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Home-range and behaviour of a fledgling Little Eagle *Hieraaetus morphnoides* in the Australian Capital Territory

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A juvenile Little Eagle *Hieraaetus morphnoides* was radio-tagged and followed from the day it left the nest until it dispersed 12 weeks later. Two methods, minimum convex polygons (MCP) and kernel analysis, were used to estimate its home range. Home range increased in size progressively over the 12 weeks of the post-fledging period, from 0.001 km^2 MCP and 0.007 km^2 kernel in Wk 1 to 3.085 km^2 MCP and 10.78 km^2 kernel in Wk 12, as the juvenile moved gradually away from the nest tree. We also scored the presence or absence during each observation period of 11 juvenile and/or adult behaviours directly observed in the field relating to changes in the juvenile's developing skills, parental provisioning, and interactions of the juvenile and adults with other species. Frequencies of these behaviours changed over the 12 wks of the post-fledging dependence period as the juvenile developed more adult-like behaviours and the adults spent less time with the juvenile. We acknowledge that this study reports observation of a single bird; although the estimates and trends of home ranges over time are valid, all interpretations and generalisations are limited and may not hold in a broader study. However, we regard the information presented as very useful for the creation of hypotheses in future studies on the ecology of this species.

INTRODUCTION

The Little Eagle *Hieraaetus morphnoides* is about 44 to 55 cm long and closely related to the Booted Eagle *Hieraaetus pennatus* of Eurasia and Africa and the Pygmy Eagle *Hieraaetus weiskei* of New Guinea. As with Booted Eagles (Ferguson-Lees and Christie 2001), Little Eagles are socially monogamous, territorial, single-brooded predators of small and medium-sized vertebrates, including birds such as Australian Magpies *Gymnorhina tibicen*, reptiles such as Cunningham's Skink *Egernia cunninghami* and mammals, especially juvenile European Rabbits *Oryctolagus cuniculus* (Olsen *et al*. 2010). Little Eagles breed during the austral spring in south-eastern Australia where this study was conducted. Observational studies have provided detailed information on the breeding cycle of the species (Bollen 1991; Debus *et al.* 2007; Fisher 2010; Debus 2011) and the development of juveniles in the post-fledging period, as well as on space use and inter-nest distances (Debus and Ley 2009). However, to date there has been no radio tracking study.

Unlike Booted Eagles, which nest on cliff ledges and in trees, Little Eagles only nest in trees. Mean weight of male Little Eagles is ~ 635 g and of females ~ 1046 g. They fledge one or two young (mean brood size ~1.1) after about 52 to 66 days in the nest and the young are said to reach independence about two months after fledging (Debus 2012; Olsen 2014).

Little Eagles have declined in south-eastern Australia to the point of being listed as vulnerable in New South Wales (NSW) and the Australian Capital Territory (ACT) (Olsen and Fuentes 2005; Olsen *et al*. 2008, 2009; Debus 2011, 2012). In the ACT, Little Eagles appear to have declined in nature parks and reserves between 1992 and 2007, their territories decreasing from about 11 to one to three (Olsen 1992; Olsen *et al*. 2008, 2009). Across the ACT, Taylor and COG (1992) recorded at least 13 occupied territories in the 1980s, but in a 2015 survey the ACT researchers found only one fledged young (Olsen, Trost and Dabb unpublished data). In NSW, Barrett *et al*. (2007) reported, from annual surveys of birds including Little Eagles, a 39% decrease in the reporting rate for this species, based on data from the first *Atlas of Australian Birds* (conducted between 1977 and 1981; Blakers *et al.* 1984) compared to the data in the *New Atlas of Australian Birds* (conducted between 1998 and 2001: Barrett *et al.* 2003). Cooper *et al.* (2014), continuing the Atlas 1 method, reported a decline in reporting rate of about 50% in NSW in the 20 years to 2006, and advised an upgrade for the species to endangered status.

One cause of the decline in the ACT is urbanisation. The ACT government directs housing development to newly created suburbs in areas used by Little Eagles for nesting. Prime habitat for Little Eagles near Canberra is river country and open woodland in the northern ACT; the species usually avoids dense forest and has not been found nesting at high elevations in Namadgi National Park south of Canberra or in adjoining Kosciuszko National Parks in NSW (Olsen 2014). Breeding Little Eagles have only been found in the northern part of the ACT where new suburbs have reduced available habitat. The remaining pairs are also on land earmarked for suburban development (Olsen *et al.* 2015) and the species may be lost as a breeder in the ACT.

Home range

Raptors need large home ranges (HR) in which to breed and hunt. (Ray 2005; Sergio *et al.* 2006, 2008; Olsen 2011). To better understand this for Little Eagles, we need to document the size and use of a Little Eagle's HR and the threatening processes that cause abandonment of a HR, so that we can formulate sound management actions. Home ranges delineate the area inhabited by an animal during its usual activities, whereas core areas denote smaller regions within that HR that are used much more intensely (Burt 1943). In practice, the HR is often considered the smallest area within which an animal spends 95% of its activity and the core area that in which it spends 50% (White and Garrott 1990). Together, HRs and core areas provide the most fundamental information about the movements and space-use patterns of raptors (Olsen *et al* 2011).

