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A comparison of the breeding and non-breeding home range of a male Little Eagle (Hieraaetus morphnoides) near the proposed Ginninderry Development, Australian Capital Territory.

Phase 2 Report



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Cover Image: Branchling Little Eagle at Campbell Park. Photo taken by Stuart Rae

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List of Acronyms

ACT – Australian Capital Territory

AEST – Australian Eastern Standard Time

ARGOS – Advanced Research and Global Observation Satellite

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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Abstract

This report presents the outcomes of a radio-telemetry study conducted on a male Little Eagle (*Hieraaetus morphnoides*) during both an unsuccessful and successful breeding season (2015/16 and 2016/17 respectively). The male bird is part of a pair of Little Eagles ('Strathnairn pair') that are known to breed in the West Belconnen area of Canberra, ACT. The aim of this report was to investigate the difference in range of movement between breeding and non-breeding years in relation to land use, including the proposed urban development of 'Ginninderry' (previously known as 'Riverview') which is located around the nest site. This report also describes winter migratory movements of the male Little Eagle on which data were collected.

From the results of this study, the Little Eagle appears to be a wide ranging species, ranging over an estimated area of 40 -70km² during the spring/summer breeding season. The range of movement was similar during a successful and non-successful breeding year, but activity became more concentrated around the nest when a chick was present. Use of particular areas within the range of movement varied both within and between seasons, but while urban areas were largely flown over, both flying and stationary activity was widespread across open woodland in rural, rural residential and conservation lands.

Throughout both years of the study the range of movement encompassed a southern area around the nest tree down to the Molonglo Valley near the confluence with the Murrumbidgee River and a northern area around the NSW border and across into the rural residential area of Wallaroo, NSW. The relative importance of these areas appeared seasonal; during late winter/early spring the male Little Eagle used the southern area more, including an area proposed for conservation. Activity shifted to greater use of the Upper Murrumbidgee and lands across into NSW during mid to late summer. There appeared to be a movement route between the southern and northern parts along the eastern side of the proposed Ginninderry development area; included areas of proposed and existing offsets as well as reserve lands. While the number of fixes increased greatly around the nest tree in the successful breeding year, the use core areas remained similar between breeding and non-breeding years.

In the autumn the male Little Eagle flew from Canberra to the Northern Territory, a flying distance in excess of 2800km. From the data it appeared that the male Little Eagle settled into an area of approximately 30km² in the region of Daly Waters as its winter range of movement. This is the first GPS data on winter migratory movements for the species.

Introduction

The Little Eagle (*Hieraaetus morphnoides*) is a medium-sized raptor endemic to Australia. Habitat for the species in the ACT is thought to be hillsides with open wooded and grassland, including riparian woodlands (Marchant and Higgins 1993). The diet of the Little Eagle is composed of medium sized mammals (especially small or juvenile rabbits), birds (particularly parrots and passerines <500gm) and reptiles.

The Little Eagle breeds in eastern Australia during the late winter/early spring (Marchant and Higgins 1993). Females lay 1-2 eggs which are incubated for around 37 days; young are fledged after approximately eight weeks, usually around mid-late December (Debus and Ley 2009; Olsen 2014). Both parents share brooding and feeding, but the female is responsible for the majority of the nestling care (Debus and Ley 2009). A pair may have a number of nest sites across a territory (Marchant and Higgins 1993).

In the ACT, the Little Eagle has been declared vulnerable under the *Nature Conservation Act 1980*. The lower Molonglo River valley is a known breeding area for the species in the ACT; however, part of the area has been identified for future housing development in order to accommodate the ACT's growing population. A recent GPS telemetry study on the male Little Eagle of a pair known to breed within the Lower Molonglo area provided insights into non-breeding range of movement and habitat use in this area (Brawata and Gruber 2016).

