr P.J. Alexander, Scientific Officer, Habitat and Wildlife Management, Department of Environment and Natural Resources, South Australia.

Red-winged Blackbirds. Recently, the repellent properties of naturally occurring substances have received attention e.g. cucurbitacin (Mason & Turpin 1990), cinnamic acid (Crocker *et al.* 1993), in particular those substances already in use as food additives for human consumption, namely dimethyl anthranilate (Askham & Fellman 1989), methyl anthranilate (Mason *et al.* 1991) and D-pugelone (Mason 1990). Methyl anthranilate is currently under investigation in South Australia for use as a repellent against rosellas in cherry orchards (R G Sinclair pers. comm.[24]). A summary of non destructive bird control techniques is presented in Table B.

The toxicity of drugs, poisons and repellents to other organisms varies although freshwater organisms generally show higher sensitivity than birds and mammals (Besser *et al.* 1967 *cf* Marking & Chandler 1981). Off target vertebrate species are exposed to the substances used to poison and/or repel pest birds through the ingestion of carcasses. The risks of secondary poisoning from the use of repellents, poisons and drugs vary. Both alphachloralose and starlicide are metabolised to non toxic compounds and excreted whilst the bird is still alive (Timm 1983, Lees 1972). Hence there is a low risk of secondary poisoning (Statham & Medlock 1987). However the undigested bait in the crop or gullet of the bird killed by strychnine is toxic to scavengers. Poisonous residues are also present in the carcasses of birds killed after contact with toxic perches. Secondary poisoning of off-target species can be minimised if collection and disposal of toxic carcasses is thorough. Collection and disposal is easier if target birds die at or near the roost. If target birds die away from the roost, the incidence of secondary poisoning is unknown but may be high (Courtsal 1983).

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[24]Dr R.G. Sinclair, Senior Research Officer, Animal and Plant Control Commission, Department of Primary Industries, South Australia.

Table B

Summary of non destructive techniques used to deter pest birds from feeding, watering and loafing sites.

Technique		Source
Audio		
Shooting		Hartridge *et al.* (1975)
Scaring (with or without shooting)		Beeton (1977), Summers (1985)
		Long *et al.* (undated)
White noise		Bomford (1990)
Bioacoustical noise		Jaremovic (1990)
Visual		
Alterations to feeding habitat		Jarman & McKenzie (1983), Allen (1990)
Conspecific effigies		Davis (1974), Fellows & Paton (1988)
Predator effigies		Conover (1984)
Human effigies		Boag & Lewin (1980)
Tactile		
Taste	4-aminopyridine	De Grazio *et al.* (1972)
	methiocarb	Mason (1989), Avery (1989)
	methyl anthranilate	Mason (1989), Mason *et al.* (1991)
	dimethyl anthranilate	Askham & Fellman (1989), Mason *et al.* (1991)
	D-pugelone	Mason (1990)
	cinnamamide	Crocker & Perry (1990)
	cinnamic acid	Crocker *et al.* (1993)
	curcurbitacin	Mason & Turpin (1990)
Touch-sticky material on perches		Johnson & Glahn (1983)
Physical exclusion		
Netting		Sinclair (1990)
Lines strung in trees, etc		Tipton *et al.* (1989b), Johnson & Glahn (1983)
Herding with light aircraft		Handegard (1988)
Other		
Nest destruction		Rappole *et al.* (1989)
Decoy feeding		Alexander (1990), Broome *et al.* (1979)
		Cummings *et al.* (1987)
Alterations to timing of harvest		Elliott (1990), Dale (1975)
Early harvest of susceptible grain crops followed by mechanical drying		Campbell (1975), Cole (1975)
Mechanical protection of seed		Decker *et al.* (1990)
Use of bird resistant varieties		Campbell (1975), George (1990)

Fertility control is receiving greater attention as a non-lethal alternative for the control of populations of problem wildlife species (Bomford 1990). The aim is to produce sexually sterile, normally behaved individuals so as to inhibit breeding success in the target population. Sterilisation has been used successfully to control some insect pests and efficacy depends first, on flooding the population with sterile males and second, on females mating only once in their lives (Caughley *et al.* 1992). Mating systems in vertebrates are more complex and involve multiple matings, matings between subordinate individuals and/or individuals from adjacent territories or suppression of sexual activity in subordinates (Bomford & O'Brien 1990b). Bomford (1990) concluded that male sterilisation was unlikely to reduce the population density in vertebrate species. Caughley *et al.* (1992) examined theoretical outcomes of female sterilisation on population control and found that sterilisation led to lowered productivity in three of four cases. In the fourth case, where breeding of the dominant female suppressed breeding in other females, sterilisation led to increased productivity.

A variety of chemosterilants have been tested for their effects on the reproductive capacity of pest birds, including triethyleneamine (TEM, Bhat & Maiti 1989a), clomiphene citrate (Bhat & Maiti 1989b), thiotepa (Potvin *et al.* 1982), Ornitrol (Lacombe *et al.* 1987), Provera (a high potency progesterone) and the fungicide, Arasan (Elder 1964). Whilst these substances can be demonstrated to affect testicular and/or ovarian function in the laboratory, their suitability and efficacy in controlling populations of pest birds has not been established. Fertility control of pest bird populations depends as much on a thorough understanding of breeding behaviour and population dynamics of the birds as on identification of sterilants.

