

# 2016

*Movements of the Little Eagle (Hieraetus morphnoides) surrounding the proposed Riverview Development Area, Australian Capital Territory.*



Image courtesy Ann Elderidge

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## List of Acronyms

ACT – Australian Capital Territory

AEST – Australian Eastern Standard Time

ARGOS – Advanced Research and Global Observation Satellite

COG – Canberra Ornithologist Group

CSIRO – Commonwealth Scientific and Industrial Research Organisation

GPS – Global Positioning System

KDE – Kernel Density Estimate

MCP – Minimum Convex Polygon

NSW – New South Wales

PTT – Platform Terminal Transmitter

UHF – Ultra High Frequency

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## Introduction

The Little Eagle (*Hieraaetus morphnoides*) is a medium-sized raptor endemic to Australia that is found in open grassland and woodland habitats across most of the mainland. While the species is widespread, in the south eastern part of its range the Little Eagle is undergoing general and continuing decline (Debus et al., 2013). In the Australian Capital Territory (ACT) between 1988 and 2011, the number of Little Eagle breeding territories with active nests declined from 13 to one (Debus et al., 2013), with only three known breeding pairs found in 2015 (pers. comm J. Olsen and M. Mulvaney). The Little Eagle was declared vulnerable in 2008 in accordance with the *Nature Conservation Act 1980* and an Action Plan was written to assist in the long term maintenance of a viable, wild population of Little Eagles as a component of the indigenous biodiversity of the ACT and region

The diet of the Little Eagle in temperate regions is known to be composed predominantly of medium sized mammals (small or juvenile rabbits), birds (particularly parrots and passerines <500gm) and reptiles; in the Canberra region rabbits comprise more than 50% of the diet (Olsen et al., 2010a; Olsen et al., 2013a). As food resources for Little Eagles remain stable in the ACT, the decline of the species across the region is thought to have been caused by a combination of loss of habitat through increasing urban development (Olsen and Fuentes 2005), baiting with Pindone on rural lands for rabbits impacting on Little Eagles through secondary poisoning (Olsen et al., 2010b; Olsen et al 2013a) and displacement by more dominant Wedge-Tailed Eagles for limited territories and nesting sites (Olsen et al., 2006; Olsen et al., 2013b).

The Little Eagle is a tree nesting species of raptor, which breeds in eastern Australia during the late winter/early spring, with fledging of the young occurring mid-late December (Olsen 2014). Both parents share brooding and feeding of young chicks, but the female is responsible for most of the nesting care (Debus and Ley 2009). Little Eagles usually nest in open woodland on hillsides or along tree-lined watercourses, with the nest typically placed in a mature, living tree (Olsen 2014). Little Eagles may move seasonally between breeding home ranges and separate winter territories as found in other regions (Baker-Gabb and Fitzherbet 1999), however lack of accurate radio-tracking data for the Little Eagle means little detail is known about seasonal habitat use and home range size of the species (Olsen et al., 2008). This large gap in basic ecological knowledge of the species makes it difficult or even impossible to understand or predict the impact of changes in land use or management activities in areas surrounding remaining Little Eagle territories or nesting sites in the ACT.

Canberra's suburban areas to the north, west and south of the city are rapidly expanding to meet the needs of an ever increasing human population. As little is known about the breeding home range of the Little Eagle, it is difficult to ascertain whether proposed development within close proximity to known breeding sites may impact the viability of the species as a breeding resident within the ACT. Similarly, the current restriction of 5km for Pindone baiting activities is not known as to whether this distance is sufficient or not to protect Little Eagles from secondary poisoning.

## Study Area and Aims

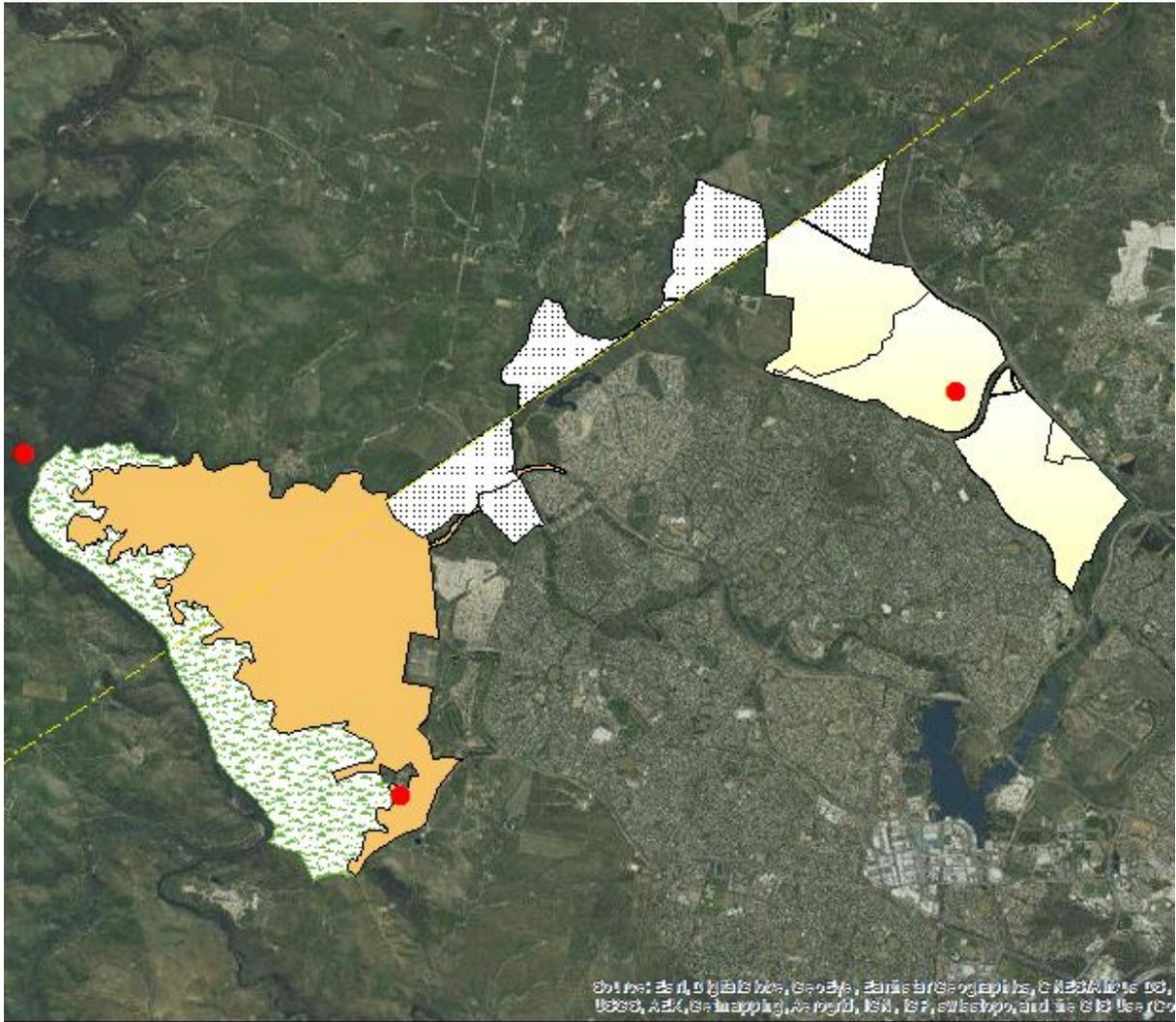
Radio-telemetry studies have not been undertaken on adult Little Eagles and little is known about the size of their home range or habitat use within the ACT region. More importantly, nothing is known about how increasing urban encroachment on habitat and breeding territories may impact either locally breeding pairs or the viability of the species in the ACT over the long term.

The aim of this research is to monitor movements of at least one of a pair of Little Eagles (known as the Lower Molonglo pair) that have recently successfully bred in a pine tree on the property of Strathnairn, which lies within close proximity (<1km) to the site of the proposed urban development known as Riverview, West Belconnen. The proposed development of Riverview, West Belconnen, lies to the southwest of the established suburb of Holt, ACT. The development proposal includes both an urban development parcel of land and conservation zone identified to the west along the Murrumbidgee River corridor. Areas to the northeast of the development (both in ACT and across the border into NSW) have been identified as possible offsets for future urban development and may be important to the outcomes of this study (Figure 1).

The Lower Molonglo pair at Strathnairn is the only known breeding pair of Little Eagles in the Lower Molonglo area. Through on-the-ground monitoring and opportunistic observations, the pair appears to have bred in the area from at least 2003, and have been recorded using five different nest sites within a 5km radius (J. Olen pers. comm.). In 2009, a report to Riverview Developments did not observe Little Eagles at the proposed West Belconnen development area (Mills 2009). This result may indicate either that the use of the development area by the Lower Molonglo Little Eagles is limited, perhaps to only a small proportion of the area if any, or that use of the area may be dependent on seasonal foraging or may change between years. As such, little is known about the dependence of the Lower Molonglo Little Eagles on the proposed West Belconnen development site.

Through monitoring the movements and habitat use of the Lower Molonglo Little Eagles this research aims to:

1. Map the foraging activity and home range of the Lower Molonglo Little Eagles;
2. Identify which parts, if any, of the West Belconnen development area and conservation zone fall within the foraging range;
3. Calculate the percentage of foraging range (if any) that falls within in the proposed West Belconnen development area and conservation zone;
4. Assessment of the relative importance of the foraging habitat within the West Belconnen development and conservation zone;
5. Summarise the likely impact of the proposed West Belconnen development on the Lower Molonglo Little Eagles, and to what degree these impacts may be minimised or offset by other actions within the home range;
6. Recommend actions that could be undertaken for future land development to avoid or mitigate impacts to the viability of the Little Eagle as a resident breeding species in the lower Molonglo;
7. Identify possible factors such as competition with Wedge tailed Eagles, the extent of urban development or the distribution of prey habitat that may appear to be influencing the home range boundary.
8. Identify gaps in the data and knowledge of the Little Eagle in the ACT that may help address the unknown impacts of future developments in the region.



**Legend**

- Little Eagle nest locations
- ACT\_Border
- CSIRO Lands
- Proposed Offsets ACT/NSW
- Development area
- Conservation Zone

0 0.5 1 2 3 4 Kilometers



**Figure 1:** Map of study area, showing land use sectors for the categories of development area, conservation zone, proposed offsets and CSIRO lands. Known Little Eagle nest locations are shown in red. In addition, urban areas were defined by the suburban boundary (indicated in this map by housing density) while the rest of the area was categorised into rural and reserves.