As is found in other regions of Australia, it is thought that Little Eagles residing in the ACT may move seasonally between breeding range and separate winter territories (Baker-Gabb and Fitzherbet 1999). Prior to this study, the lack of accurate radio-tracking data for the Little Eagle meant that little was known about the species' seasonal habitat use and range of movement size. This large gap in basic ecological knowledge has restricted the ability to predict the impact of changes in land use or management activities in areas surrounding known Little Eagle territories and nesting sites. The present study begins to address this knowledge gap through monitoring both breeding and winter migratory movements of a male Little Eagle nesting in the Molonglo River valley of the ACT.

Study Area and Aims

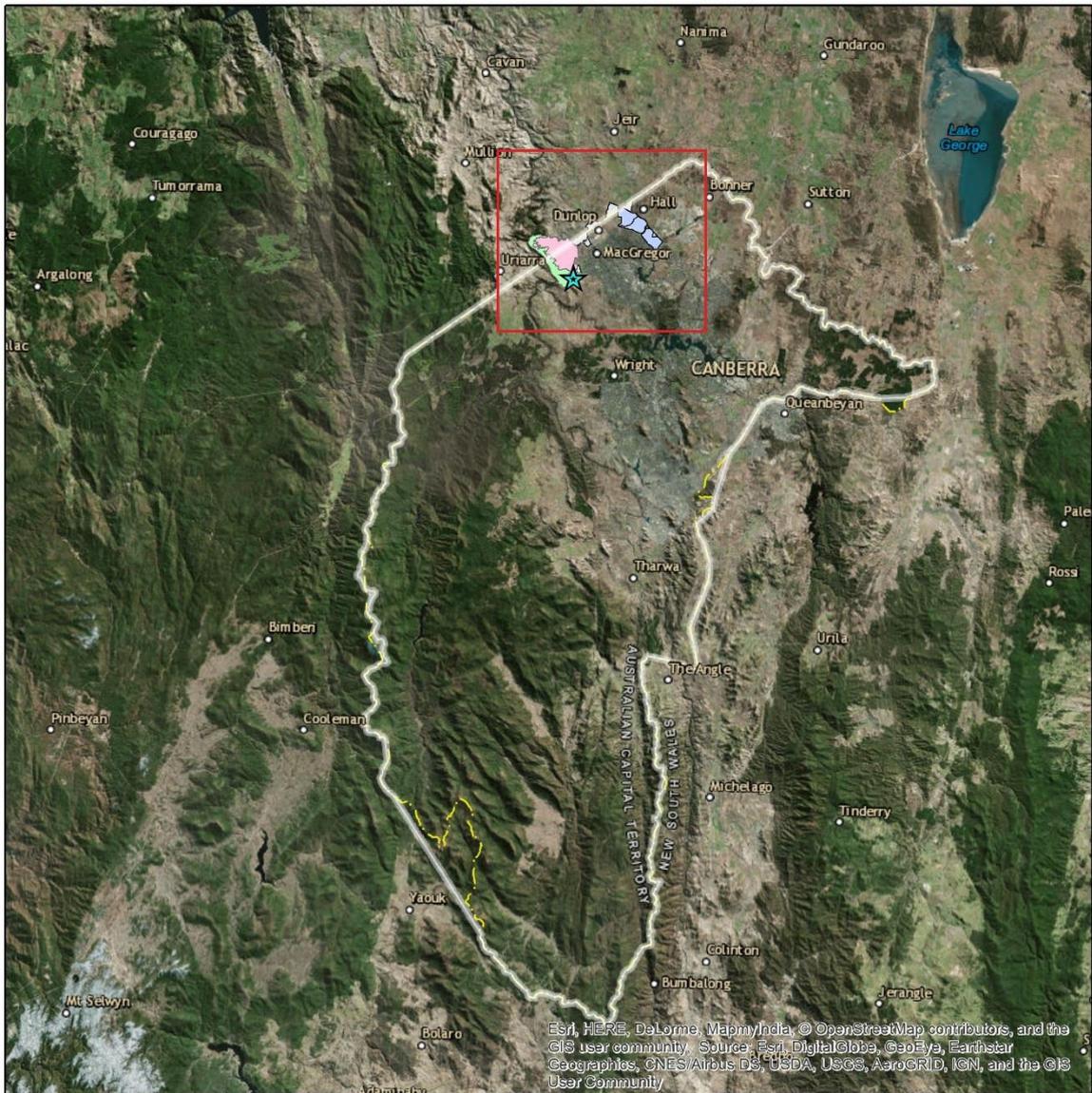
This report represents the second phase of a radio-telemetry study on the male bird of the Lower Molonglo Little Eagle pair (referred to hereafter as the ‘Strathnairn pair’). The Strathnairn pair of Little Eagles has historically bred at ‘Strathnairn’, a rural property located in the West Belconnen area of Canberra, ACT. The property forms part of the Ginninderry development, a new urban development that lies to the southwest of the established suburb of Holt, ACT (Figure 1).