Discussion

Where problems with abundant birds are experienced, the destruction of the offending birds is often a popular option amongst the affected community. However, the large scale destruction of birds presents a series of logistical problems that are unique to each bird species concerned. Since each bird pest situation is different, and the development and implementation of destruction methods is often expensive and time consuming. Most workers report that efforts to reduce existing bird populations are not effective in the long term because of the birds' mobility (Flegg 1980, Woronecki *et al.* 1989), evasive behaviour during culls, inherent breeding rate (Elliott 1990) and/or compensatory breeding following culling (Potvin *et al.* 1982). Large scale destruction is often cost ineffective when compared to the potential or real benefits of crop protection (Dolbeer 1981, Weatherhead 1982). Nonetheless, destruction efforts aimed at the standing population may be useful in situations where damage is very localised (Tipton 1989a), in situations where short term control is sufficient (Tahon 1980), where the pest population is isolated (Dyer and Ward 1977, Dolbeer 1989), or in other special circumstances such as nesting gulls near an airstrip (Caithness 1968). The use of chemosterilants, in which the reproductive capacity of the pest bird is inhibited, may prove more effective in the reduction of pest bird populations in the longer term.

Most workers conclude that no single method is effective in controlling the damage done by birds and that the best approach is a combination of non destructive techniques supplemented by destructive techniques where suitable (Rappole *et al.* 1989, Tipton 1989b, Dolbeer 1990).

Appendix 2
List of all items found in the crops of 333 Little Corellas collected in the Flinders Ranges in the period January 1990 to March 1991.

Seed material
Boraginaceae
**Echium plantagineum*
Compositae capitulae
Chenopodiaceae
Maireana sp.
Sclerolaena sp
Compositae
*?*Carthamus/Emex*#
**Hypochoeris*
**Sonchus* sp.
Cruciferae
**Brassica tournefortii*
*?*Raphanus*
Cucurbitaceae
**Citrullus* sp.
**Cucumis* sp.
Cucurbitaceae ?sp.
Geraniaceae
**Erodium* sp.
Graminae
**Avena* sp.
Dactyloctenium radulans
?*Echinochloa*
**Ehrharta* sp.
Gramineae ?sp.
**Hordeum vulgare*
**Phalaris* sp. 1
**Phalaris* sp. 2
**Triticum aestivum*
Leguminosae
Acacia sp.
**Medicago* sp.
Nyctaginaceae
Boerhavia sp.
Polygonaceae
**Rumex vesicarius*
**Polygonum ?aviculare*
Solanaceae
?*Solanum* sp
Unidentified seed (1)

Non-seed material
Lepidopteran larvae
Psyllid casings
Corms of *Oxalis pes-caprae*
Acacia arils
Pieces of leaf
Gravel
Pig swill
Stem pieces
Bark pieces sp
Dried plant material

* denotes introduced genera

? denotes that seed samples could not provide positive identification at level of family (e.g. Cucurbitaceae ? sp), genus (e.g. ?*Raphanus*) or species (e.g. *Polygonum ?aviculare*).

\# *Carthamus* sp (Saffron Thistle) could not be distinguished from *Emex* sp (Three cornered jack) because all specimens were dehusked and most were also broken.

Appendix 3
A list showing the dates, locations and numbers of Little Corellas collected in the northern and southern sections of the study area between 7 March 1989 and 23 March 1991.

Date	Nearest named place	Number
07/03/89	*Colebrook*, Stoney Ck, Quorn	52
30/03/89	Quorn Dump,Quorn	10
31/03/89	*Hieblat* Arden Vale Rd N Quorn	5
31/03/89	Prop. N Whitehead, Quorn	29
06/04/89	Showgrounds, Melrose	13
07/04/89	*Billabong*, Wandearah East	24
10/06/89	Prop N Whitehead Quorn	10
14/06/89	Kanyaka Ck main Rd btwn Hawker & Quorn	3
14/06/89	1st ck junction with Martins Well Rd *ca* 1km E of Martins Well turn off	1
14/06/89	Price Ck, N of Hawker	1
15/06/89	Price Ck, N of Hawker	2
15/06/89	The Dam 6 km N Wilpena (Upalinna Station)	1
15/06/89	Cazneaux Tree, Wilpena Turn Off	1
15/06/89	Old Wilpena Station Shearing Shed	2
15/06/89	Oraparinna Gorge	4
15/06/89	Oraparinna Homestead Flinders Ranges National Park	5
16/06/89	Mt Billy Ck, near Tommy Gunyah Bore Oraparinna section Flinders Ranges National Park	12
03/07/89	Wilkawillina Gorge, Flinders Ranges National Park	5
18/07/89	Old Wilpena Station Shearing Shed	1
27/07/89	Oraparinna Homestead Flinders Ranges National Park	5
17/09/89	junction Wilpena Ck & Gas pipeline Rd, Martin's Well Station	1
18/09/89	junction Wilpena Ck & Gas pipeline Rd, Martin's Well Station	2
18/09/89	junction Wilpena Ck & Gas pipeline Rd, Martin's Well Station	6
19/09/89	junction Wilpena Ck & Gas pipeline Rd, Martin's Well Station	20
11/10/89	junction Balcaracana Ck & main Rd, Wirrealpa Station	11
11/10/89	Six Mile Bore (betwn 10 Mile & Balcaracana Cks, Wirrealpa Stn)	10
11/10/89	Mt Billy Ck, Wilkawillina Gorge, Flinders Ranges National Park	9
12/10/89	Six Mile Bore, Wirrealpa Stn	11
12/10 90	Mt Billy Ck/Arkaroola Rd	17
13/10/89	Airstrip Balcanoona Homestead Gammon Ranges National Park	4
04/11/89	Spring Creek, S Wilmington	2
10/11/89	junction Hawks Nest Creek & Main Rd Wilmington	2
14/11/89	Prop. M Britza, Richman Valley	8
14/11/89	5 km N Warren Gorge TurnOff, Quorn	4
14/11/89	Prop. M Britza, Richman Valley	8

