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Movement of introduced Little Corellas *Cacatua sanguinea* and Long-billed Corellas *C. tenuirostris* in south-western Western Australia

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Abstract. Two species of corella, the Little Corella *Cacatua sanguinea* and Long-billed Corella *C. tenuirostris,* have been introduced into south-western Western Australia. To determine how they used the landscape, we undertook a wing-tagging study in 2012–2013 to monitor movements of individual birds. Sixty-two birds (44 Little Corellas and 18 Long-billed Corellas) were tagged and released from five sites and a total of 390 sightings was recorded over a 7-year period. There was a significant difference in the mean distances from tagging sites that corella species were sighted, with Little Corellas travelling further than Long-billed Corellas. The greatest distance from its tagging site recorded for a Little Corella was 145 km and for a Long-billed Corella was 77 km.

Introduction

Invasive species can have multiple and often unpredicted impacts on native plant and animal communities, yet the biology of many such species is not well known (Long 1981; Sol *et al*. 2012). It is often assumed that their ability to reproduce quickly is the reason why invasive species are so successful, but other life-history strategies may also be important. For example, the ability to undertake nomadic movements may increase the likelihood of finding resources to exploit and allow them to respond to ecological pressures.

The Little Corella *Cacatua sanguinea* and Long-billed Corella *C. tenuirostris* (also known as Eastern Long-billed Corella) have been introduced to south-western Australia and have become established as a result of deliberate and accidental releases of aviary birds. At the time of European settlement, the only corella occupying the region was the Western Corella *C. pastinator*, a species endemic to south-western Western Australia (WA). The Western Corella has two geographically isolated subspecies, Butler's Corella *C. p. derbyi* and Muir's Corella *C. p. pastinator* (Johnstone & Storr 1998; Abbott 2008).

There are some minor uncertainties regarding the historic range of Butler's Corella. Storr (1991) suggested that Butler's Corellas most likely occurred in small groups confined to the valleys of major watercourses. He knew of no records of them anywhere other than along the Irwin and Hill Rivers before 1927, and thought that they began expanding their range south and south-east only after the establishment of farms with dams and introduced food plants that the corellas could exploit. Abbott (2008) suggested that in 1900 Butler's Corellas occurred in the area bounded by Mingenew, Morawa, Moora, and Cockleshell Gully, including the Hill and Irwin Rivers, and were quite numerous. Tagging studies of Butler's Corellas at Burakin conducted by Smith & Moore (1992) suggest that the tagged birds were part of a locally nomadic flock that moved over an area of 250 km^2, with individual birds regularly making a 55-km post-breeding movement to Dalwallinu. It is likely that, historically, Butler's Corellas made similar post-breeding movements but these were not recorded. Butler's Corellas are occasionally observed in the Perth metropolitan area, with more individuals seen in the north around the Wanneroo area, but they have also been observed in the Bold Park area (I. Abbott pers. comm. 2020).

Muir's Corellas ranged from the Swan and Avon Rivers in the north, south-east to Broomehill and west to Augusta. They were recorded at Upper Swan in 1830 and were still present near Perth in the 1880s but appear to have been extirpated from the Avon Valley by 1889 (Abbott 1999, 2008). Sometime after this, their numbers reduced greatly, and they became locally extinct from most of their range. At around 1900, the only breeding population, consisting of ~100 birds, was restricted to the Lake Muir area (Abbott 1999). The provision of grain laced with poison such as arsenic, and shooting killed many of the corellas that were eating crops planted by early settlers, and collection for food by early settlers would have also contributed to their decline (Abbott 2008). It is also possible that early pastoralists greatly reduced native foods (e.g. corms, bulbs and rhizomes) available to Muir's Corellas when the native vegetation in the more fertile valleys was converted to farmland, as was the case with Long-billed Corellas in Victoria (Storr 1991; Emison *et al.* 1994). Muir's Corella was listed as threatened fauna under the *Wildlife Conservation Act 1950* (WA) in 1990, but numbers gradually increased to ~3000 birds by 1985 (Massam & Long 1992; Department of Parks & Wildlife 2015). In 2012, Muir's Corella was removed from the Western Australian threatened species list (Department of Parks & Wildlife 2015).