Post-fledging dependence period

Before becoming independent, most fledgling birds, including raptors, have a substantial period of dependence on their parents (Newton 1979). This post-fledging dependence period (PFDP) extends from a juvenile's first flight from the nest to its dispersal from the breeding territory and the cessation of parental care. It is a poorly studied transition phase in Australian raptors. In the PFDP, juveniles mature physically and develop hunting and other survival skills in preparation for independence. Immediately after fledging, the young of many species exhibit clumsy movement and no response to potential enemies or foraging opportunities compared to mature individuals (Marcetti and Price 1989). If juveniles fail to acquire hunting skills during this period they may starve, even in the presence of abundant food. They need to attain these skills before winter cold and food shortage increase the chances of mortality (Olsen 2014). The PFDP of most raptors is structured around the nest site or a location close to it – adults return to the nest or nest area with food, deliver it, sometimes feeding the young, or simply dropping it and staying or leaving. Fledglings 'know' that prey will be delivered to this site, so they stay close and watch for delivery (Olsen 2014).

The duration of the PFDP depends on several factors (Bustamante and Hiraldo 1990; Ferrer 1992) and departure from natal areas can be influenced by progressively decreasing parental investment (Balbontín and Ferrer 2005). Radio-tracking juveniles during the post-fledging period as they acquire these skills needed for independence can lend insights into adult HR and foraging. When coupled with field observations of vocalizations, foraging, different modes of flight and other behaviours, HR analysis provides a useful approach for understanding the spatial needs and behaviour of fledged raptors (Olsen *et al*. 2011; Hatton *et al*. 2015).

In this study, we used point location data and field observations to study space-use patterns and behaviour of a just-fledged male Little Eagle over 80 days from 13 December 2014 when it fledged to 2 March 2015 when it dispersed. We computed HR and core areas over 12 weeks and noted flight activities and other behaviours.

Figure 1. *Nest location for Little Eagles in this study.*

METHODS

Study Area

The nest was located at Strathnairn near Canberra, Australia (148˚59' E, 35˚14' S) at an elevation of 600 m (Figure 1). The study area comprised mostly cleared grazing land with open woodland with dominant tree species of Scribbly Gum *Eucalyptus rossii,* Brittle Gum *E. mannifera,* Red Stringybark *E. macrorhyncha* and Blakely's Red Gum *E. blakelyi,* also Red Box *E. polyanthemos* and Yellow Box *E. melliodora.* It was bordered by the Murrumbidgee River (NCDC 1988).

Radio-telemetry

We radio-tagged the focal Little Eagle as a nestling, about 5 weeks old, on 22 November 2014 and fitted a stainless steel numbered band on its right leg, and an aluminium colour-band attached with two rivets to its left leg.

The back-pack style Sirtrack® single-stage transmitter was attached to the eagle with a string harness and had a weak link designed to break if the bird became entangled by its transmitter and harness (Karl and Clout 1987). The transmitter weighed 5.4 g and the harness 1 g, making a 6.4-g package on the 740 g male eagle (i.e. 0.9% of body mass). We located the eagle by triangulating the location of the radio-tagged bird with a hand-held Sirtrack Yagi-antenna and Telonics TR–4 receiver, and by sighting the colour-band (Figure 2).

The juvenile was observed in the nest on 1 and 5 December. On 7 December, he had 'branched' and was sitting 1 m from the nest, and on 9 December he was back in the nest. He was first observed fledged and perching in a roost tree 140 m from the nest tree on 13 December. The eagle was tracked during

Figure 2. *Radio-tagged juvenile Little Eagle one day after fledging.*

the latter part of the breeding season from 13 December 2014 to 2 March 2015**,** after it had fledged (Figure 2) and eventually achieved independence and dispersed. We visited the area on several days per week, in the morning and in the afternoon, and stood 200 to 500 m from the perching or flying eagle and viewed it through binoculars or a spotting scope. It was tracked continuously for 1.2 hours each visit, recording its spatial location at 30-min intervals. A relatively short tracking interval was chosen so that the spatial extent of the eagle's movements could be more precisely documented. We tracked the eagle for a total of 80 days over the duration of the study. In total, there were 223 recorded locations. It was last seen on 2 March 2015, high soaring, at the north end of the Golf Course, and then the signal was lost. There was no signal on 3 or 4 March around Strathnairn, and in the areas near Ginninderra Falls and towards Gooromon Ponds, or from an area we searched with Yagi antennae in a 10 km radius of the nest over the next 14 days, so we concluded that the eagle had dispersed.

Roost trees

Whenever possible we recorded the location and species of each tree used by the juvenile to roost in at night.

Behaviour

We scored the occurrence/non-occurrence during the observation period of 7 behaviours of the juvenile observed in the field and defined as: (1) eating, (2) calling (seen and/or heard), (3) lying down on a branch or nest (all of these away from the original nest), (4) flying – flap, or flap and glide movement, often between a roost where he slept at night and a perch where he perched during the day or between two perches, (5) soaring – circling without landing, and using thermals to gain height, (6) being harassed by other birds – other bird species circling the tree where the juvenile was sitting, birds sitting close and giving alarm calls, birds attacking the juvenile when he was flying, and (7) hunting – flying low, coursing over open ground. We also recorded when adults: were seen, delivered food to the juvenile, were harassed by other birds (as in 6 above), and soared (as in 5 above).