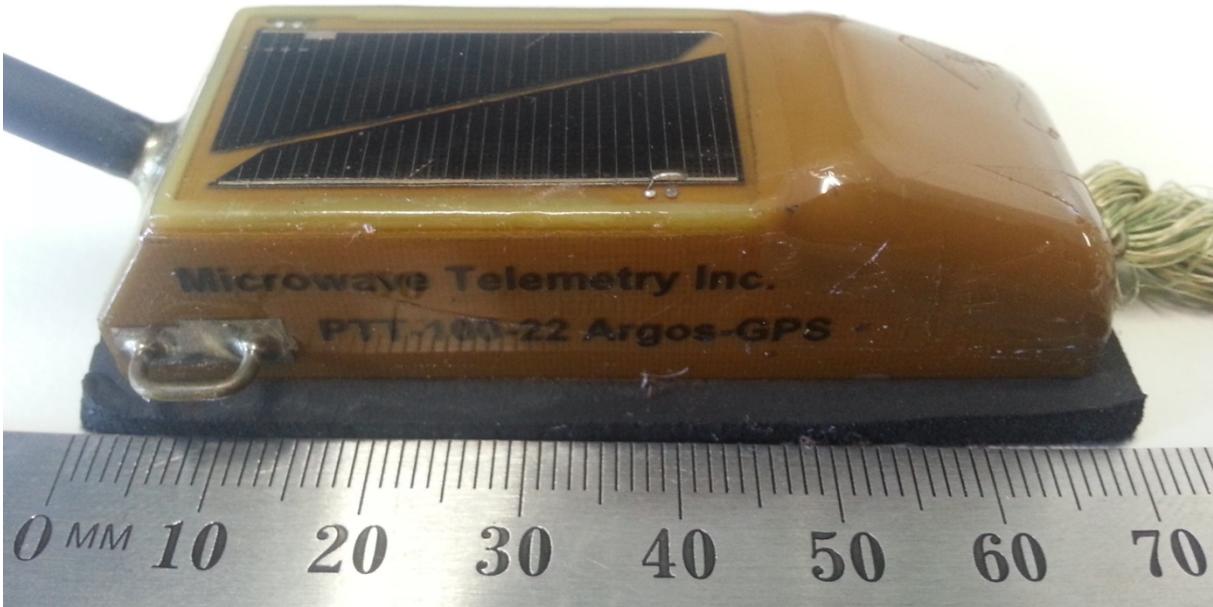
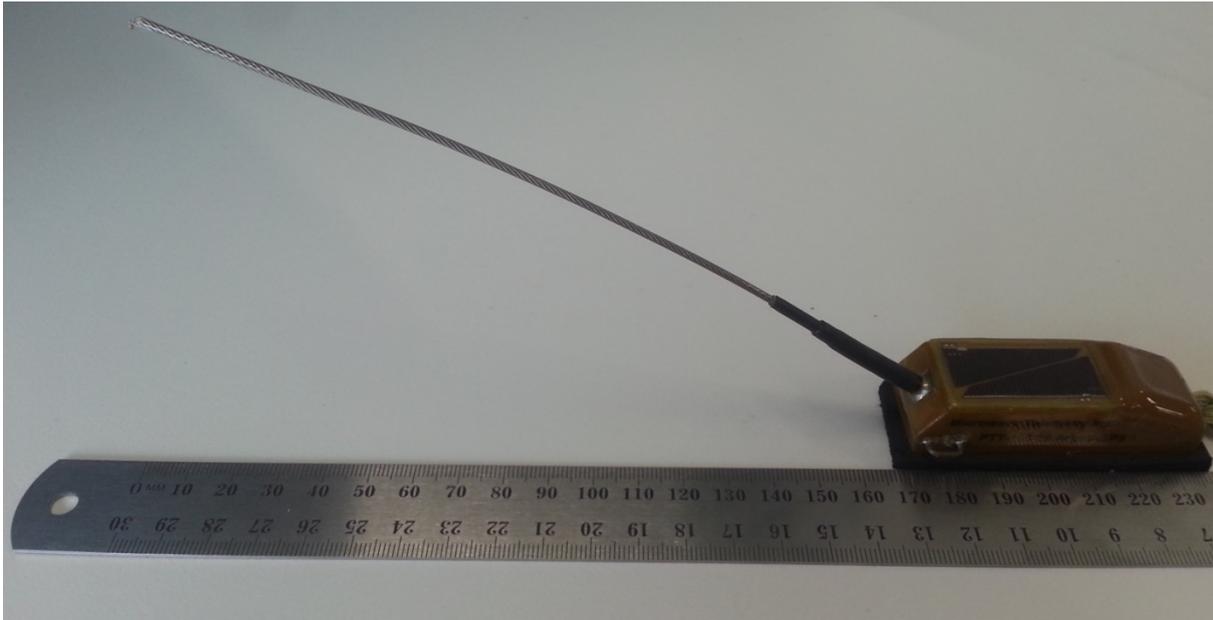
## GPS Telemetry Units

Two PTT-100 22gm Solar ARGOS/GPS PTT transmitters (Figure 2) were purchased from Microwave Telemetry (Canada) for use in this study. The transmitters, specifically designed for use on birds, are light-weight, programmable and solar powered with a battery life expectancy of 9-12 months. The accuracy estimation for the GPS units is  $\pm 18\text{m}$ . The units operate through the ARGOS satellite system; GPS fixes are taken and uploaded through the ARGOS satellite daily to the server, where the user then logs on electronically through the ARGOS website to download the GPS location data. The units have both 2D and 3D capacity; the 3D units collected data on both speed and altitude of the bird in addition to the GPS location. The two units were programmed to take 8 fixes per day; the amount of GPS fixes taken was a compromise between the collection of enough data to enable accurate monitoring of the birds' activities and minimising the draw on battery power to enable the unit to recharge enough by the time of the next fix. The fixes were taken 2-3 hours apart from 5am through to 8pm, with a midnight fix also collected for roosting location information. The units were also programmed with a ground-tracking capability which allowed the users to track the birds manually from the ground using a UHF antenna and receiver for a limited time of the day. The ground track capability for our units was set for four hours between the hours of 4 – 8 pm every day. More detail on the transmitters used in this study can be found on the Microwave Telemetry website: [http://www.microwavetelemetry.com/bird/solarArgosGPS\\_22g.cfm](http://www.microwavetelemetry.com/bird/solarArgosGPS_22g.cfm)

Prior to the commencement of trapping, a trial of the two transmitters took place to ensure estimation of the accuracy of GPS fixes was reliable. The transmitters were placed in a known location approximately 50m apart where they were open to sunlight and weather elements. The transmitters were activated and left in place for three days. A total of 19 viable fixes were collected with an average accuracy of  $48.37 \pm 14.54\text{m}$ .

Trapping for Little Eagles was conducted in the Strathnairn area during October 2015 by experienced raptor experts Jerry Olsen and Sue Trost. A harness to allow for the attachment of the transmitters was developed to enable the correct placement of the GPS units on the bird's upper back whilst not to interfering with the birds normal daily activities (such as flying/hunting). The correct fit of the harness and GPS unit was critical for both the solar charging and operation of the unit and the welfare of the bird.

Data collected from the GPS units included location and time of fix, speed and altitude of the bird at time of fix. It was hoped that the daily fixes would provide information on areas used for hunting and roosting, while speed and altitude data provided insight as to when the bird was traveling to and from areas of use (at higher altitudes) in comparison to times resting during the day. Data from the unit was downloaded weekly and parsed through software provided by transmitter manufacturers so that locational, speed and altitude data could be saved in Microsoft Excel file format and viewed as 3D locations in Google Earth TM.



**Figure 2.** Microwave Telemetry PTT-100 22gm Solar ARGOS/GPS PTT transmitter used in this study.

## Definition of land use sectors

For the purpose of this study, and for informing management of the likely impact of the Riverview/West Belconnen development on the Lower Molonglo pair of Little Eagles, land use within the study area was classified into six major land use types, hereafter referred to as sectors. The six sectors were “Development area” (the area currently proposed for urban development by Riverview Projects), “Conservation zone” (the area to the west of the development area along the Molonglo corridor, proposed as a conservation offset for the development), CSIRO lands (in which a little eagle nest is located), “Proposed offsets” (land identified either side of the ACT/NSW border which may be possible offsets for future development), “Urban” (current urban areas including housing and industry) and “Rural and reserve areas” (including all rural areas such as rural residential, leasehold, as well as Dunlop reserve) (Figure 1).

In addition, we also examined the proportional use of major habitat types in the region. Habitat types included woodland, open woodland, grassland, shrubland, urban vegetation (such as urban parks and nature strips) and urban areas.



*Image of the Murrumbidgee River looking north from Shepherds Lookout, ACT, showing the conservation zone along the eastern side of the river. Photo courtesy of Mark Jekabsons.*

## Home range size and sector use

A male Little Eagle was captured at Strathnairn and the GPS transmitter affixed at the end of October 2015 (Plate 2). The bird was released and monitored for approximately three months before the transmitter failed after a week of very wet weather.

During this time, a total of 918 usable location fixes were collected, of which 27% were taken whilst the bird was flying, and the remainder 73% whilst roosting. The average distance travelled per day was recorded at 9.87km, with the maximum distance travelled 27.97km and the minimum distance travelled only 130m. The average speed measured for the male Little Eagle when flying was 17km/hr, with a minimum speed of 1km/hr and a maximum recorded speed of 47km/hr.

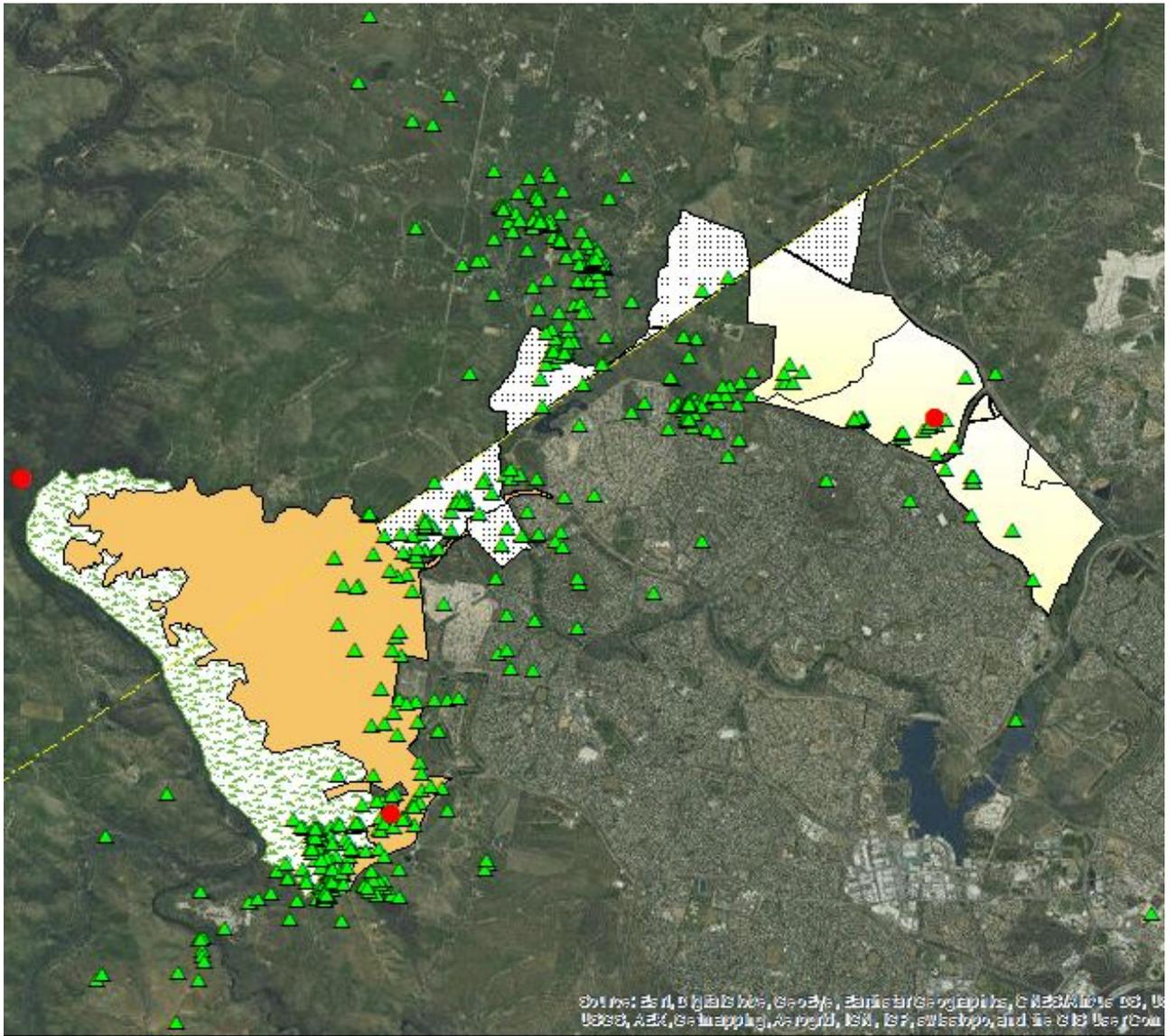
Table 1 shows the number of GPS fixes captured per week over study period, while Figure 3 shows the location of the total fixes taken with the GPS unit over the entire study period in relation to known Little Eagle nest sites and identified land use sectors.

The home range of the male Little Eagle during the study period extended from west of the Murrumbidgee River in the south, through to Wallaroo (NSW) in the north and across to the end of the CSIRO lands at William Slim Drive and the Barton Highway to the east. Localities such as Strathnairn, Gooromon Ponds, Dunlop Reserve and CSIRO lands were frequently visited during the monitoring period (Figure 3).

**Table 1.** Number of fixes collected each week from the male Little Eagle captured at Strathnairn.

Week No. (in Year)	Week commencing	No. of fixes
44	25/10/2015	29
45	1/11/2015	68
46	8/11/2015	70
47	15/11/2015	66
48	22/11/2015	70
49	29/11/2015	69
50	6/12/2015	70
51	13/12/2015	70
52	20/12/2015	70
1	27/12/2015	69
2	3/01/2016	67
3	10/01/2016	70
4	17/01/2016	70
5	24/01/2016	60

For ground-truthing of the data and welfare of the bird, an attempt was made to locate the Little Eagle on more than 20 occasions using the UHF ground-tracking receiver and the Ground-Track signal, which was emitted from the unit between 4-8pm. The Little Eagle male was sighted from the ground at Strathnairn, Dunlop Reserve and by rural land holders in the vicinity of Gooromon Ponds.