The nest of the Strathnairn Little Eagle pair lies within close proximity (<1km) to the site of a proposed development called ‘Ginninderry’. The Ginninderry development proposal includes both an urban development parcel of land, a deferred development block (pending research outcomes on how significant this area may be for the Little Eagle), a buffer zone of 200m around the nest of the Little Eagle pair and a conservation zone to the west along the Murrumbidgee River corridor. There are areas of land to the northeast of the development (both in ACT and across the border into NSW) that are current or have been identified as possible offset areas for future urban development as well as lands currently owned and managed by CSIRO that are proposed for future development (Figure 3).

This study forms part of a larger research project on Little Eagle ecology and breeding in the ACT. This second phase of this study collected movement data on the Little Eagle from August 2016 to May 2017. This period included a successful breeding event and the long-distance movement of the Little Eagle to northern Australia during the winter months. Phase 1 of this project was conducted on the same Little Eagle during an unsuccessful breeding event during October 2015 – January 2016 (Brawata and Gruber 2016). The aim of this report is to compare the movements of the Little Eagle over spring/summer during an unsuccessful breeding event (2015/16) and a successful breeding event (2016/17). This comparison will help inform the overarching aim of the study, which is to investigate the potential impact of the Ginninderry development on the range of the Little Eagle during successful and unsuccessful breeding events. In addition, little is known about the winter movements of the species in the ACT region.

Through monitoring the movements of the male Strathnairn Little Eagle, phase two of this research aims to:

- Map the seasonal breeding range of movement of the male Strathnairn Little Eagle and compare this to the non-breeding range of movement (Brawata and Gruber 2016) over the same time period;
- Calculate the proportion of GPS fixes in each land use sector, including the West Belconnen development area, deferred development, conservation zone, proposed offsets, CSIRO lands, rural and urban areas during a successful breeding event and compare this to the non-breeding range of movement;
- Identify areas where flying and stationary activity (roosting) were conducted;
- Describe and map winter movements at the end of the breeding season;
- Where possible 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;
- 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

-  Straithnairn_nest_location
-  Deferred development
-  Development area
-  Conservation zone
-  2017_golf_course_development
-  ACT_Border
-  CSIRO Lands
-  Proposed Offsets ACT/NSW

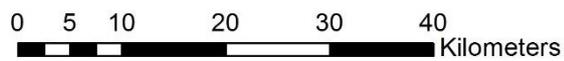


Figure 1: Map showing the location of the study (highlighted in red) in the West Belconnen area of Canberra, ACT.

Methods

The GPS transmitter used to monitor the movements of the male Little Eagle was a PTT-100 22gm Solar ARGOS/GPS PTT. The unit was programmed to take 8 fixes per day; the timing of the fixes were changed seasonally with four pre-programmed duty cycles. In general, the fixes were taken 2-3 hours apart from 5am through to 8pm, with an additional midnight fix collected for roosting location information. The units were programmed with a ground-tracking capability between the hours of 4 – 8 pm every day. More detail on the transmitter used in this study can be found on the Microwave Telemetry website: http://www.microwavetelemetry.com/bird/solarArgosGPS_22g.cfm or see Brawata and Gruber (2016) for a more detailed review of the study methods.