Little Corellas were first recorded in the western suburbs of Perth in the 1960s (Saunders *et al*. 1985; Higgins 1999) and in Bunbury in approximately 1996 (Strang *et al.* 2014). They now occur from Two Rocks in the north to

Figure 1. Little Corellas of different subspecies. The bird on the left has a smaller bill, less red in the lores, and its periophthalmic ring is paler than in the bird on the right, These two individuals were observed copulating moments earlier. Photo: Mark Blythman

Augusta in the south and occasionally turn up on Rottnest Island (Burbidge 2006; R. Priemus pers. comm. 2019; MB pers. obs.). Our observations indicate that flocks of Little Corellas are often comprised of multiple subspecies and hybrids of these subspecies (Figure 1). Long-billed Corellas occasionally interbreed with Little Corellas and with Sulphur-crested Cockatoos *Cacatua galerita* in Victoria (Environment & Natural Resources Committee 1995; Kentish & Brennan 2016), so it is possible that they do the same in WA although we have not observed this. Corella × Galah *Eolophus roseicapilla* hybrids are sometimes seen amongst the flocks of corellas in south-western WA, with up to 11 individuals identified through photography between July 2011 and February 2015 (G. Ringer pers. comm. 2020) (Figure 2).

Western Australian Museum records show that Long-billed Corellas were first observed within flocks of Little Corellas in Perth in the mid 1980s and had become established by the late 1980s (R. Johnstone pers. comm. 2018). They now range from Two Rocks in the north to Busselton in the south (as also observed by us). Long-billed Corellas form distinct groups that regularly occupy the same sites and exploit the same resources as Little Corellas.

Sulphur-crested Cockatoos have also been introduced to south-western WA as a result of aviary escapees or deliberate releases, and were first recorded near Pinjarra in 1935. The wild population has been reduced from an estimated 300–500 individuals in 1982 (Saunders *et al*. 1985) to less than 50 today, but individuals continue to integrate into the main flock as escapees or deliberate releases (L. Strange pers. comm. 2020).

Population estimates of introduced corellas over several years have shown significant temporal and spatial variation, suggesting that movements are common (Blyth 2004) but the scale of these movements is unknown. In order to test the hypothesis that introduced corellas move widely in south-western WA, we undertook a wing-tagging study to monitor movements of individual birds.

Figure 2. Galah × Little Corella hybrids, Armadale, Western Australia. Photos: Graham Ringer

Study area and methods

In 2012 and 2013, 44 Little Corellas and 18 Long-billed Corellas were trapped and wing-tagged at five locations where large numbers congregated: four in the Perth metropolitan area and one (Australind) in an urban centre 160 km south of Perth (Table 1).

Corellas were attracted to feed-sites that had been established by providing Wheat *Triticum aestivum* and Sunflower *Helianthus annuus* seeds via a self-feeding unit. (For the purpose of this document, feed-sites are considered to be anywhere that humans deliberately provide seed for birds to consume.) The unit was a modified 'wheelie bin' with a feed chute retrofitted to its base. The wheelie bin was filled with feed and the adjustable chute regulated how much would flow onto the ground under the influence of gravity. As birds ate the exposed grain from around the chute opening, it was replaced from the reservoir in the wheelie bin. The frequency and number of birds feeding from the feeding units determined when the bin needed to be refilled. A Reconyx® Professional PC900 Hyperfire camera was set up at feed-sites to determine times and the number of birds attending them. Once corellas had established a regular feeding pattern at the site, random healthy individuals were trapped for wing-tagging (Blythman 2017).

Individually marked wing-tags were attached to each corella's right wing using methods described by Rowley & Saunders (1980). Tags were made from round, coloured anodised aluminium pet-identification tags (diameter 31.6 mm, 1 mm thick). The protruding attachment point used to attach the tag to a pet collar was filed down, and two 2.7-mm holes were drilled into the top and bottom of the tag to take the stainless-steel wire to fix the tag to the wing. Using an iMARC engraving machine, the faces of the tags were engraved with large two-digit codes that were filled in with white or black paint to help them stand out against the master colour (Figure 3). A return address was engraved on the back of each tag. An individually numbered Australian Bird and Bat Banding Scheme size 21 stainless-steel leg-band was applied to a bird's right tarsus. Each bird's tagging location was designated a master colour, which applied only to birds tagged at that particular location (Table 1).