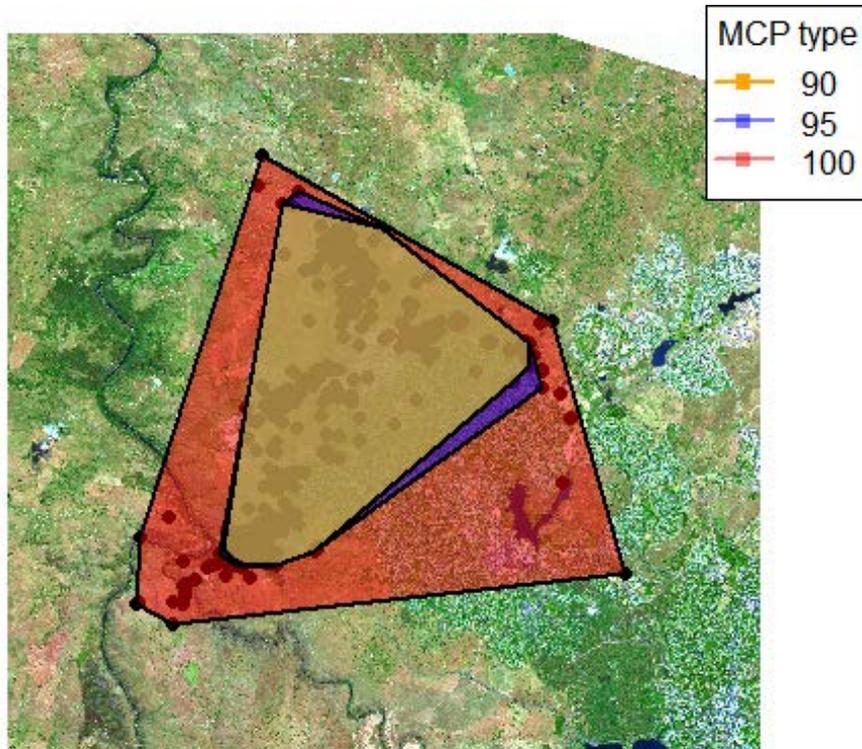
**Legend**

- ▲ Male\_Little\_Eagle
- Little Eagle nest locations
- ACT\_Border
- CSIRO Lands
- Proposed Offsets ACT/NSW
- Development area
- Conservation Zone



**Figure 3.** Map showing the distribution of GPS fixes collected for the male Little Eagle in the study area, in relation to land use sectors and known Little Eagle nest locations.

Total home range was estimated using both the minimum convex polygon method (MCP; Figure 4, Table 2) and kernel density estimates (KDE; Table 2). Taking the generally accepted 90-95<sup>th</sup> percentile isopleth, results from these methods show the total home range of the male Little Eagle to be approximately 47-67km<sup>2</sup> over the three month period.

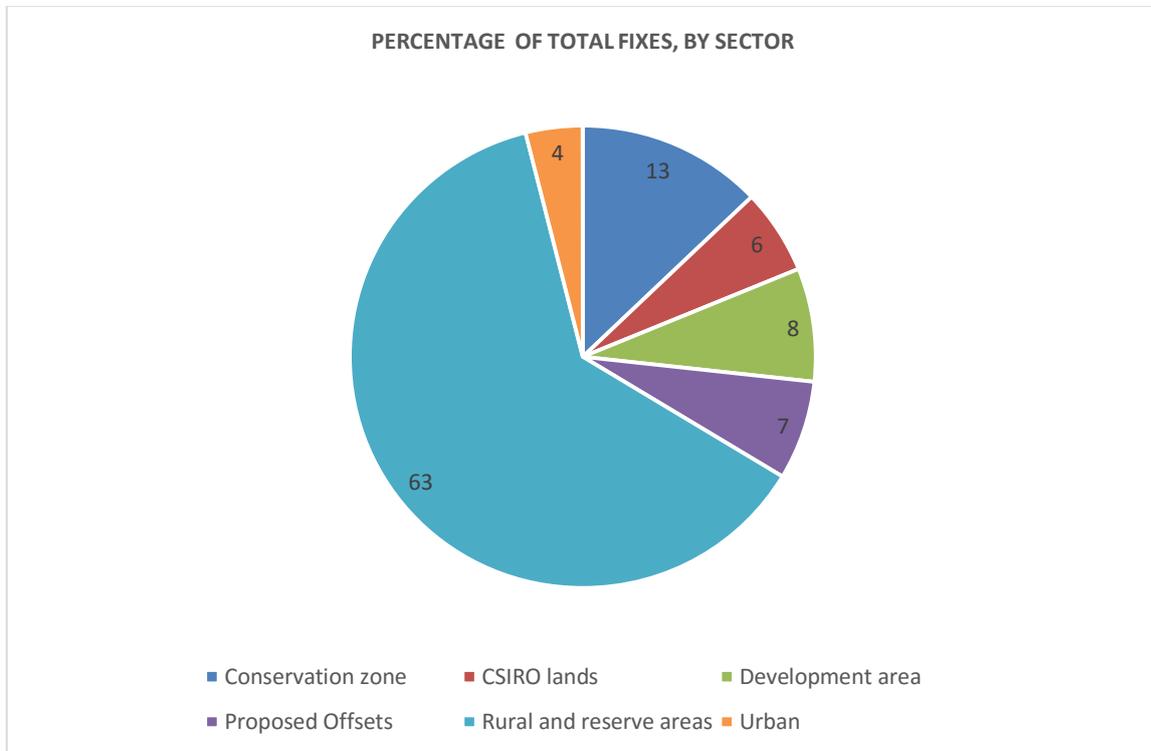


**Figure 4.** Home Range of the male Little Eagle captured at Strathnairn using minimum convex polygon (MCP), showing 90, 95 and 100% isopleths.

**Table 2.** Home range size (km<sup>2</sup>) for different isopleth (contour) levels of MCP and KDE.

Isopleth	Area km <sup>2</sup> (MCP)	Area km <sup>2</sup> (KDE)
50	21.97	12.38
55	24.16	14.85
60	28.18	19.81
65	31.68	22.28
70	35.93	27.23
75	38.21	32.18
80	43.06	37.14
85	45.48	44.56
90	47.52	51.99
95	50.96	66.84
100	108.8	151

When examining the proportion of fixes taken in different sectors, results indicate that most of the fixes were taken within rural and reserve areas (63%). The next largest sector used was the area allocated as a Conservation zone (13%), followed by the Development area (8%), Proposed offset areas (7%), CSIRO lands (6%), with Urban areas the least used (4%) (Figure 5a).

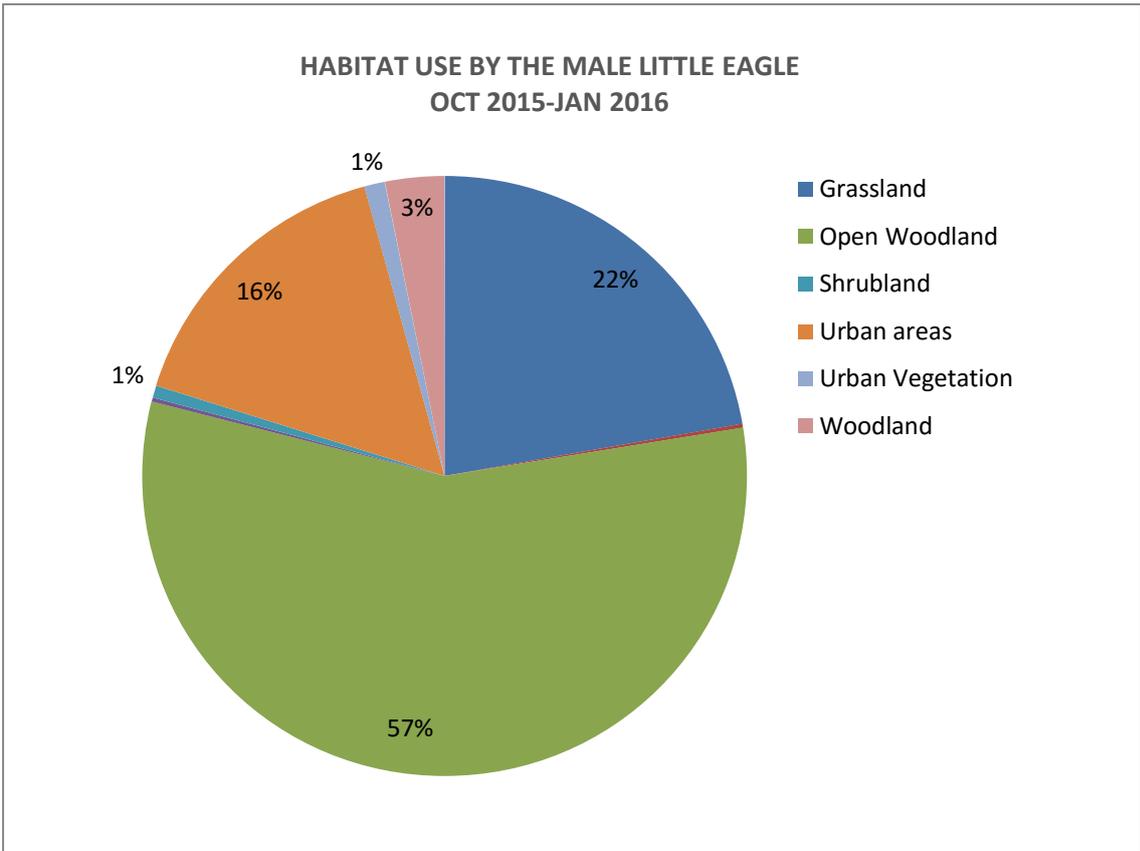


**Figure 5a.** Overall use of by the Male Little Eagle of different sectors within the home range.

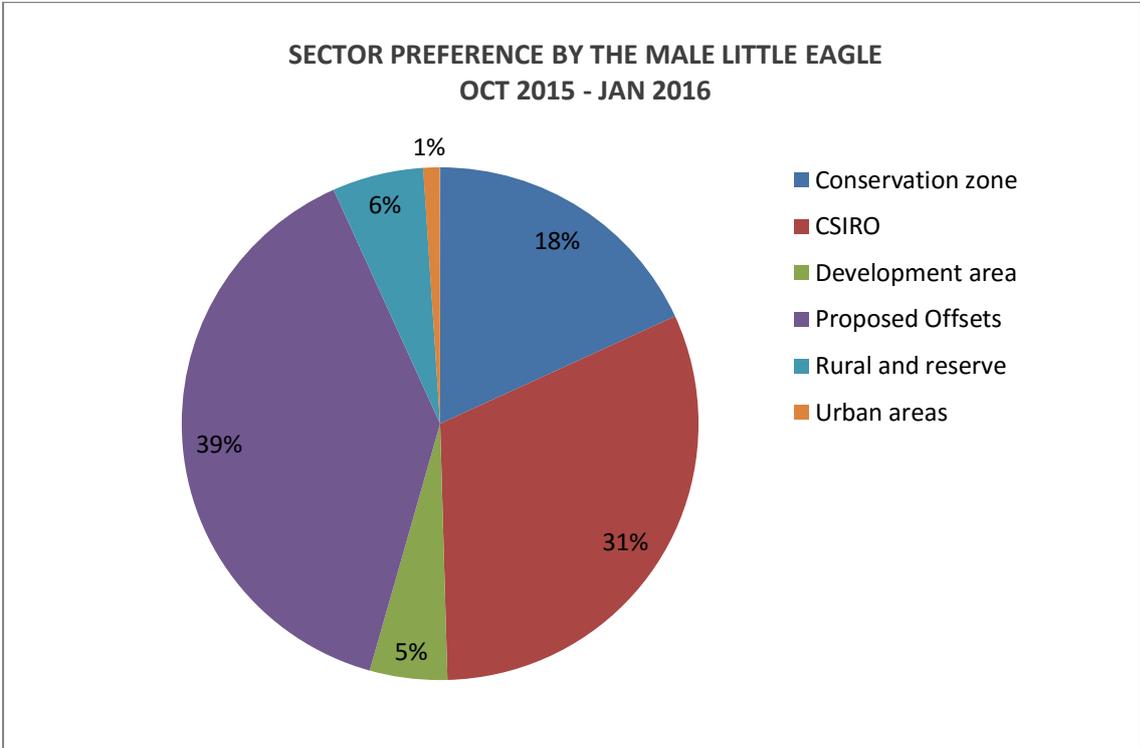
When habitat type of these areas was examined, fixes for the male Little Eagle were located predominantly in open woodland habitat (57% of fixes), followed by grassland areas (22% of fixes) (Figure 5b). The higher use of urban areas (16% of fixes) in this analysis may indicate flying zones as the bird moved between habitat patches, rather than urban area use for roosting or foraging, as is discussed later in this document. On one occasion the male Little Eagle moved north of Lake Ginninderra and across to the area of the Australian Institute of Sport in Belconnen (Figure 3). However, if we examine the use of sectors compared to availability (size of area in hectares), we see a strong preference for the proposed offset areas and CSIRO lands (Table 3, Figure 5c).