Home-Range Analysis

We computed HRs from the telemetry data using minimum convex polygons (MCP) and kernel methods. MCP, the smallest polygon containing all points such that all outer edges are convex, is the oldest HR estimation technique (Mohr 1947). Numerous studies criticize the method for overestimating HR size or not overlapping the true HR well (Barg *et al*. 2005; Franzreb 2006; Downs and Horner 2008; Olsen *et al*. 2011), particularly when the true HRs have non-convex edges. However, the method is so commonly applied for avian species including raptors (e.g., Baekken *et al*. 1987) and especially for Australian owls (Kavanagh and Murray 1996; Kavanagh and Jackson 1997; Soderquist and Gibbons 2007; Olsen *et al*. 2011), that we include it here to allow comparison with other studies. To avoid overestimation of the MCP HR we used, as is often suggested, the 95% MCP, which helped to remove the effects of the most peripheral points.

The kernel method has been declared a better HR estimator than the MCP (Nilsen *et al*. 2008). The kernel estimate has a higher density where there is a greater concentration of points (Worton 1989), and is thus more ecologically meaningful than the MCP. Kernel estimation produces more realistic HR results, irrespective of sample size and outliers (Pérez-García *et al*. 2013). The kernel method is more ecologically meaningful because it can detect areas of frequent use, whereas the MCP simply calculates the area within the outermost locations (Nilsen *et al*. 2008; Doucette 2010). Nevertheless, many studies of HR size report both MCP and kernel results (e.g. Elchuk and Wiebe 2003; Bosch *et al*. 2010; Doucette 2010; Pérez-García *et al*. 2013). To allow for a better comparison between methods, we computed the kernel HR also on 95% of the location data.

The two methods tend to give different HR sizes in absolute terms, the MCP estimates tending to be smaller, but the ranking order is often maintained. We checked this by standardising the estimates by the area found after 12 weeks. For both methods, we computed HR areas using the R package "adehabitatHR" (R Development Core Team).

RESULTS

Home range

The juvenile HR increased in size progressively over the 12 weeks of the post-fledging period (Figures 3a, 3b). Both methods used to estimate HR size showed a very similar trend once standardised by the maximum HR size in week 12. There was a shift of the HR northwards over the 12 weeks in which we collected data. As expected, the 95% MCP estimate was always

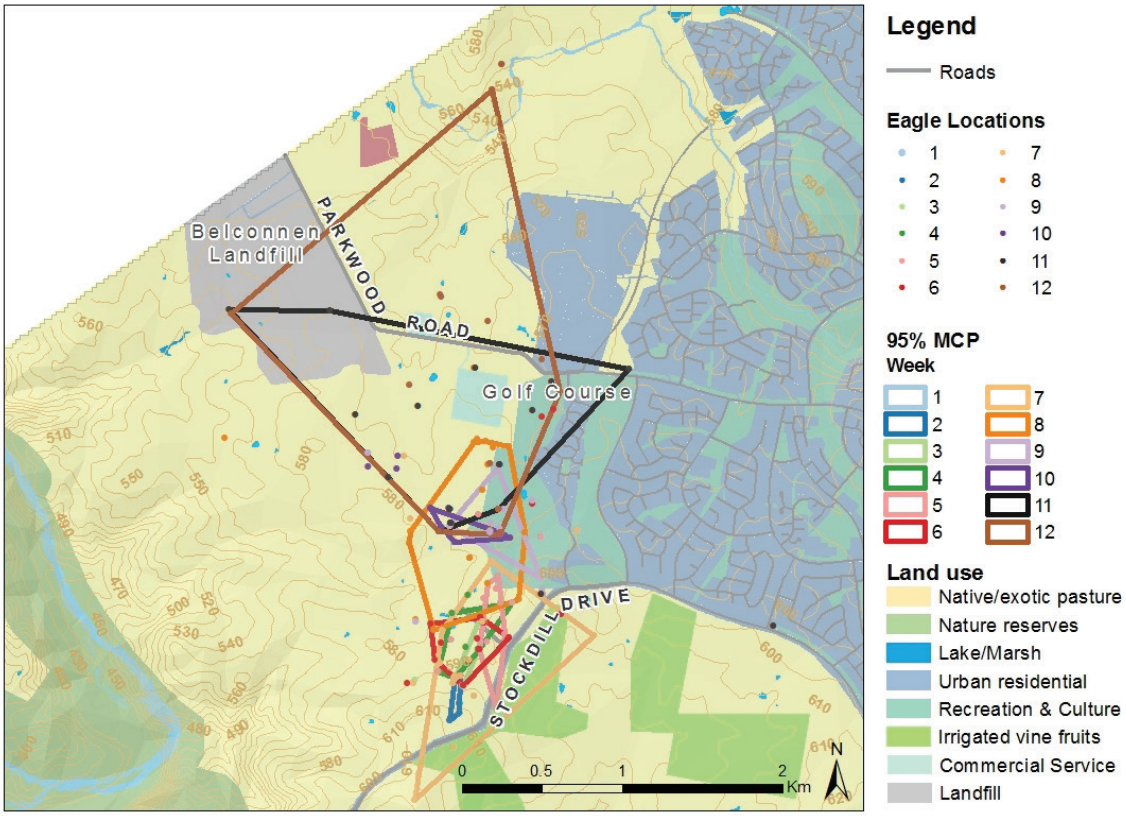

Figure 3a. *95% MCP home range over 12 weeks.*

Table 1

Increase in home range showing MCP and Kernel measurements. '# locations' (row 1) are the number of points that were available for each week to calculate home ranges; 'HR 95% MCP' (row 2) is 95% MCP in km2. 'HR 95% Kernel' (row 3) is 95% Kernel in km^2; '95% MCP/95% Kernel' (row 4) is the ratio of MCP versus kernel (so in general MCP is estimated about 10% of the size of Kernel; 'relative 95% MCP' (row 5) and 'relative 95% Kernel' (row 6) are the home range over time, standardised by the area (max) in week 12.