Figure 3. Long-billed Corella with a blue wing-tag and Australian Bird and Bat Banding Scheme leg-band. This bird was tagged at Wanneroo. Photo: Gary Tate

Flocks of corellas were scanned using binoculars and, where possible, attempts were made to check every bird for the presence of a tag, and then to determine the two-digit code on the tag. This involved waiting at feed-sites for birds to attend or seeking out flocks of corellas that had congregated in grassed areas to forage. The time needed to check small flocks containing <50 birds ranged from 5 to 20 minutes but larger flocks could take *c*. 20 minutes to 1 hour to complete.

Observations were made ~2–3 times a week in the first 6 months following tagging, but 1–2 times a week for the following 6 months. Opportunistic observations were made for the remainder of the study period.

Sightings were received by members of the public throughout the study period. Determining the colour of the tag was usually relatively easy but extra effort and patience were needed to record the two-digit code accurately. Advice on how to encourage corellas to show their right wing was included as part of a publicity campaign (Blythman 2012). The importance of choosing a single side to tag the birds was immediately evident, as time was not wasted viewing both sides of the bird to rule out the presence of a tag. Given that most cockatoos are left-footed, in hindsight the corellas would have been tagged and banded on their left side. This would have enabled easier field identification

Table 1. Numbers of corellas fitted with coloured wing-tags at five sites in south-western Australia. See Figure 4 for relative proximity of these sites.

Colour	*Location*	*Little Corella*	*Long-billed Corella*	*Total*
Black	Guildford (–31.893, 115.969; –31.891, 115.976; –31.903, 115.961)	13	6	19
Pink	Fremantle (–32.018, 115.789)	7	3	10
Blue	Wanneroo (–31.793, 115.804)	1	9	10
Green	Carine (–31.849, 115.791)	13		13
Orange	Australind (–33.280, 115.749)	10		10

of leg-banded corellas as they usually raise their left foot/tarsus when feeding or manipulating objects (Brown & Magat 2011). There was one instance where a corella's wing-tag became entangled in a hanging plant basket at a backyard feed-site. The tag was removed and this bird was released alive and well with its leg-band still attached.

A two-sample *t*-test that does not assume equal variances was performed to determine whether there were statistically significant differences in average distances that Little and Long-billed Corellas moved from their tagging sites.

A modest but targeted publicity campaign was used to inform BirdLife WA members about the project and to request members to report sightings of tagged birds (Blythman 2012). We also had personal contact with members of the public who were able to contribute to the study (e.g. those who maintained feed-sites). We scrutinised all public sightings and discarded those that were not considered credible/usable (e.g. incorrect code or tag colour) or had no location specified.

Results

The first bird was tagged and released for this study on 21 May 2012. Sightings continue to be recorded but for the purpose of this study the last sighting occurred on 21 June 2019, a period of 2587 days. During this period, the mean distance that Little and Long-billed Corellas were resighted from their tagging site was 16.3 km and 7.6 km, respectively, and the mean maximum distance from their tagging sites was 31 km and 16 km, respectively (Table 2). Of the 62 corellas that were tagged, eight have not been observed since they were released, four were removed as part of a control program, two were hit by cars, one died from a dog attack, one was picked up by a member of the public and died in captivity (cause unknown), and one bird had its wing-tag removed and was released with its leg-band still in place (Table 3). A total of 54 wing-tagged birds was resighted following release (87% of total tagged birds, and representing 72% of tagged Long-billed Corellas and 91% of tagged Little Corellas).

Of the 421 sightings, 153 were made by us. Two hundred and sixty-eight sightings were made by members of the public but 31 of these were not considered credible and were not included in this study. The majority of the 390 accepted sightings (47.5%) were of birds seen in parks or on open lawns, 45% were made at feed-sites, and the remainder of the sightings (7.5%) were of birds in areas other than parks or feed-sites or the habitat type was not recorded (Table 4).

There was a significant difference between the mean distances that Little Corellas (16.3 km ± standard deviation 22.4 km; n = 294) were sighted away from their tagging sites compared with Long-billed Corellas (7.6 ± 9.3 km; n = 96) (two-sample t-test for unequal variances, t = 5.35, P <0.05).

Little Corellas were far more mobile than Long-billed Corellas, travelling an average of three times further than Long-billed Corellas. The greatest distance from the tagging site was almost twice that of Long-billed Corellas.