Trapping for Little Eagles was carried out in the Strathnairn area during October 2015. A backpack harness used to attach the transmitter to the bird enabled the correct placement of the GPS unit on the bird's upper back (Figure 2). The correct fit of the harness and GPS unit was vital to ensure that it did not interfere with the birds' normal daily activities. Correct fit was also important for solar charging, operation of the unit and for the welfare of the bird. The bird was monitored from the ground whenever possible throughout the duration of the study to ensure that the transmitter remained in place.

The 3D GPS unit collected data on the bird's location, speed and altitude, and also recorded the time at which fixes were taken. Locational data were used to provide information on areas used for hunting and roosting, while speed and altitude data gave information as to when the bird was travelling 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 so that location, speed and altitude data could be saved in a Microsoft Excel file format and viewed as 3D locations in Google Earth™.



Figure 2. Strathnairn male Little Eagle in flight showing Microwave Telemetry PTT-100 22gm Solar ARGOS/GPS PTT transmitter attached by a harness/backpack. Photo courtesy to John Bundock.

For the purpose of this study, land use within the study area was classified into seven major land use types, hereafter referred to as sectors. The seven sectors were the 'Development area' (the area currently proposed for urban development by the Ginninderry Joint Venture), 'Deferred development' (an area currently deferred from urban development) the 'Conservation zone' (the area to the west of the development area along the Molonglo corridor, proposed as a conservation area for the development), 'CSIRO lands' (in which a Little Eagle nest is located; proposed for future development), 'Proposed offsets*' (land identified either side of the ACT/NSW border which includes existing and possible offsets* for development), 'Urban areas' (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). A neighbouring golf course urban development site is also shown (Figure 3).

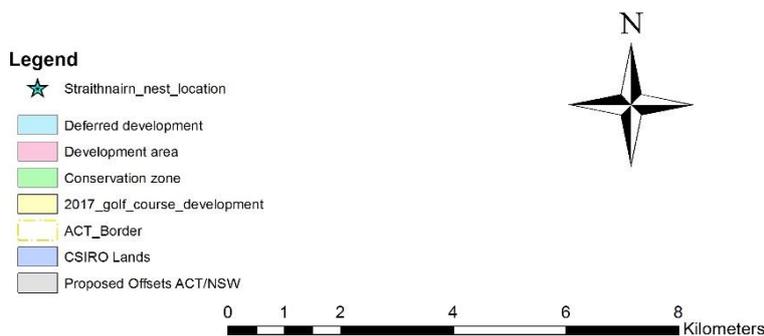
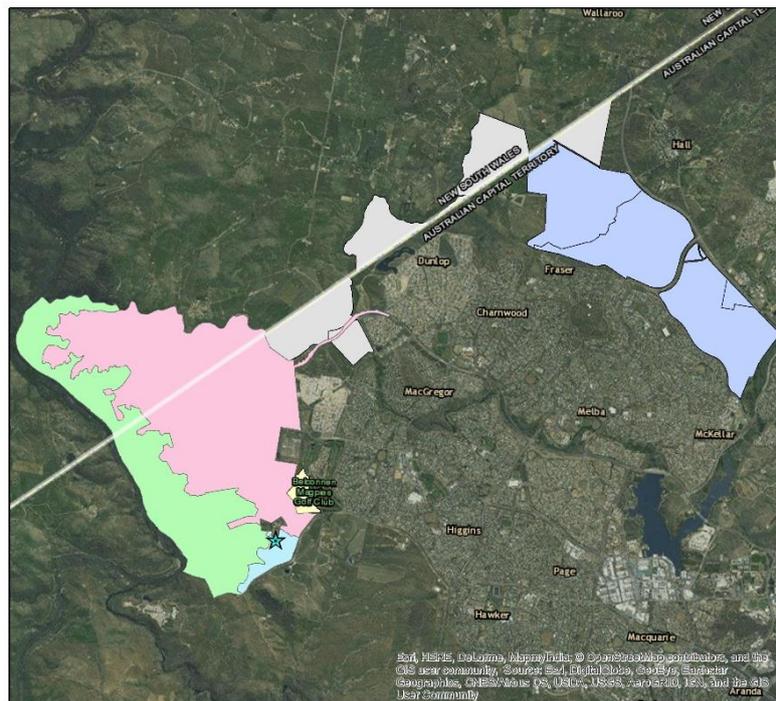