	week											
	1	2	3	4	5	6	7	8	9	10	11	12
# locations	6	25	24	24	18	24	22	19	15	14	16	16
HR 95% MCP	0.001	0.011	0.024	0.101	0.077	0.127	0.715	0.593	0.154	0.043	1.696	3.085
HR 95% Kernel	0.007	0.089	0.318	0.396	0.665	1.545	2.69	2.814	0.891	0.649	9.623	10.78
95% MCP / 95% Kernel	0.143	0.124	0.075	0.255	0.116	0.082	0.266	0.211	0.173	0.066	0.176	0.286
relative 95% MCP	0.0003	0.004	0.008	0.033	0.025	0.041	0.232	0.192	0.05	0.014	0.55	1
relative 95% Kernel	0.0006	0.008	0.029	0.037	0.062	0.143	0.25	0.261	0.083	0.06	0.893	1

smaller than the 95% kernel HR and showed estimates between 12% and 29% of the 95%-kernel area if compared between weeks (Table 1). That is, each method produced quite different values in absolute numbers, but both showed a similar trend over the 12 weeks.

Distance from nest tree

The juvenile's distance from the nest increased significantly over the weeks [$F_{1, 221} = 268.9$, $P < 0.0001$] (Figure 4).

Roost trees

The juvenile roosted (slept for the night) in eucalypts. One roost was a Red Stringybark, one a Mealy Bundy *Eucalyptus nortonii,* and seven were Blakely's Red Gum.

At first the eagle spent most of the day perching in trees, and had favourite day perches and night roosts (Figure 5). From Week 1 to 12 he night-roosted further and further from the nest (Figures 4). On the first night out of the nest, 13 December 2014, the eagle roosted in a mature Red Stringybark 140 m from the nest tree and roosted there each night and perched there during the day from 13 to 26 December 2014 (observed on the 10 observation days in Weeks 1–2). In Week 3, the juvenile moved 150 m to a new roost. On one occasion, he was roosting with an adult**.** In Weeks 5 and 6 the juvenile returned to his original roost (in a Red Stringybark), in Week 8 he roosted at the Golf Course 920 m from the nest, and in Weeks 9–12 he moved to the North Field where he used two large Blakely's Red Gums 900 m from nest.