Movement by Little Corellas from this study exceeded the previously known maximum movement (115 km)

Table 2. Range of number of days between tagging and most recent sighting, mean distance (km) from tagging site, and mean maximum distance (km) recorded from tagging site for tagged Little and Long-billed Corellas. See Figure 4 for sighting locations. Distances are given ± standard deviation. Sample sizes are shown in parentheses.

Corella species	*No. of days from tagging to last sighting*	*Mean distance of sightings from tagging site*	*Mean maximum distance from tagging site*
Little	31–2465 (41)	16.3 ± 22.4 (294)	31 ± 31 (41)
Long-billed	65–2486 (13)	7.6 ± 9.3 (96)	16 ± 20 (13)

Table 3. Fate of recovered wing-tagged corellas, number of days alive after tagging and straight-line distances (km) from tagging site. Dates are given as day/month/year.

Corella species	*Tag*	*Date of tagging*	*No. days alive*	*Final distance from tag site*	*Furthest recorded distance from tag site*	*Fate/cause of death*
Little	OX	24/07/2012	13	0.1	0.1	Control program
Long-billed	8P	19/06/2012	22	0.1	0.1	Died in care
Long-billed	JC	24/08/2012	237	8.3	8.3	Died in care
Long-billed	H9	30/08/2012	241	13.7	13.7	Dog attack
Long-billed	2W	30/08/2012	267	1.6	1.6	Car strike
Little	5H	24/08/2012	317	5.4	5.4	Control program
Little	BT	2/08/2013	671	12.5	12.5	Control program
Little	5O	20/02/2013	1422	0.1	37.4	Control program
Little	3P	22/06/2012	1462+	21.7	21.7	Tag removed; bird released alive

Table 4. Number of sightings of wing-tagged corellas at feed-sites, parks and lawns, and other/unknown locations.

Location of sighting	*Little Corella*	*Long-billed Corella*	*Total*
Feed-sites	146	29	175
Parks and lawns	126	59	185
Other/unknown	22	8	30
Total	294	96	390

Table 5. Comparison of movement and sighting data for Little Corellas in this study with all Australian Bird and Bat Banding Scheme (ABBBS) records, and for Long-billed Corellas from this study with data from Emison *et al*. (1994) of Long-billed Corellas in their native range. NA = not available.

	Little Corella		*Long-billed Corella*	
	This study	*ABBBS*	*This study*	*Emison* et al. *(1994)*
No. tagged birds	44	1479	18	704
No. sightings	294	33	96	700
Mean distance of sightings from tagging site (km)	16.3 ± 22.4	19	7.6 ± 9.3	2.7
% sightings within 5 km of tagging site	47	57	41	85
Longest distance from tagging site (km)	145	115	77	77
Average no. resightings per bird	6.7 ± 9.6	1	5.3 ± 5.5	NA

recorded by the Australian Bird and Bat Banding Scheme (Table 5). The longest confirmed distance of a Little Corella from its tag site was for 'Black 5M', which was tagged in Guildford and was last recorded 145 km south of its tagging site on the sporting oval at Harvey town site 1819 days later (Figure 4). Throughout this study, Little Corellas were observed feeding on seeds from Wheat, Sunflower, Oats *Avena sativa*, Coastal She-oak *Casuarina equisetifolia* and Marri *Corymbia calophylla*, rhizomes from grass in planted lawns, seeds and corms of Guildford Grass *Romulea rosea*, cones of Chinese Arborvitae *Platycladus orientalis* and the flesh of Olive *Olea europaea* drupes.

The longest recorded distance of a Long-billed Corella from its tag site was for 'Black 4H', at 77 km. Tagged at the Guildford site, this bird then flew south to Mandurah and was later observed back in the Perth suburb of Bentley (Figure 4). The highest number of resightings of a Long-billed Corella was 19, and none of these was >12.5 km from the tagging site. Throughout this study, Long-billed Corellas were observed feeding on seeds of Wheat and Sunflower, seeds and corms of Guildford Grass, Maritime Pine *Pinus pinaster* seeds, rhizomes of grass in lawns, and Olives, and they were also were being fed unknown grains.

Discussion

Average distances travelled by introduced corellas in this study demonstrate that both species are highly mobile within their current range in south-western WA. Little Corellas regularly travelled longer distances than Long-billed Corellas.