**Table 3.** Habitat preference scores, by sector.

Land use sector	Overlap	No. of fixes	Habitat preference
Conservation zone	3.04	117	38.49
CSIRO	0.824	55	66.75
Development area	6.926	71	10.25
Proposed Offsets	0.739	61	82.54
Rural and reserve	47.953	580	12.1
Urban areas	15.228	34	2.23

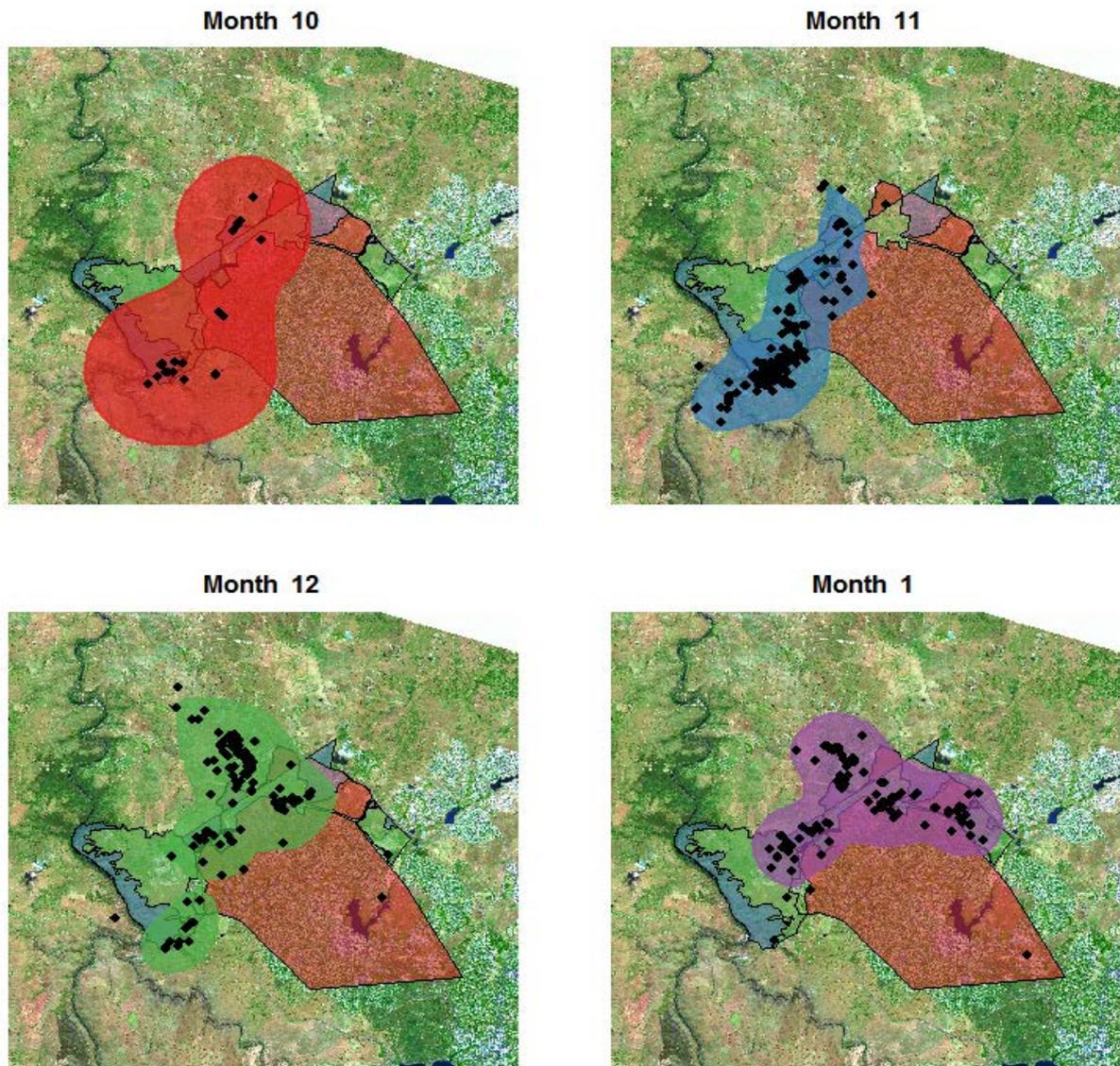


**Figure 5b.** Habitat use by the male Little Eagle over the study period.



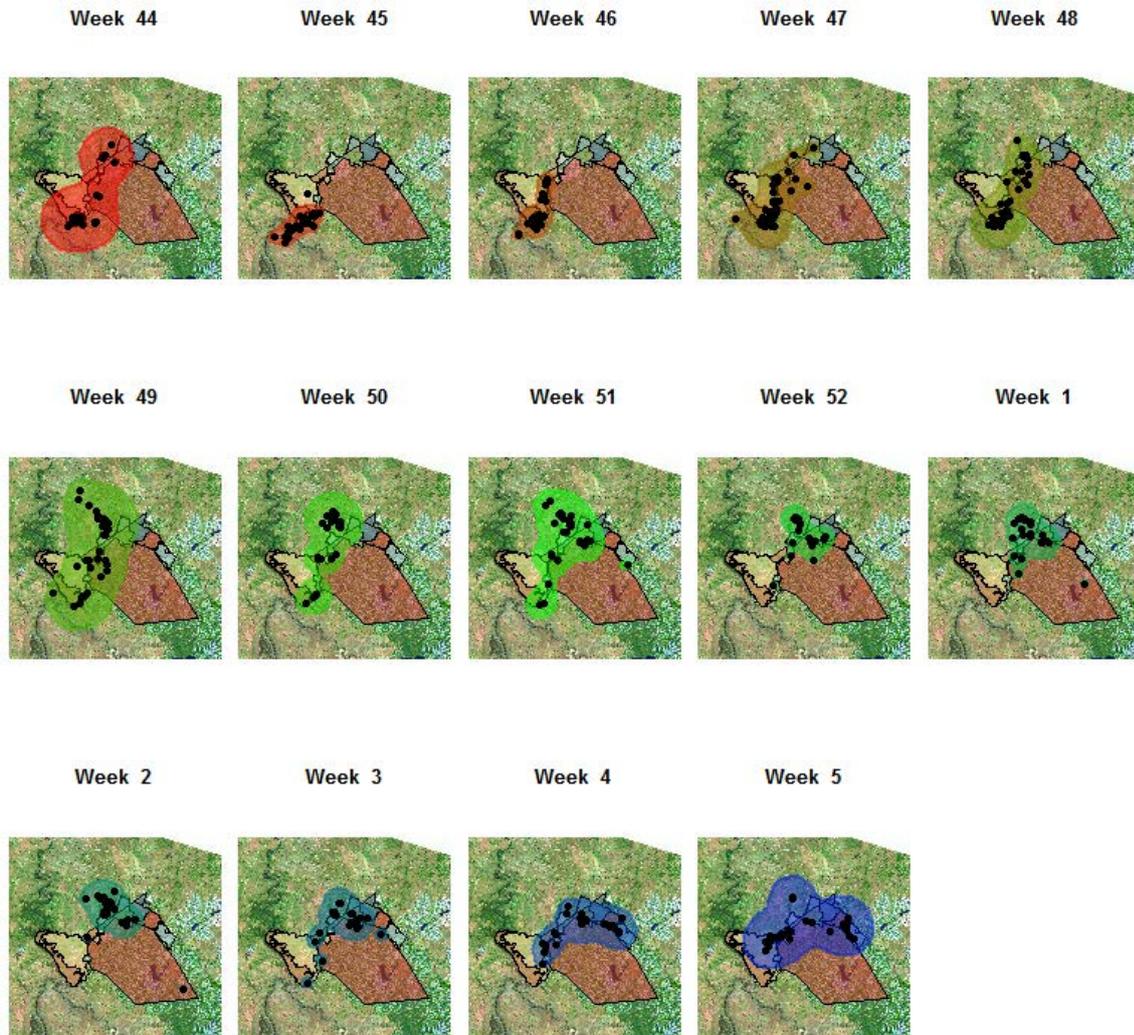
**Figure 5c.** Preferred use of sectors by the male Little Eagle, in comparison to availability.

When the home range was examined by month, there was a clear shift of movement from the southernmost area of the home range around Strathnairn and the proposed development area to an increase use of the northern and eastern areas of the home range, around the areas of Hall, Wallaroo and the property of Jaramalee (Figure 6). The Little Eagle used the rural and reserve lands to the north east of the development area to move between Strathnairn and around the urban fringe into the proposed offset areas, CSIRO lands and across the border into NSW.

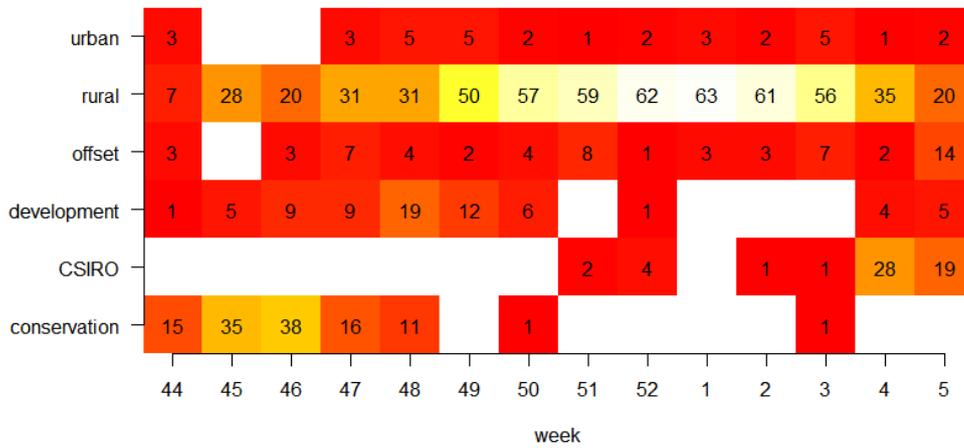


**Figure 6.** Home range movements of the male Little Eagle, by month. Note that Month 10 had only three days data (29 fixes compared to approximately 350 fixes in the other months); therefore home range area is likely to be over-estimated.

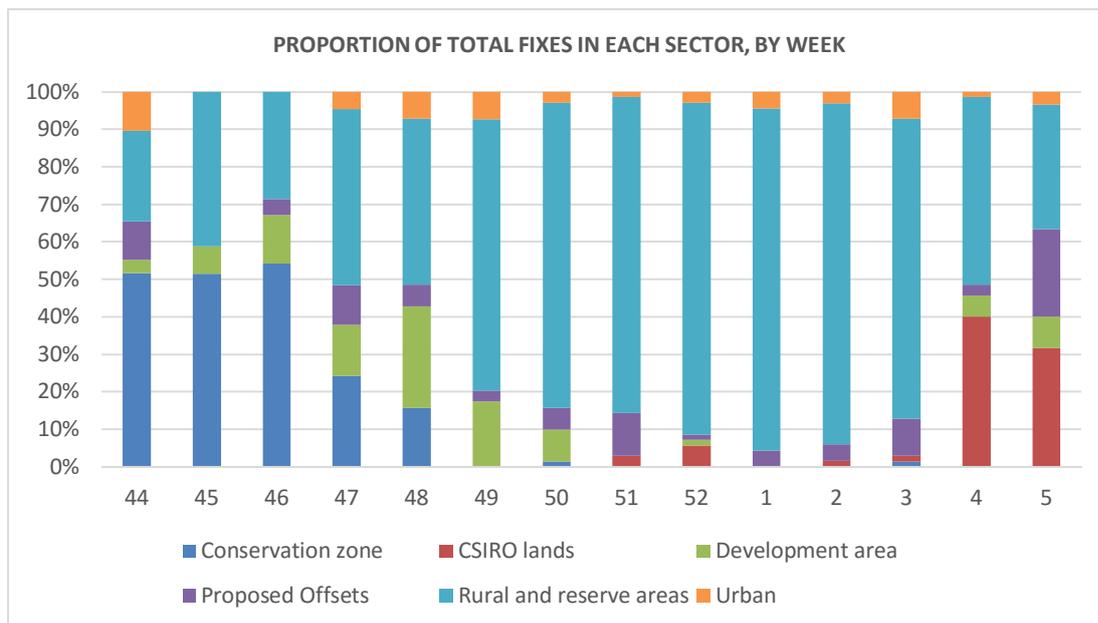
When examined at the weekly scale, the shift of the occupied areas northwards over time can more clearly be seen (Figure 7). As the use of the home range shifted northward, the use of the different sectors also changed. In the first few weeks of monitoring, the male Little Eagle used the conservation zone to the west of the development area, however as the nest failed and summer progressed, there was a shift in activity to rural and reserve lands and CSIRO lands (Figure 8, 9). Similarly the total distance travelled per day showed a decreasing towards the end of the monitoring period, suggesting the bird may have settled into a possible summer range (Figure 10).