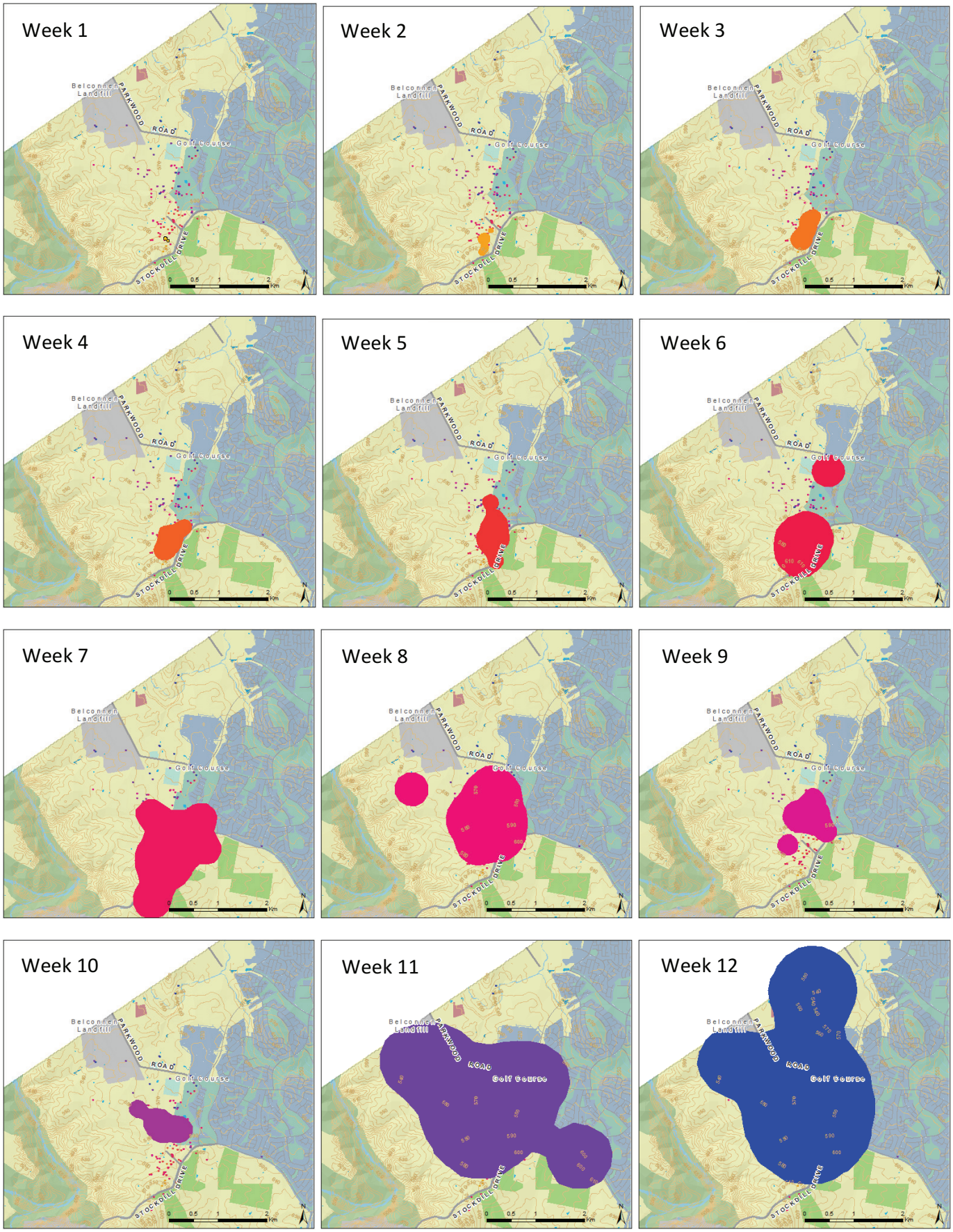

Figure 3b. *95% Kernel home range size over 12 weeks.*

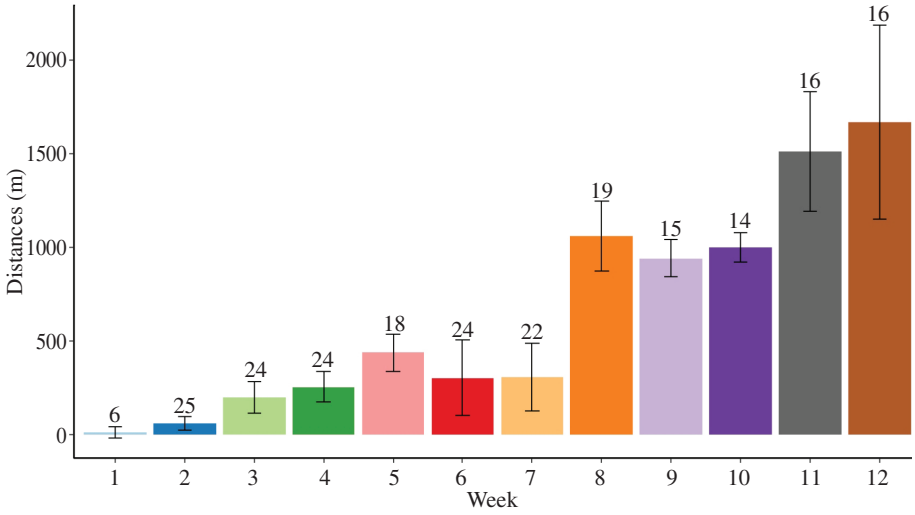

Figure 4. *Mean distance (m) from the nest of night roost trees used by the fledged juvenile Little Eagle over twelve weeks. Error bars represent 95% confidence intervals and numbers above error bars indicate the number of samples per week.*