15/11/89	Prop. M Britza, Richman Valley	8
15/11/89	Devil's Peak TurnOff, Richman Valley	1
17/11/89	Prop. N Whitehead, Quorn	13
19/11/89	3.5km N Melrose (roadkill)	1
17/01/90	junction Stoney Ck & Hawker Rd E Quorn	31
17/01/90	Pine Glen, Richmans Valley	2
30/01/90	Olive Grove, Richmans Valley	45
08/02/90	Temporary grain bunker Quorn	15
05/03/90	Prop.I Rodgers, Richmans Valley	49
06/03/90	Wirrabarra Oval	20
13/03/90	Yandiah/Appila Junction Wirrabarra	29
29/03/90	Prop. N Whitehead, Quorn	44
04/04/90	Prop. I Rodgers, Richmans Valley	8
11/04/90	Prop. N Whitehead, Quorn	8
28/04/90	Ckline just SW Martins Well HS on main Rd	7
28/04/90	junction Wilpena Ck & Gas pipeline Rd, Martins Well Station	14
29/04/90	junction Wilpena Ck & Gas pipeline Rd Martins Well Station	4
01/05/90	*Hieblat* Arden Vale Rd N Quorn	14
09/05/90	Oraparinna Homestead Flinders Ranges National Park	1
09/05/90	Wilkawillina Gorge Flinders Ranges National Park	2
06/06/90	7km W Gas pipeline Rd along Wilpena Ck	24
07/06/90	Prop. N Whitehead, Quorn	18
08/06/90	Prop. D Jared, Laura	17
16/07/90	junction 10 Mile Ck & main Rd Wirrealpa Station	3
16/07/90	junction Balcaracana Ck & main Rd Wirrealpa Station	12
17/07/90	junction Wilpena Ck/Gas pipeline Rd Martins Well Station	12
18/07/90	junction Wilpena Ck/Gas pipeline Rd Martins Well Station	7
19/07/90	Prop. N Whitehead, Quorn	23
20/07/90	*Lagoon* G & S Slee, Hawks Nest Ck via Wilmington	8
23/08/90	Prop. N Whitehead, Quorn	13
27/08/90	Balcaracana Ck, Wirrealpa Stn	13
26/09/90	junction Wilpena Ck/Gas pipeline Rd Martins Well Station	10
27/09/90	junction Wilpena Ck/Gas pipeline Rd Martins Well Station	10
27/09/90	Balcaracana Ck, Wirrealpa Stn	14
27/10/90	junction Wilpena Ck/Gas pipeline Rd Martins Well Station	7
28/10/90	junction Wilpena Ck/Gas pipeline Rd Martins Well Station	6
28/10/90	junction Wilpena Ck/Gas pipeline Rd Martins Well Station(nestlings)	3
28/10/90	6 Mile Bore btwn 10 Mile & Balcaracana Ck, Wirrealpa	20
29/10/90	Prop. N Whitehead, Quorn	2
30/10/90	Devil's Peak T/Off, Quorn	12

17/12/90	junction Wilpena Ck/Gas pipeline Rd Martins Well Station	4
18/12/90	junction Wilpena Ck/Gas pipeline Rd Martins Well Station	7
18/12/90	6 Mile Bore, Wirrealpa Stn	23
19/12/90	junction Stoney Ck & Hawker Rd E Quorn	15
16/01/91	6 mile Bore btwn 10 Mile & Balcaracana Ck, Wirrealpa Station	2
21/01/91	Prop. M Britza, Richman Valley	76
06/02/91	Melrose 60kph-80kph signs N Melrose	4
12/02/91	Prop. M Britza, Richman Valley	19
13/03/91	John Well Ck (tank) Wertaloona	4
23/03/91	*Depot Flat* GD Stokes N Quorn	120
TOTAL		**1155**

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