**Figure 7.** Home range movements of the male Little Eagle, by week. Note the shift in movements to the northern end of the study area over time. Week 44 had only 29 fixes compared to approximately 70 fixes in other weeks.

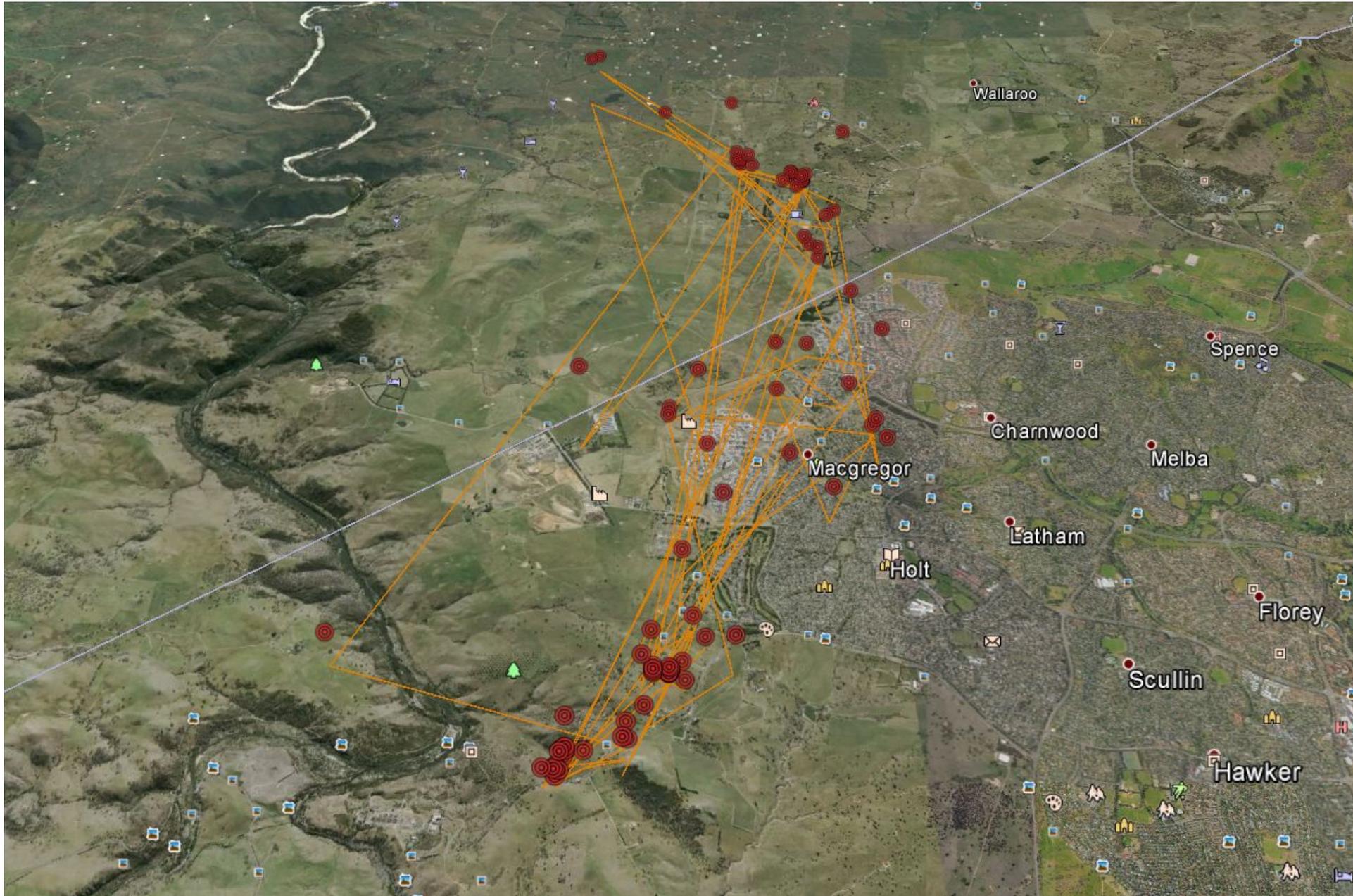


**Figure 8.** Heat map of activity showing the number of fixes in each sector by week. Note the shift from the conservation zone and development area used at the beginning of the study to the rural and CSIRO lands from around week 50 onwards.

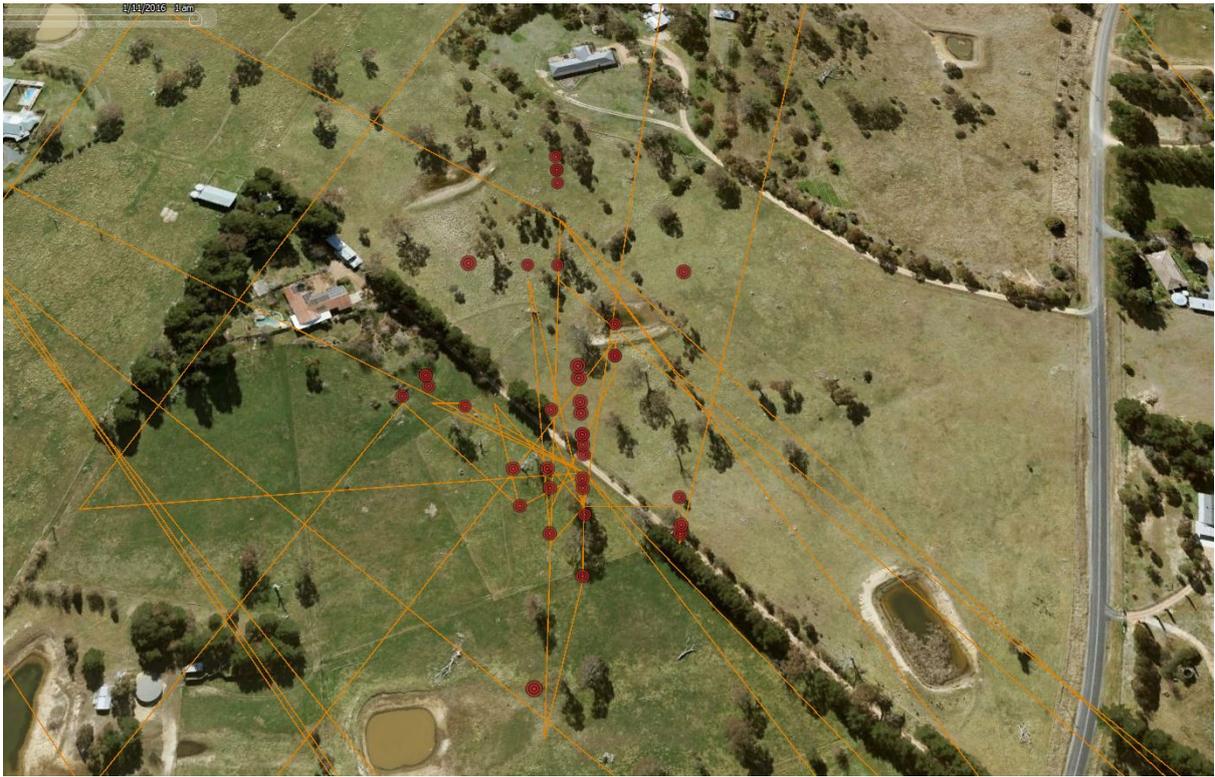


**Figure 9.** Change in the proportion of fixes in each sector, by week. Note the shift in use from the conservation zone to rural and CSIRO lands.

When the GPS fixes were examined using Google Earth TM, the flight pathways of the male Little Eagle were more clearly visible. Popular roosting locations at Strathnairn and further to the north at Gooromon ponds were linked by travel routes over Dunlop and the West Belconnen area (Figure 10).

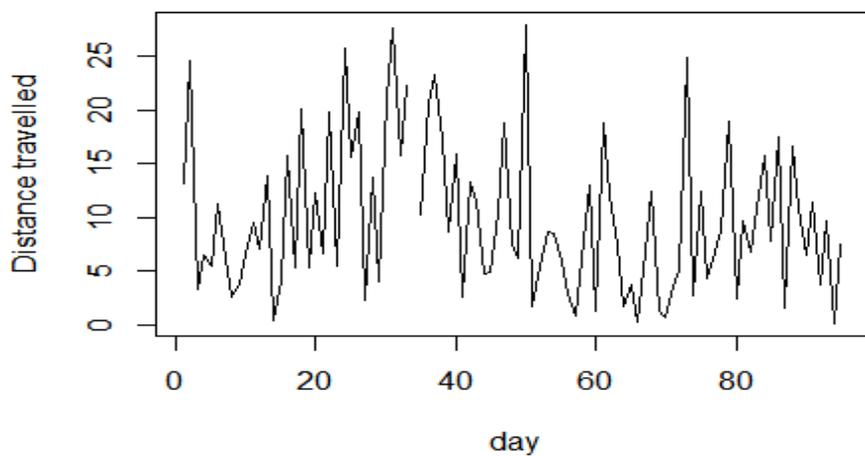


**Figure 10.** Google Earth 3D plot of GPS fixes, showing hotspots of activity at Strathnairn and Wallaroo, and flight paths over the urban fringe.



**Figure 11.** Google Earth 3D plot of GPS fixes on rural residential lands at Wallaroo, NSW, along Gooromon Ponds Rd. The male Little Eagle spent many weeks in the region at the end of the study.

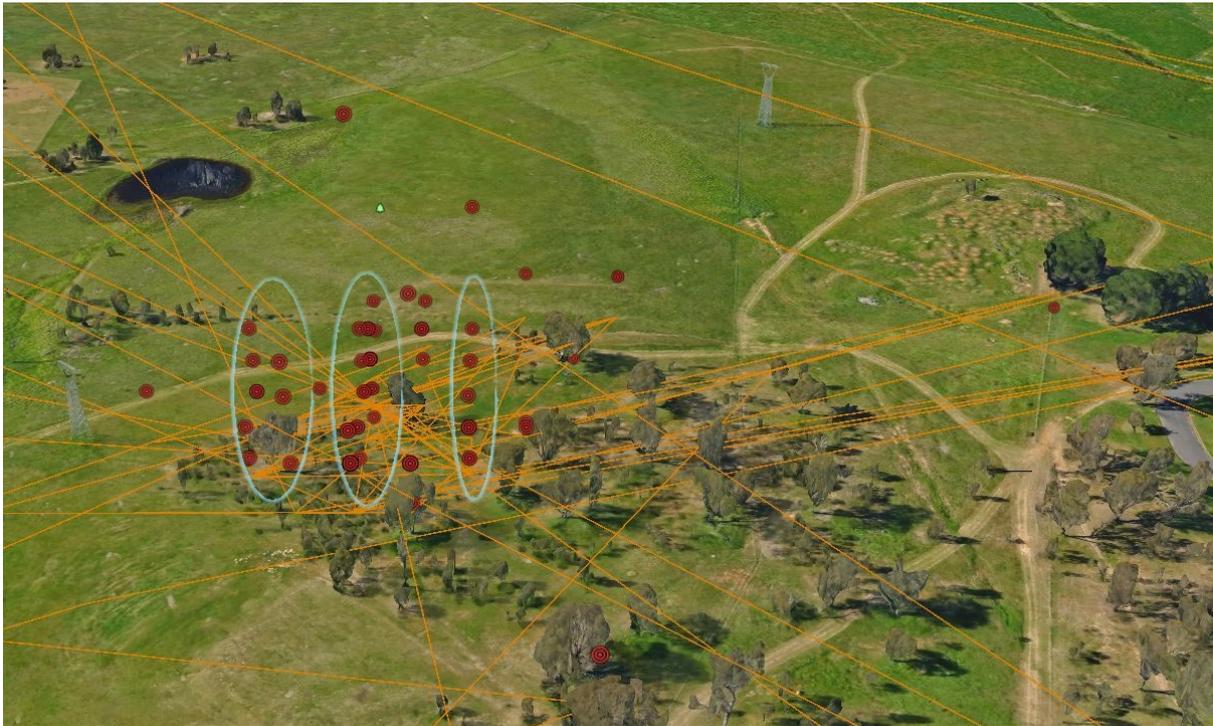
Towards the end of the study, the male Little Eagle spent much of its time in the rural-residential area of Gooromon Ponds (Figure 11). While there was shift in home range northwards as the summer progressed, there was also a decrease in the distance flown per day (Figure 12)