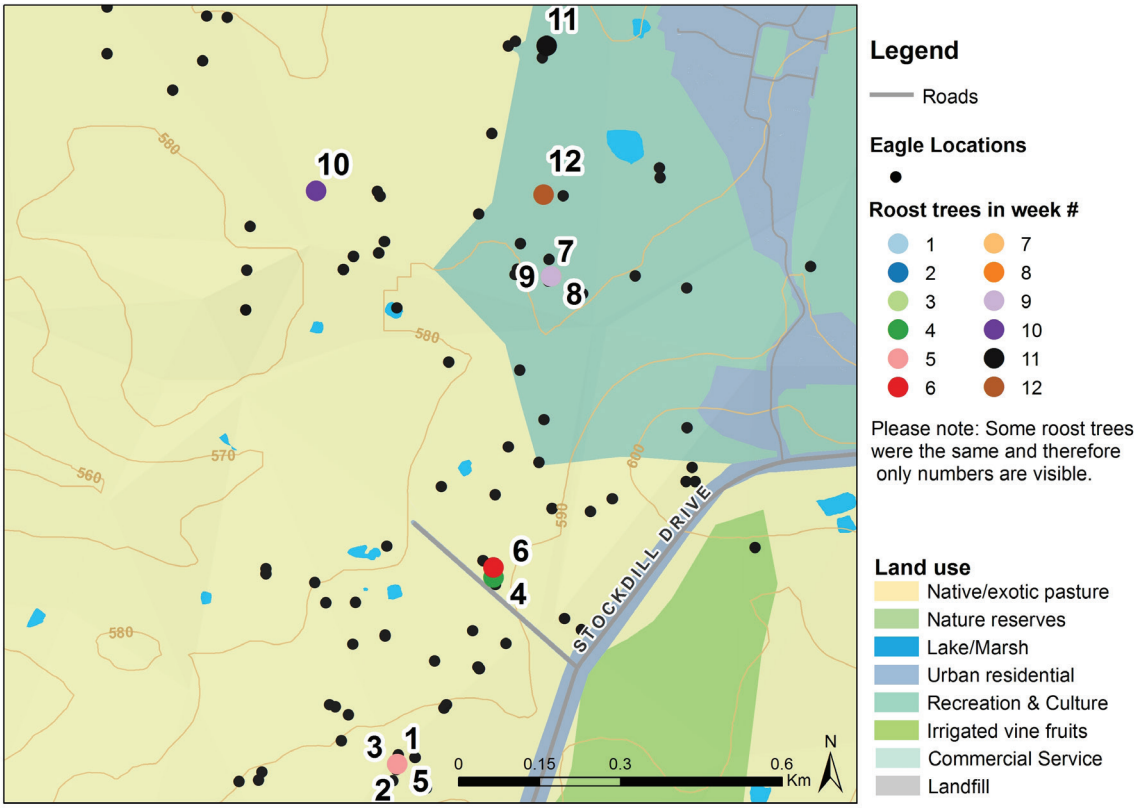

Figure 5. *Roost trees used by the fledged juvenile Little Eagle in Weeks 1-12.*

Juvenile eating

The juvenile was seen eating on 12 days in the first half (Wks 1–6) and on 5 days in the second half of the post-fledging period. This reduction in frequency perhaps occurred because his parents were delivering fewer food items in Wks 7–12 (Tables 2 and 3), or were delivering food well away from the nest area, or the juvenile was hunting well away from the nest area and eating in those areas.

Juvenile food-begging

Juvenile food-begging was observed on nine observation days in Weeks 1-6 and 10 observation days in Weeks 7-12, so the rate appeared to remain constant throughout the post-fledging period, although the number of days on which we saw adults declined in the second period. Long bouts of food-begging continued up to 10 weeks after fledging, with the last observation of a long calling bout being on 16 February 2015, 15 days before the juvenile dispersed (Table 2).

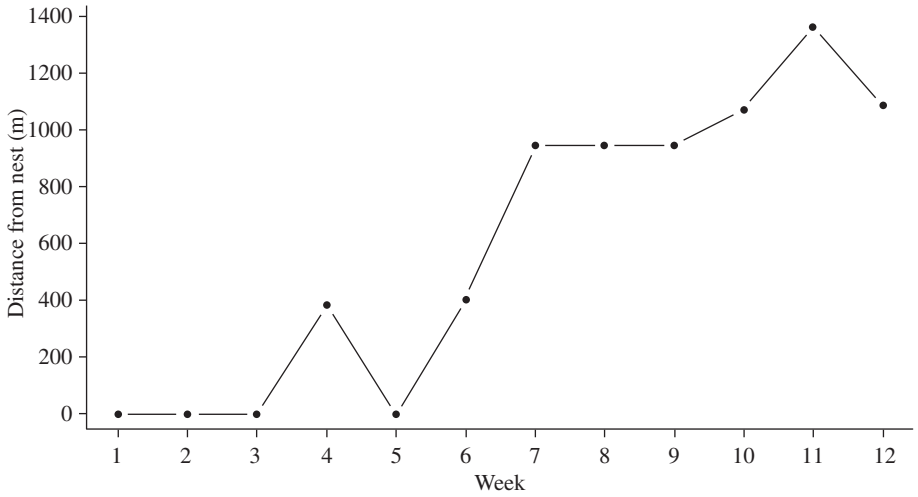

Figure 6. *Distance from the nest of night roost trees used by the fledged juvenile Little Eagle in Weeks 1-12.*

Table 2

Observations of juvenile behaviour post-fledging. Number of times behaviour observed per week, and percent (%) number of times behaviour observed per observation day each week. (Note: some days there were observations conducted both in the morning and the afternoon.)

Week number	Dates	No. of observation sessions per week	Eating	Calling	Lying down	Flying from perch to perch	Soaring	Harrassed by other birds
First half post-fledge:								
1	Dec.13 - Dec. 19	12	2 (16.7%)	0	3 (25%)	1 (8.3%)	0	0
2	Dec. 20 - Des. 26	8	1 (12.5%)	1 (12.5%)	2 (25%)	5 (62.5%)	2 (25%)	0
3	Dec. 27 - Jan. 2	9	3 (33.3%)	1 (11.1%)	0	6 (66.7%)	2 (22.2%)	0
4	Jan. 3 - Jan. 9	5	1 (20%)	3 (60%)	0	4 (80%)	2 (40%)	3 (60%)
5	Jan. 10 - Jan. 16	8	3 37.5%)	2 (25%)	0	4 (50%)	3 (37.5%)	2 (25%)
6	Jan. 17 - Jan. 23	8	2 (25%)	2 (25%)	0	3 (37.5%)	3 (37.5%)	1 (12.5%)
Second half post-fledge:								
7	Jan. 24 - Jan. 30	8	1 (12.5%)	3 (37.5%)	0	3 (37.5%)	3 (37.5%)	3 (37.5%)
8	Jan. 31 - Feb. 6	5	1 (20%)	3 (60%)	0	2 (40%)	3 (60%)	1 (20%)
9	Feb. 7 - Feb. 13	7	1 (14.3%)	1 (14.3%)	0	4 (57.1%)	2 (28.6%)	2 (28.6%)
10	Feb. 14 - Feb. 20	7	1 (14.3%)	3 (42.9%)	1 (14.3%)	2 (28.6%)	2 (28.6%)	1 (14.3%)
11	Feb. 20 - Feb. 26	7	1 (14.3%)	0	0	1 (14.3%)	5 (71.4%)	1 (14.3%)
12	Feb. 27 - Mar. 6	8	0	0	0	2 (25%)	2 (25%)	3 (37.5%)
Week 1 - 6 Total		50	12 (14%)	9 (18%)	5 (10%)	23 (46%)	12 (24%)	6 (12%)
Week 7 - 12 Total		42	5 (11.9%)	10 (23.8%)	1 (2.4%)	14 (44.3%)	17 (40.5%)	11 (26.2%)

Juvenile lying down

The juvenile was seen lying down (away from the nest tree) on a wide branch or in an abandoned corvid nest on 5 days in the first half and on 1 day in the second half of the post-fledging period (Table 2), reflecting his physical development as he progressed towards independence.