Figure 3: Map of study area, showing land use sectors for the categories of Development area, Deferred development, Conservation zone, Proposed offsets* and CSIRO lands. The Strathnairn Little Eagle nest location is also shown. Urban areas were defined by the suburban boundary (indicated in this map by housing density) while the rest of the area was categorised into Rural and reserve areas.

* At the time of publication of this report, the three most southern offset parcels known as West Macgragor, Jarramalee and Wallaroo Road, were confirmed as conservation reserves (environmental offset areas).

Data Analysis

General information and context.

To enable interpretation of the analysis and results contained within this document, a timeline of events is shown in Figure 4.

The male Little Eagle was captured at Strathnairn and the GPS transmitter attached at the end of October 2015. The bird was released and GPS fixes were obtained until the end of January 2016 at which time the transmitter stopped working. This first period of data collection on the movements of the male Little Eagle is termed 'Phase 1' of the study (Figure 4); details were reported in Brawata and Gruber (2016).

After 6 months of no data, the transmitter on the male Little Eagle began transmitting again in August 2016. The first transmissions located the bird in Wagga Wagga, NSW, approximately 250 km west of Strathnairn. Over the next day the transmissions showed the bird moving east along the Murrumbidgee River towards the ACT, where it subsequently settled in the general vicinity of the Strathnairn nest tree location (Figure 5).

From 20th August – 7th March 2017 the male Little Eagle remained in its range of movement in the vicinity of the Strathnairn nest. The Strathnairn Little Eagles had a successful breeding event in spring of 2016 (possibly in late September, around week 39), hatching a chick late in the season, estimated to have occurred in early November (around week 44). The chick was raised by the pair and fledged in early January 2017 (Week 1). Movement data on the male Little Eagle was collected during this period, and is referred to throughout this document as 'all data year 2' (Figure 4).

The period of overlap between the two years of study (the non-breeding event in 2015 and the breeding event in 2016) was between 25th October and 31st January. Direct comparisons are made for the breeding and non-breeding years for these dates only. As such, the period of 25th October 2016 through to the 31st January 2017 is termed 'Phase 2' of the study (Figure 4). Table 1 shows the number of GPS fixes captured per week over the comparison period for Phase 1 and 2 of the study.

The male Little Eagle remained in the vicinity of the nest until 8th March 2017, when it suddenly left the ACT and journeyed to the Northern Territory for the winter. This epic journey to a winter range of movement, although suspected previously using sightings of banded individuals, has never before been recorded through accurate data on GPS movements for the species. The transmitter continued to function until it finally ceased transmission on the 24th May 2017 while the male Little Eagle still remained near Daly Waters, NT. The final section of this document provides details of this winter migration.

Phase 1 of the study collected a total of 918 usable location fixes during this period, while 1021 were collected in Phase 2 (Table 1). The average distance travelled per day in Phase 1 was 9.87km, with the maximum distance travelled 27.97km and the minimum distance travelled only 130m. In Phase 2 the average distance travelled per day was 14.12km, with the maximum distance travelled 39.05km and the minimum distance travelled 1km. The average speed measured when flying for both Phase 1 and Phase 2 was 17km/hr, with a minimum speed of 1km/hr and a maximum recorded speed of 47km/hr in Phase 1 and 55km/hr in Phase 2.