**Figure 12.** Total distance travelled per day over time.

## Flying vs roosting behaviours

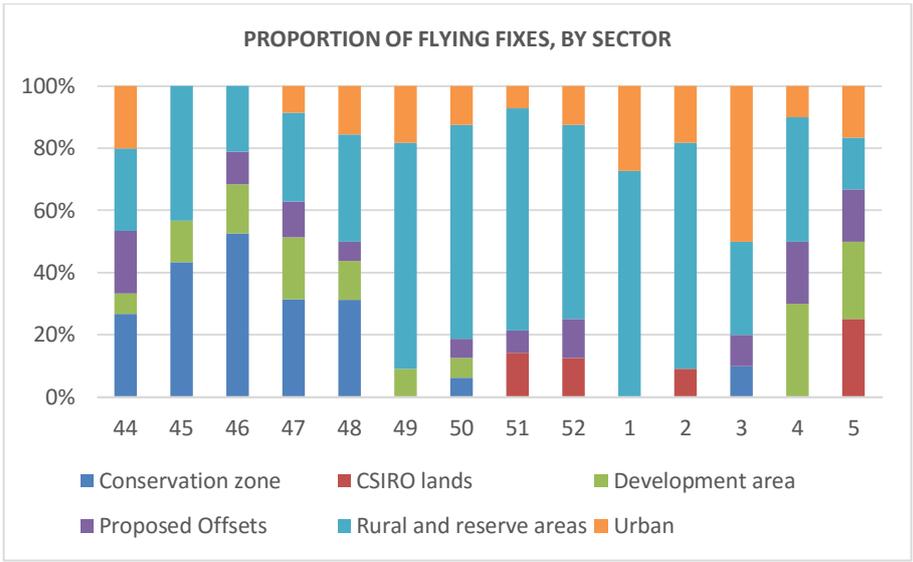
Roosting fixes were defined as having zero flying speed, while flying points were the remainder. While we were unable to definitively distinguish between flying and foraging, it is likely that areas with both flying and roosting sites during the daylight hours may indicate foraging areas. For example, in the open woodland at Dunlop Reserve (Figure 13) and NSW rural residences along Gooromon Ponds Road (Figure 11) both had roosting and flying areas. Roosting trees were also indicated by repeated fixes in the one location as shown in Figure 13.



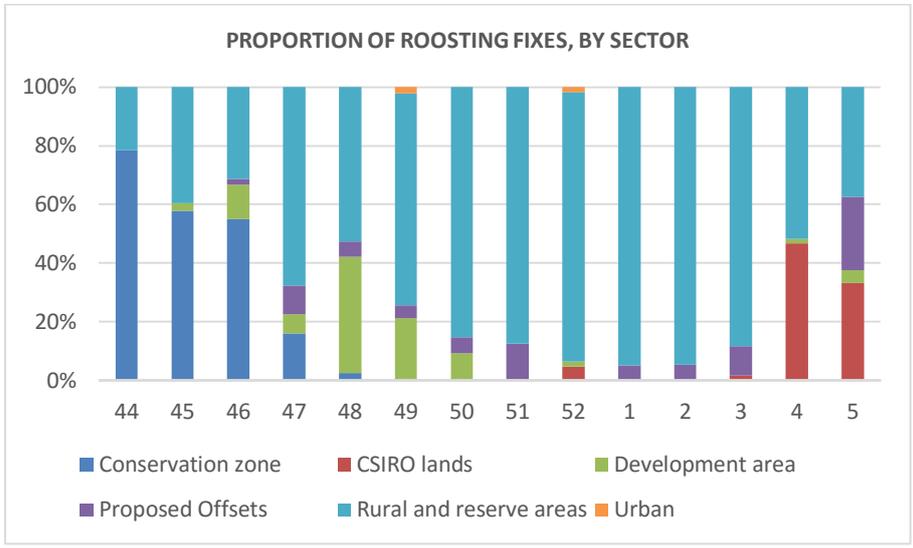
**Figure 13.** Google Earth 3D plot of GPS fixes within Dunlop Reserve, ACT, showing altitude of flying fixes and roost sites, indicated by repeated positions at the same location (circled in blue).

When roosting and flying fixes were examined by land use sector, it was clear that most fixes taken in urban areas were during flying (Figure 14a). In the early part of the study, the conservation zone and rural and reserve lands were the main roosting areas while the proposed offsets and development areas had more flying fixes (Figure 14b). Whether this indicates foraging or travel routes is unclear, but an increase in roosting in these areas suggests they may have been used for foraging. Between week 48 and 50, which coincides with the shift in home range from north to south, the male Little Eagle increased its use of the development area (Figure 14b). Towards the end of the study, there was a shift towards an increase in roosting (and use in general) of the CSIRO lands while the use of rural and reserve lands remained high (Figures 14a and b).

When examined across all sectors, there was a distinct increase overall in roosting fixes as the season shifted from spring into summer (Figure 15).

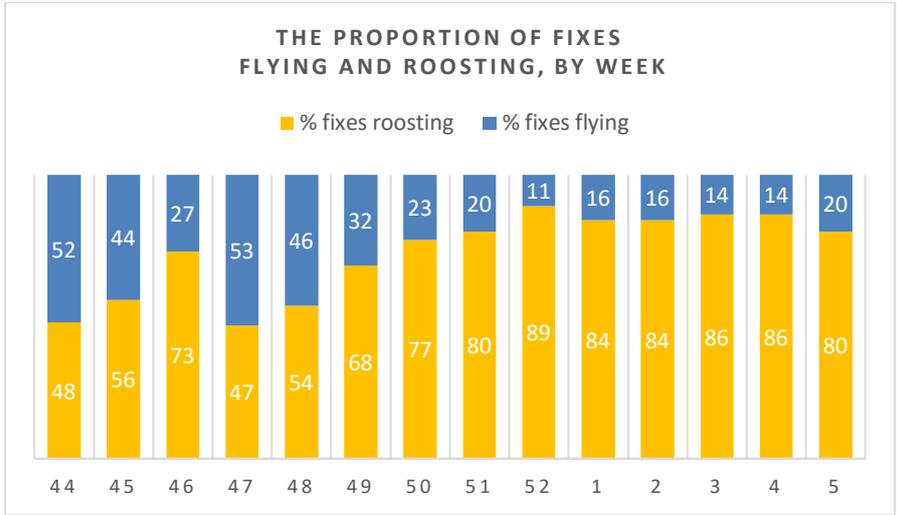


(a)

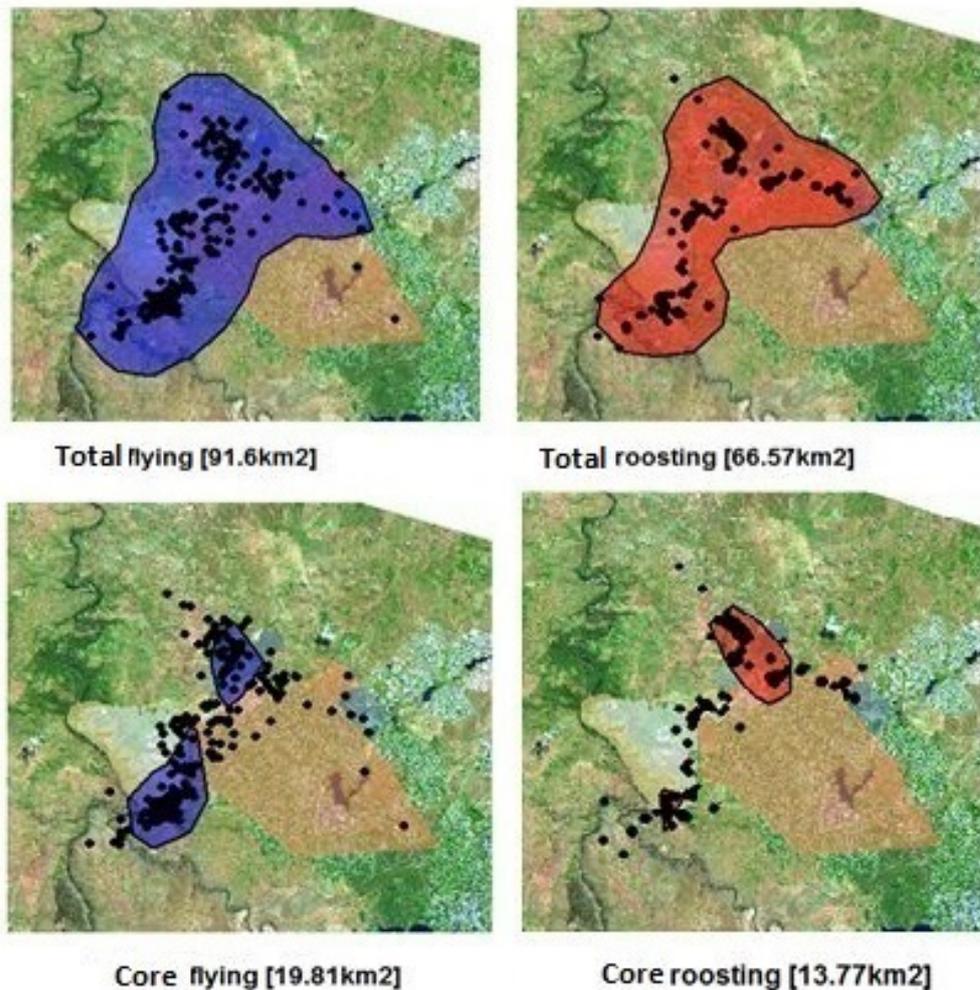


(b)

**Figure 14.** The proportion of flying (a) and roosting (b) fixes, by sector.



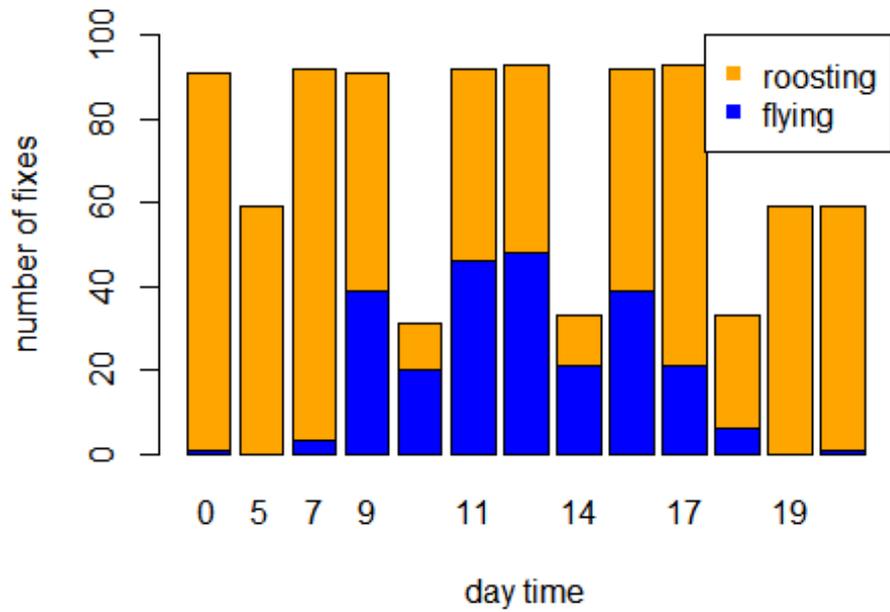
**Figure 15.** The proportion of flying and roosting fixes by week.