Movement records held by the ABBBS indicate similar distances travelled by Little Corellas at other locations across Australia. Although relatively few Little Corellas were involved in the present study (44) compared with records held by the ABBBS (1479 banded Little Corellas) and a wing-tagging study conducted by St John (1994: 1336 wing-tagged Little Corellas), over the 7 years of our study period we were able to demonstrate that tagged birds moved from the core of their range in the Perth metropolitan area close to the northern edge of their range and also close to the southern edge and many places in between.

Consistent with earlier reports (Blyth 2004; Department for Environment & Heritage 2007; Burbidge 2008; Department of Environment & Conservation 2009), most of the tagged Little Corellas appeared to be somewhat nomadic, moving wherever food was available. Individuals of both species were observed to readily utilise novel food sources that they would have been unlikely to encounter in their native range (see also Burbidge 2008). Local nomadism and flexibility in locating food resources are general behaviours of flocking species (Environment & Natural Resources Committee 1995), although there appear to be some resident birds within the population of introduced corellas. The overall trend shows that most Little Corellas ended up south of their tagging sites, demonstrating how populations might have established themselves in urban centres to the south of Perth, such as in Mandurah and Bunbury.

A few tagged Little Corellas remained resident during the present study, and this could be attributed to their ability to exploit food sources made available by members of the public. An example of this is 'Green MB' and 'Green 69', which, between them, were recorded at least 53 times at the same feed-site located 4.5 km west of their tagging site. They were also both recorded together at two other feed-sites, one 2 km west and one 5 km south-west of their