Juvenile flying

Initially the juvenile's flights were over short distances e.g. flying about 50 m from the roost tree to a nearby power pole. As his flying skills improved, his flights became longer, ranging further from the roost tree.

Juvenile soaring

The juvenile gradually spent more of each day flying in wide circles without landing, and by early January his flying skills were well developed and he was soaring, using thermals to gain height. The juvenile was seen soaring on 12 days in the first half of the post-fledging period and on 17 days in the second half as his flying ability increased and warmer weather produced more thermals on which to soar (Table 2). So, there was more soaring in the second half of the post-fledging period in contrast with flying from perch to perch (see above) which decreased over time.

Table 3

Observations of adult behaviours after juvenile fledged. Number of times behaviour observed per week, and percent (%) number of times behaviour observed per observation days each week. (Note: some days there were observations conducted both in the morning and the afternoon.)

Week number	Dates	No. of observation sessions per week	Adult seen	Observed food delivery by adult birds	Adult harrassed by other birds	Adult soaring
First half post-fledge:						
1	Dec.13 - Dec. 19	12	4 (3.3%)	0	1 (8.3%)	1 (8.3%)
2	Dec. 20 - Des. 26	8	4 (50%)	2 (25%)	1 (12.5%)	2 (25%)
3	Dec. 27 - Jan. 2	9	7 77.8%)	3 (33.3%)	3 (33.3%)	3 (33.3%)
4	Jan. 3 - Jan. 9	5	5 (100%)	1 (20%)	1 (20%)	4 (80%)
5	Jan. 10 - Jan. 16	8	4 (50%)	2 (25%)	0	1 (12.5%)
6	Jan. 17 - Jan. 23	8	5 (62.5%)	0	1 (12.5%)	2 (25%)
Second half post-fledge:						
7	Jan. 24 - Jan. 30	8	1 (12.5%)	1 (12.5%)	0	1 (12.5%)
8	Jan. 31 - Feb. 6	5	0	0	0	0
9	Feb. 7 - Feb. 13	7	0	0	0	0
10	Feb. 14 - Feb. 20	7	0	0	0	0
11	Feb. 20 - Feb. 26	7	1 (14.3%)	1 (14.3%)	0	1 (14.3%)
12	Feb. 27 - Mar. 6	8	0	0	0	0
Week 1 - 6 Total		50	29	8 (16%)	7	13
Week 7 - 12 Total		42	2	2 (4.8%)	0	2

Juvenile harassed by other birds

The juvenile was seen being harassed by other birds on 6 days in the first half and 11 days in the second half of the post-fledging period (Table 2). As the juvenile's skills and strength increased and he was seen flying more often and further from the nest site (Figures 3a and 3b), he may have been perceived as more of a threat to other birds.

The earliest instances of harassment were from Australian Magpie-larks *Grallina cyanoleuca*. The first time that we observed the juvenile being harassed was 4 January 2015, 23 days after fledging. On 12 January 2015, the juvenile appeared to be forced from his roost by four Magpie-larks. Further harassment was noted on 16 January (by a Magpie-lark), and on 17 and 18 January (by unidentified small birds). On the morning of 25 January 2015, 44 days after fledging, the juvenile experienced harassment on three separate occasions, from a Magpie-lark, an Australian Magpie, and a Sulphur-crested Cockatoo *Cacatua galerita*. In the afternoon of 25 January 2015, he was forced off the power pole by at least two Magpie-larks, and then forced out of a tree by an Australian Magpie. On 22 February 2015 magpies harassed him, but he stood his ground and did not move.

Other forms of harassment used by cockatoos and Little Ravens *Corvus mellori* were to circle around the roost tree or perch, calling, or to chase him when he left the tree. For example, on 9 February 2015 ten Sulphur-crested Cockatoos circled the juvenile's perch, and on 2 March 2015 he was chased by four Little Ravens.

Juvenile hunting

We saw the juvenile attempt hunting on three occasions but saw no kills. On 25 January 2015, he flew low back and forth over the open field near the roost tree, gained a little height and circled, then dropped low and continued flying to and fro along the ridge at the top of the field. Similar flying was seen over the golf course on 29 January 2015 and 1 March 2015.

Adults seen

As the post-fledging period progressed, the juvenile was left on his own more and more to defend himself and forage. Adults were seen on 29 days in weeks 1–6 after fledging but on only two days in weeks 7–12. Adults were apparently hunting further from the nest area and/or avoiding the food-begging and harassment by the juvenile (Table 3).

Prey deliveries

We saw the parents deliver prey on 8 days during weeks 1–6 after fledging (Table 3). As the juvenile's flying ability improved in weeks 7–12, we saw parents deliver prey on only 2 days. The last known food delivery was on 26 February 2015 when the juvenile was about 76 days old. This delivery, 3.57 km north of the nest tree, was at the furthest point away from the nest tree that we tracked the juvenile before we were unable to track him any further. Although we searched in a 10 km radius of the nest tree, he had ranged beyond the distance at which we could detect a radio signal.