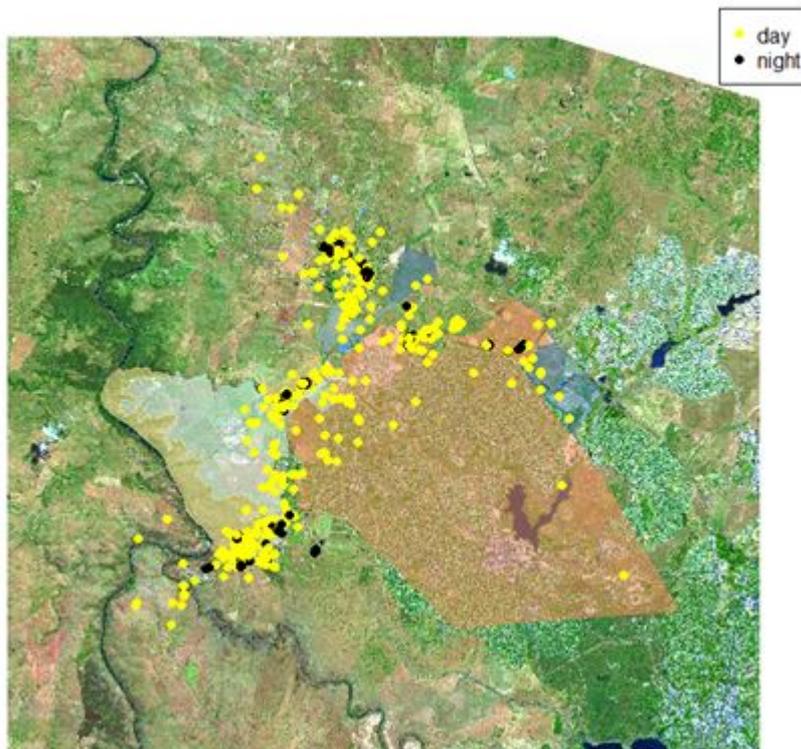
**Figure 16.** Home range of the male Little Eagle, based on flying and roosting behaviours, for total home range (95% kernel) and core home range (50% kernel).

When we examined the home range kernels of roosting and flying behaviours, it is clear that the core areas for flying during the study period were in the Strathnairn region (including south towards the conservation zone), the south-eastern end of the development area and the rural areas around Gooromon Ponds (Figure 16). The flying route along the eastern side of the development area is also regularly used and offers a corridor of habitat between these two areas. Core areas used for roosting were similar: Strathnairn and Gooromon Ponds were the core roosting areas. The Little Eagle’s roosting range was reduced from that of its flying range, with the Little Eagle rarely roosting within urban areas (Figure 16).

Roosting behaviour occurred at all times of day when GPS fixes were taken, but there was an increase in flying activity from 9am though to 5pm (Figure 17). The male Little Eagle used most locations within its home range during the day, but roosted at night at key locations such as Strathnairn, Dunlop Reserve, Gooromon Ponds and CSIRO lands (Figure 18).

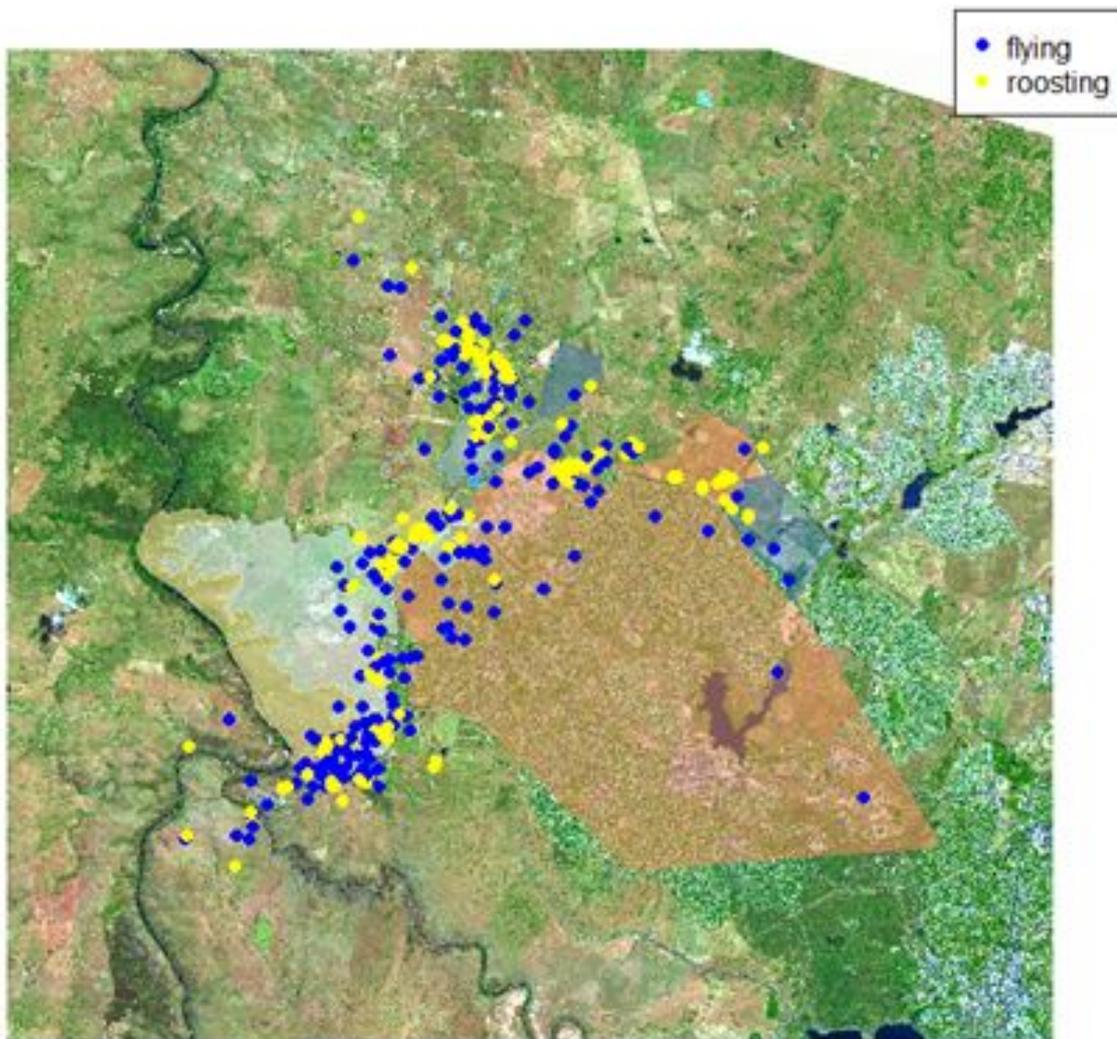


**Figure 17.** Roosting and flying behaviours by time of day (AEST).



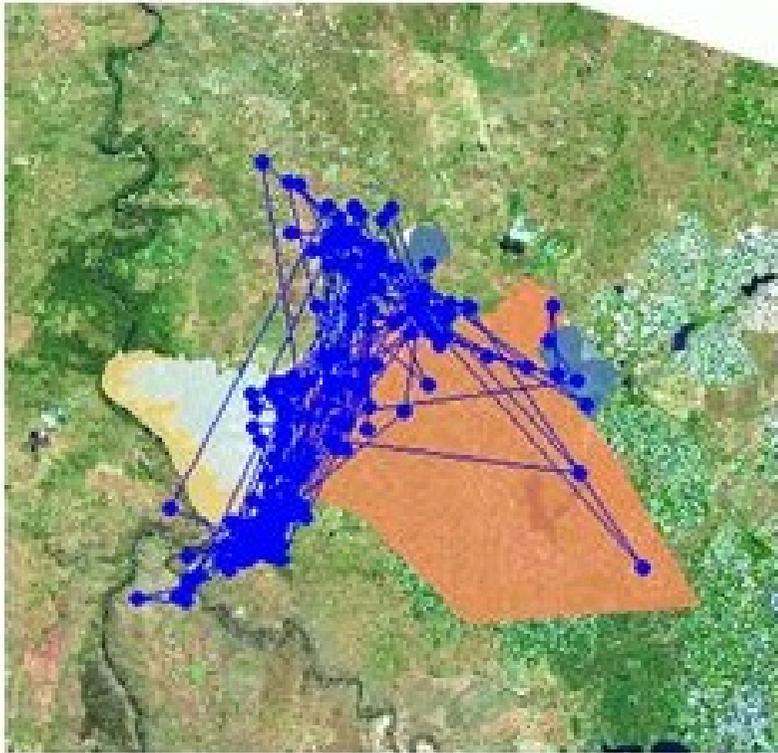
**Figure 18.** The location of day (n=525) and night (n=393) fixes for the male Little Eagle, where day fixes were taken between 9am and 5pm AEST.

The male Little Eagle roosted in similar areas during the day as to night, with the exception of the north and eastern section of the development area and urban areas, which were used during the day only (Figures 18 and 19). There was a clear reduction in roosting fixes in urban areas overall, and reduction in the amount of area used in the development area. This is most likely due to the selection of large mature trees in which to roost, and from which flying/foraging activities can be conducted (Figure 20).

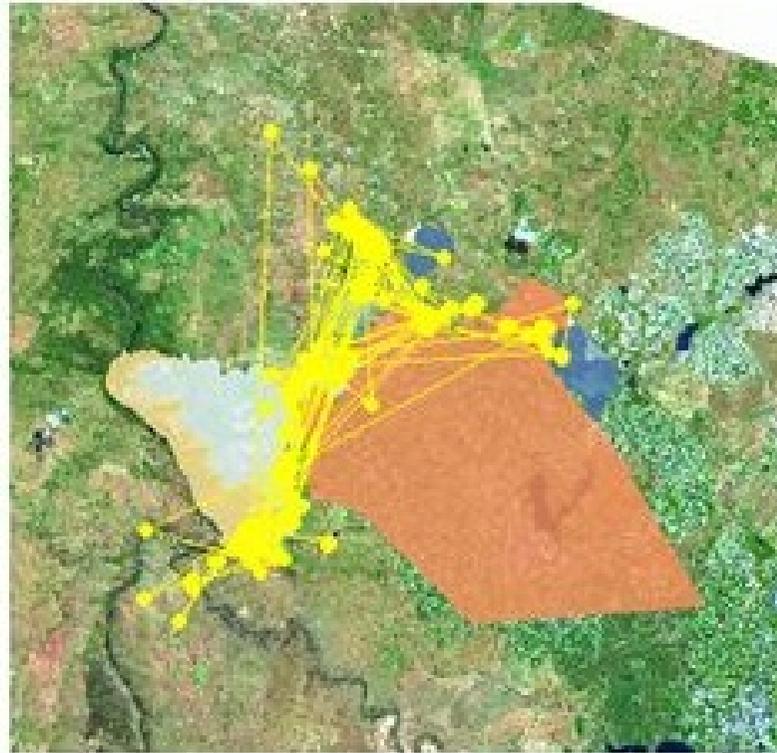


**Figure 19.** Total flying and roosting GPS fixes for the male Little Eagle.

flying



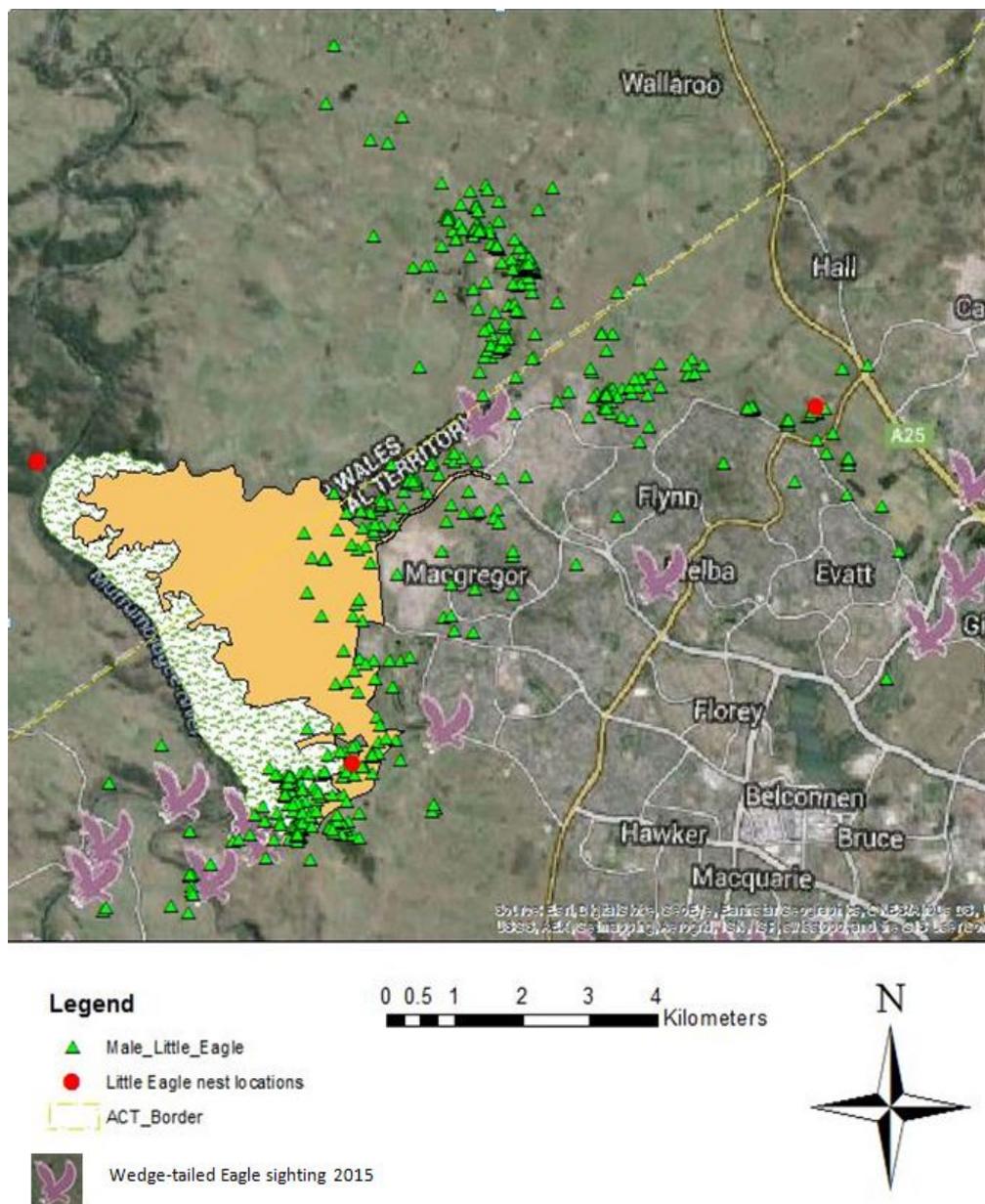
roosting



**Figure 20.** Total flying and roosting fixes showing movement pathways between locations and land use zones for the male Little Eagle.