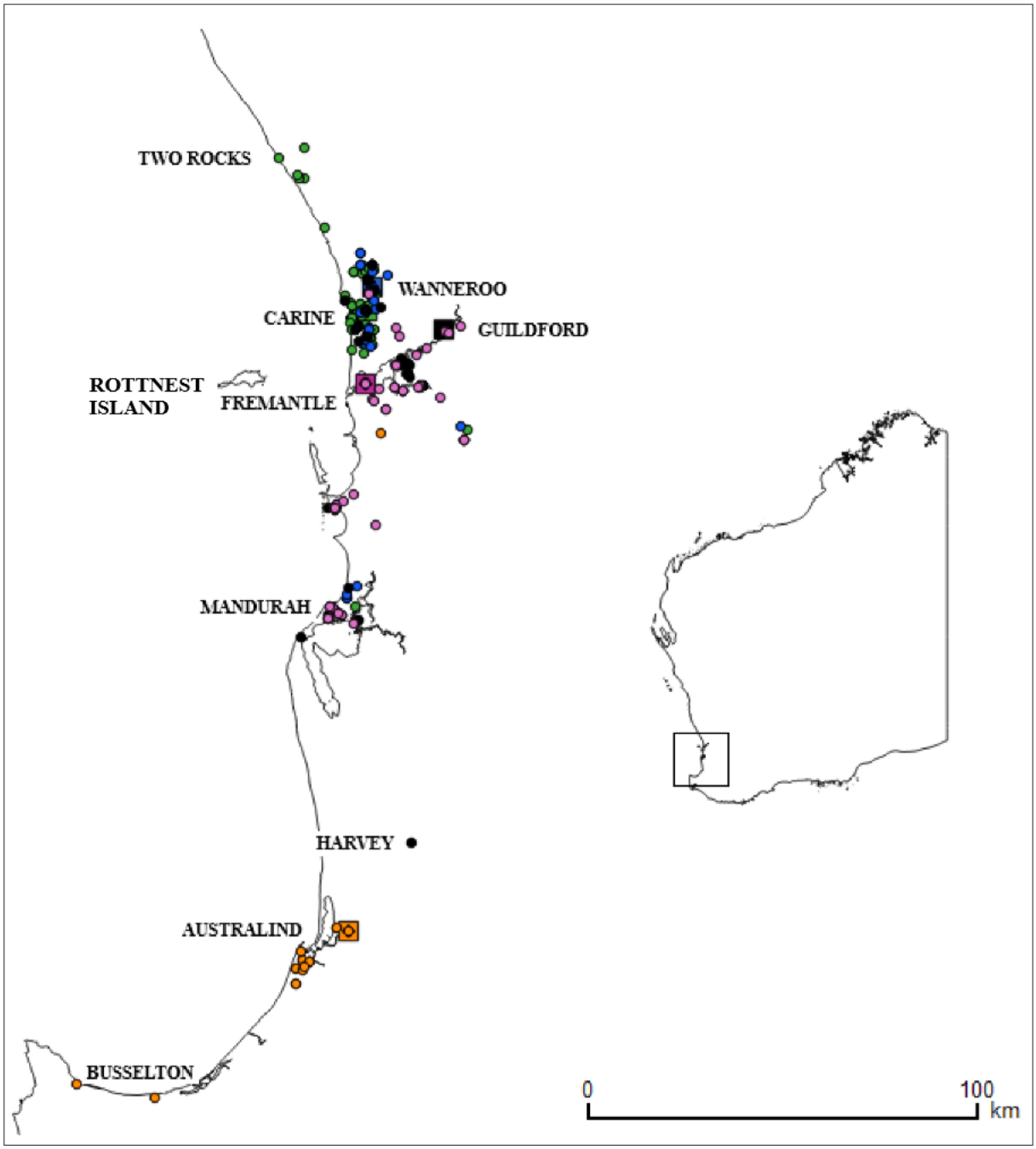

Figure 4. Map showing the locations of different tagging sites (different coloured squares) and subsequent sightings of tagged birds from those sites (corresponding coloured dots) of Little Corellas and Long-billed Corellas.

tagging site. In contrast, 'Black 5M' was sighted 12 times, none at a backyard feed-site, but its 13th sighting was at a feed-site 145 km south of its tagging site.

A comparable movement study of Little Corellas in their native range in the Flinders Ranges in South Australia was conducted in 1988–1990: in total, 1336 Little Corellas were fitted with wing-tags and observed over the following 2 years (St John 1994). As with the Perth birds in the present study, Little Corellas in the Flinders Ranges were not faithful to roost-sites and regularly shifted their locations of roosts. This also implies that, because of the mobility of individual corellas, the corella flocks within our study area should not be considered closed flocks.

A comprehensive study of Long-billed Corellas in their native range carried out between 1978 and 1984 (Emison *et al*. 1994) allows a comparison of their movements with the introduced population in WA in the present study: both moved similar distances. There are reports of Long-billed Corellas making much longer daily journeys (50 km) from roosts to feeding sites and back again in their native range (Environment & Natural Resources Committee 1995).

In the Perth metropolitan area, Long-billed Corellas have been observed forming geographically distinct groups (MB & GP pers. obs.), which behave largely independently of Little Corellas in the same area, although foraging and roosting sites often overlap and individuals of both species forage in close proximity to each other. One group that was

followed closely regularly moved from the northern to the western suburbs. When this group of Long-billed Corellas was in the western suburbs, Long-billed Corellas were absent from their usual foraging grounds in the northern suburbs and vice versa. This movement was supported by sightings of individual tagged birds in groups in the northern suburbs that were seen again later in similar-sized groups in the western suburbs. Although there is some mixing between groups of Long-billed Corellas throughout their introduced range, they could be considered as separate flocks within the larger nomadic mixed flock. The study of native Long-billed Corellas in farming areas showed that 85% were resighted within 5 km of their tagging sites (Emison *et al*. 1994), which is twice the percentile of birds resighted within 5 km in the present study. This discrepancy may indicate that the introduced birds are slightly more mobile than birds in their native range, but it is more likely that, because our study was conducted in the metropolitan area, there were more chances of tagged birds being resighted further away from their tagging sites.

Conclusion

This tagging study demonstrated that introduced Little and Long-billed Corellas in the south-west of WA do not vary greatly in behaviour from those in their native ranges. They are quite mobile, readily take advantage of feed-sites, and the individuals observed on any one day are not necessarily the same individuals foraging at the same site the next day. Neither species demonstrated increased mobility in its introduced range, but the inherent ability to readily move tens of kilometres may help explain why they have been so successful as invaders in south-western Australia, where resources are likely to be seasonal in nature.

The data presented here indicate that the management of corellas at any scale needs to take into account the high mobility of the species. Actions taken at one site within their introduced range are likely to help reduce the negative impacts associated with the birds in other areas of their range. This also implies that, for management at a particular site, it may also be necessary to consider actions at distant sites.

Given that individual corellas can be long-lived (Little Corella 44 years and Long-billed Corella 43 years in captivity: Young *et al*. 2012) and that the patagial wing-tags can remain viable for at least 34 years (Rowley & Mawson 2001; Saunders & Dawson 2009), we expect tagged corellas to remain identifiable in the south-western WA population for years to come.

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