Prey items we found under perches and roosts used by the juvenile included Rosella *Platycercus* sp., Magpie-larks, European Rabbit, Galah *Elophus roseicapilla* (freshly killed, without head), and unidentified birds.

Adult harassed by other birds

Adults were seen being harassed by other birds on 7 days in the first half of the post-fledging period, but never in the second half,

mainly because they were absent then (Table 3) and harassment from other birds was directed to the juvenile (see left).

Adult soaring

Adults were seen soaring on 13 days in the first half of the post-fledging period and on one day in the second half. This decrease related to the adults disappearing from the area near the juvenile in the second half of the post-fledging period (Table 3).

DISCUSSION

It is important to note that this study is based on the tracking and observation of a single individual. The reported estimates of HR size and trends over time are valid estimates, as adequate sample sizes were obtained. Nevertheless, the limitation of such a study is that generalisations based on a single individual need to be taken with extreme caution. Therefore, we would like to draw the reader's attention to the fact that the generalisations and conclusions drawn below are meant to be used to inspire future hypotheses that would need to be tested on studies based on suitable sample sizes.

The fledgling's behaviours at the beginning of the PFDP reflected the constraints of immaturity i.e. staying close to the nest tree in a small HR (Figures 3a, 3b, Table 1), flying from perch to perch with no soaring, little interaction with other bird species, lying down on branches and in the nests of other birds, frequent presence of adults and frequent food-deliveries (Tables 2 and 3). The behaviours progressed to proportionally more individual strategies adopted by mature, independent raptors towards the end of the PFDP i.e. the juvenile ranging further from the nest tree in a larger HR and soaring more, which attracted more harassment from other bird species. There were fewer prey deliveries and an infrequent presence of adults.

The juvenile behaviours that we observed during the PFDP resembled those described in previous studies (Debus *et al.* 2007; Debus and Ley 2009; Debus 2011). Juvenile behaviours resembled those of the closely related Booted Eagle and Bonelli's Eagle *Aquila fasciata* (cf. Balbontín and Ferrer 2005, 2009; Cadahía *et al.* 2007, 2008). One Booted Eagle juvenile was dependent for at least 64 days after fledging (Ferguson-Lees and Christie 2001).

The passage of the PFDP is marked by progressively decreasing dependence on parents and decreasing parental investment in the fledgling (Balbontín and Ferrer 2005). Debus (2011) said that fledged Little Eagles are dependent on their parents for at least 2 mo. The Strathnairn juvenile appeared independent at 80 d old. Some juvenile Little Eagles return to the natal area, as reported by Debus and Ley (2009), a behaviour also seen in Bonnelli's Eagles (Balbontin and Ferrer 2009). In our study there was no evidence of the juvenile returning to the natal area after dispersal, and we believe that the adults dispersed soon after our last confirmed sighting of the juvenile. The adults were not seen after 26 February 2015, so they seemed to have left the nest area around that time. The adults returned to the nest area on 9 August 2015 (R. Blemings pers. comm.), well after the juvenile had disappeared.

There are limitations with observational studies in determining dispersal. Even though Debus and Ley (2009) did get up to 3 months of observations of a juvenile, and multiple observational studies independently got ~ 2 months for juvenile presence on the natal HR (Debus *et al.* 2007; Debus 2011), it is harder to follow juveniles as they become independent and disperse, especially as some ACT Little Eagles migrate (Olsen 2014) and hence the need for telemetry. In choosing the most appropriate method for radio-tracking, the effect of the transmitter on a juvenile's flying skills must be considered. GPS trackers will be more accurate for calculating HR, as they are able to track flights further from the nest (Bosch *et al.* 2016); however, these transmitters tend to be large and may interfere with flight and hunting skills of a young raptor (Dixon *et. al*. 2016; Peniche *et al*. 2011).

From the foraging behaviour of the adults at Strathnairn (Olsen and Trost unpublished data) and ranging behaviour of this juvenile, we gained some idea of the area needed by these Strathnairn eagles. The housing development planned for Strathnairn has already destroyed roost and ranging areas used by the juvenile in this study, and will destroy foraging areas used by the adults and possibly cause the abandonment of yet another Little Eagle HR in the ACT. The statutory Action Plan for protection of the Little Eagle as a vulnerable species (ACT Government 2013) noted that the main threat to the species was loss of habitat, which was 'mostly due to the encroachment of urban development on remnant woodland and grassland'. The 'primary conservation issue' was stated to be 'retention of adequate foraging and breeding habitat'. Among proposed actions was giving 'identified nest sites and foraging sites a high priority for protection', and to 'protect known previous nest sites … with a buffer'. The Strathnairn site is one of very few left, and has been used in successive seasons, and this study provides important data on space use and behaviour of the fledged juvenile at the Strathnairn site.

Native Wedge-tailed Eagles *Aquila audax* may affect Little Eagle breeding (Olsen and Fuentes 2005) and these larger eagles need to be monitored. This Little Eagle pair seems to be 'hemmed in' by breeding Wedge-tailed Eagle territories to the immediate south, east and west (Olsen and Trost unpublished data) so, if these larger eagles maintain their territories, the Strathnairn Little Eagles can only move to the immediate north. However, at the time of writing, residential housing is being constructed over the HR north of this Little Eagle nest site where this juvenile roosted and foraged (figures 3a, 3b and 5), so the territory may be lost.

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