## Home range use and Wedge-tailed Eagle sightings

As we did not conduct any Wedge-tailed Eagle monitoring using GPS, we used recorded sightings from the region during 2015 to compare with the male Little Eagle data. We used Wedge-tailed Eagle data taken from Canberra Nature Map (<http://canberranaturemap.org>) as supplied by Canberra Ornithologists Group (COG). Although this data does not provide a comprehensive account of local Wedge-tailed Eagle activity, when overlaid with the GPS fixes taken from the Little Eagle there does appear to be some avoidance by the male Little Eagle of the areas where Wedge-tailed Eagles had been sighted (Figure 21). In particular, for the most part, the Little Eagle stayed east of the Murrumbidgee River, to the north of Parkwood Dr and avoided crossing from the CSIRO lands towards Giralang and Gungahlin where Wedge-tailed Eagles had been sighted.



**Figure 21.** Location of male Little Eagle fixes in relation to Wedge-tailed Eagle sightings 2015.

## Project Outcomes and Recommendations

The home range of the male Little Eagle from the Lower Molonglo pair was monitored from late October 2015 through to the end of January 2016. The home range during this period extended from south of Strathnairn, to the east of the Murrumbidgee River, across to Wallaroo in the north and the CSIRO lands in the east and encompassed two known nesting sites (Strathnairn and CSIRO lands).

The male Little Eagle showed higher use of open woodland habitat, followed by grassland, but often flew over urban areas to access foraging grounds that were separated by up to 20km. In terms of availability compared to use, the CSIRO lands and a section of the proposed offset areas were favoured. The results indicate a preferred use of the corridor of open woodland/rural habitat that extended from the proposed development area along the ACT/NSW border into both Gooromon Ponds and CSIRO lands. These areas provided large trees for roosting and shelter as well as foraging habitat.

Most of the male Little Eagles home range was in rural or reserve lands; however the conservation zone and the eastern section of the development area were used for both roosting and flying in the spring and early summer. These areas may form part of the home range for foraging during the breeding season, perhaps particularly when the Strathnairn nest is used and successful. The male Little Eagle shifted its activity northwards to the Gooromon Ponds region as the summer progressed. The movement northward may reflect a shift from the chosen breeding area to the summer home range; Little Eagles have been shown to have seasonal movement patterns in other parts of Australia (Baker-Gabb and Fitzherbet 1999).

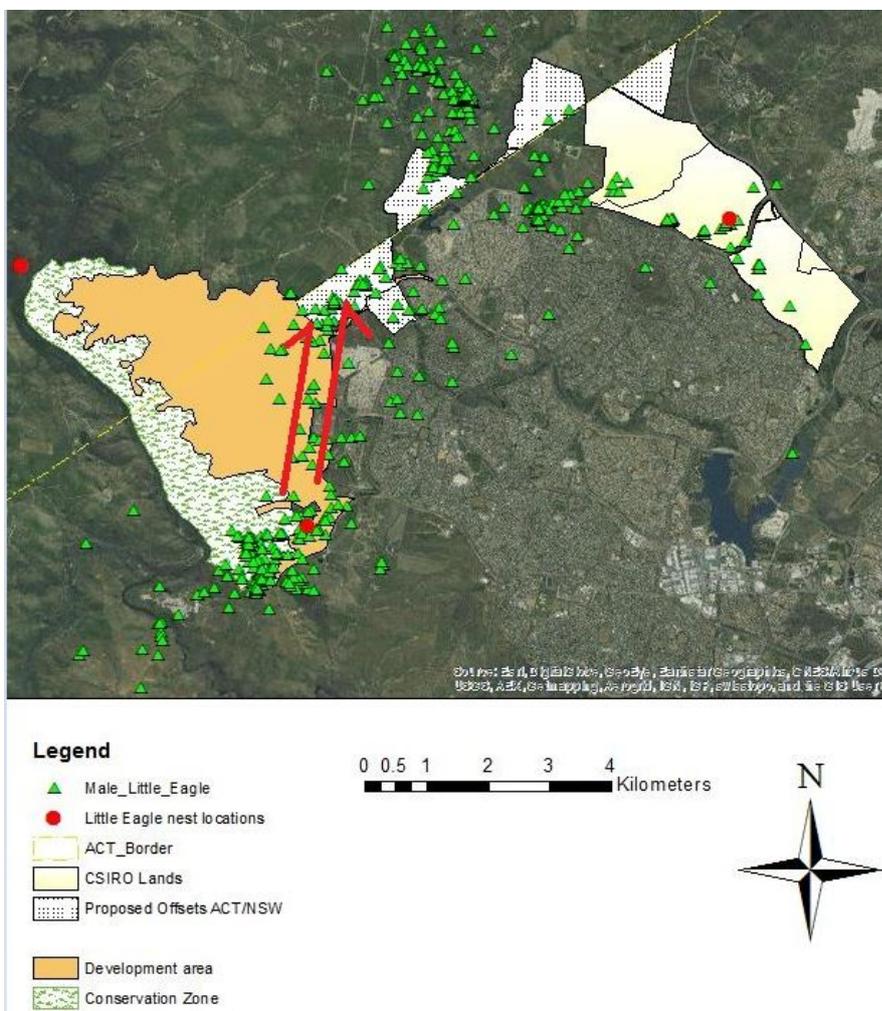
While limited to only three months, the data collected from this study revealed that the male Little Eagle is wide ranging, with the spring/summer home range area estimated to be greater than 65km<sup>2</sup> (95<sup>th</sup> percentile KDE). The results indicate that the male Little Eagle was not totally reliant on either the conservation zone or proposed development areas for its foraging or roosting resources. Similarly, diet analyses of Little Eagles in the ACT (Olsen et al. 2013b) suggest that Little Eagle is not a specialist forager, rather it is able to forage across open woodland and grassland areas to feed on rabbits, reptiles and common bird species. The ability to range widely across a large area and generalist diet requirements suggests that there is no particular restriction to certain foraging sites essential to the survival of adult Little Eagles in the area.

However, as the male Little Eagle shifted from south to north over time, use of the development area during the shift (particularly between weeks 48-50) increased quite intensively. Though the overall use of the developmental area was quite low for the duration of the study, it was considerable during some weeks (~40% of total use in week 48). This may indicate the importance of the development of the area in providing roosting sites during the shift to the northern sections of the home range.

While the male Little Eagle ranged widely, flying over and occasionally roost in urban areas, and indeed spent a significant amount of time in Dunlop Reserve on the urban fringe, this behaviour may not necessarily reflect a willingness to breed near urban development. In a separate recent study, a VHF transmitter placed on one of the Strathnairn fledglings showed a similar pattern of movement to the adult male Little Eagle, moving northwards from the nest, and in the early period as the

juvenile dispersed, the use of the development area was significant (J. Olsen, S. Trost and B. Gruber, unpublished data). Taking into account the need of the fledglings to have open woodland for dispersal and for learning to forage close to the nest, the development area, particularly the eastern fringe, lies within a key movement corridor for this Little Eagle pair and likely their young.

One possible mitigation action to assist in maintaining the Strathnairn nest as suitable breeding habitat may be retaining a corridor of open woodland habitat to in the eastern section of the development, allowing passage of adults and younger birds to northern roosting and foraging areas across the NSW border (Figure 22). The offset areas proposed along the ACT/NSW border, even though targeted for the conservation of other species, may also benefit this pair of Little Eagles. Offset areas may be used to provide a link of open woodland habitat between the ACT, key use areas such as Dunlop Reserve and NSW foraging areas, highlighting the importance of cross-border management of the species. Little Eagles are known to roost for much of the day (Olsen 2014) it crucial that an adequate amount of open woodland habitats, with mature trees for roosting close to foraging areas, are maintained between seasonal parts of the home range.



**Figure 22.** Map of possible movement corridor for the male Little Eagle (indicated by red lines) from Strathnairn to roosting and foraging areas in the northeast and across the NSW border. The retainment of large roosting trees in these areas may be beneficial to enable passage between the northern and southern areas of the home range.

The maintaining of the Strathnairn nest as a successful breeding site for the Lower Molonglo Little Eagle pair, given development plans for West Belconnen, is arguably questionable even with the addition of buffer zones around the nesting site. Little Eagles are known to use alternate nests (Olsen 2014) and if development of the West Belconnen area continues as proposed, it may be that the Strathnairn nest is abandoned in favour of other nesting sites that remain still within open woodland areas. . Furthermore, if future urban development extended to encompass the CSIRO lands, this will likely force the Little Eagles to more reliance on the NSW portion of their home range.

Alternatively, if the Strathnairn nest is still used post development, foraging activities and movement may focus more towards the south and the conservation zone. One possible issue with the use of the southern region may be competition for territories with other raptors such as Wedge-tailed Eagles. We did note that the area surrounding the known Little Eagle nest along the Murrumbidgee River corridor was not used during this study. The presence of these larger raptors regularly along the Murrumbidgee River corridor may reduce or prevent the Little Eagles from accessing this area, and may be one reason why the northward corridor is preferred for movement and foraging.

It is important to note the limitations of the data presented in this study. First, due to nest failure, this study was not able to show breeding home range or movement activities by the Molonglo Little Eagle pair, nor did it shed light on activity patterns of the female Little Eagle or dispersing young. If the nest was successful, different movement patterns may have been observed. Second, due to equipment failure only two seasons (spring and summer) were included in the data, and monitoring over autumn and winter may reveal different movement patterns. Third, while all effort was made to select times of day for GPS fixes that made biological sense, the data is limited to these selected time periods only. Finally, the data presented on Wedge-tailed Eagle presence is limited to opportunistic observational sightings therefore only limited assumptions can be made about possible interactions between the two species. In addition, sightings of Wedge-tailed Eagles may be biased as they may have a higher likelihood of being reported in or close to urban areas.

Never-the-less, the use of GPS technology enabled a large amount of movement data to be collected over a short period of time. This study represents the first GPS tagging of a Little Eagle, and one of the few GPS studies of raptors in Australia. The information from this study is vital to help increase our understanding of the species in temperate woodlands of south-eastern Australia in general, and may provide assistance with the review of not only urban developments, but current land management strategies, such as distance restrictions for the use of pindone for rabbit baiting on rural lands. Given that results from this study have shown the average daily distance travelled by the male Little Eagle was around 10km, the current 5km distance restrictions on pindone baiting from active nests is likely to be inadequate.

Ideally the information gained from this study on the movements and activity of the male Little Eagle should be combined with data on juvenile survival and dispersal, and potentially another adult next breeding season for a more accurate estimation of land use during breeding. In addition to an increased sample size, future research considerations may include a possible before-and-after research design looking at the response of the Little Eagle to urban development within the home range. It is important to gain an improved knowledge of Little Eagle movements and behaviour to better mitigate the impacts of future urban development and to devise effective management strategies to maintain the viability of the species as an ACT breeding resident in the long term.

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