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

Week Number	No. of fixes Phase 1	No. of fixes Phase 2
44	29	69
45	68	69
46	70	70
47	66	70
48	70	57
49	69	66
50	70	69
51	70	64
52	70	69
1	69	70
2	67	70
3	70	69
4	70	69
5	60	70

For the purpose of analysis of 'all data for year 2', the first 6 data points were removed from the analysis as these occurred during the return journey of the male Little Eagle from Wagga Wagga to Canberra. At 20th August 2016, 13:00 the male Little Eagle was about 44 km away from Canberra (to the NW, Speed 40, Course East) and on the same day at 14:00 he arrived at his range of movement in west Belconnen, Canberra where he basically rested until the next day (Table 2).

Table 2. The first 10 data points received when transmission recommenced in August 2016.

Date	Lat	Long	Speed	Course	Altitude
20/08/2016 0:00	-35.12	147.3	0	0	280
20/08/2016 8:00	-35.12	147.3	0	0	220
20/08/2016 9:00	-35.12	147.3	0	0	240
20/08/2016 10:00	-35.12	147.3	0	0	250
20/08/2016 11:00	-35.11	147.5	26	130	380
20/08/2016 13:00	-35.05	148.6	40	93	1040
20/08/2016 14:00	-35.16	149	0	0	760
20/08/2016 15:00	-35.18	149	0	0	690
20/08/2016 16:00	-35.18	149	0	0	690
20/08/2016 17:00	-35.18	149	0	0	640

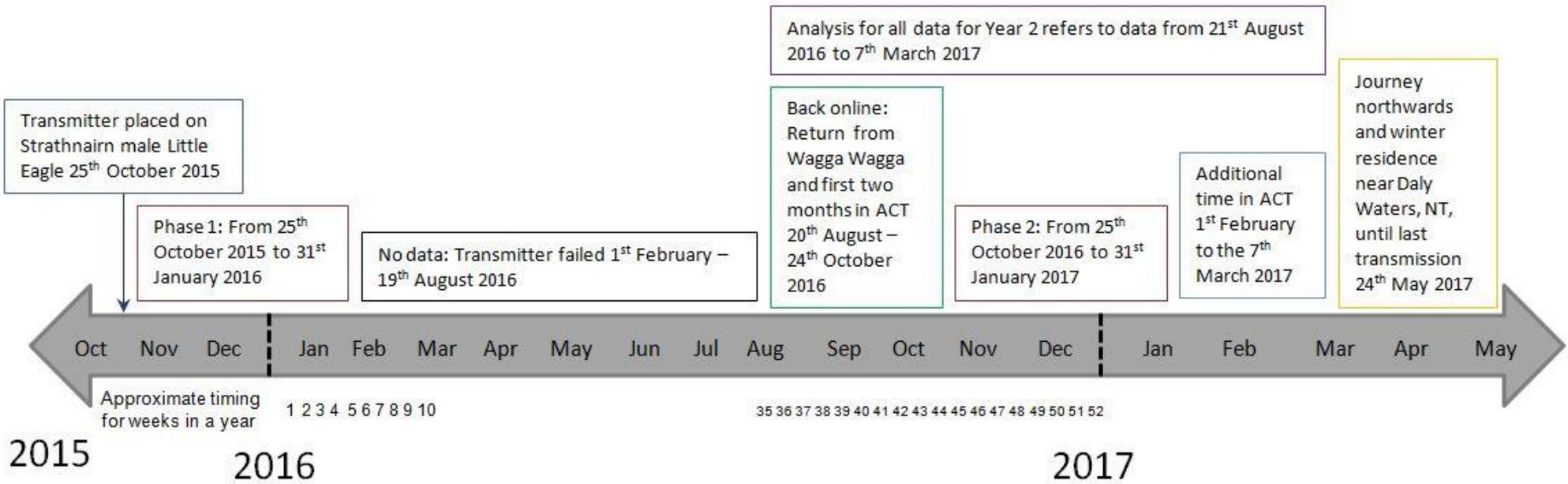


Figure 4. Timeline of events for showing the comparison periods (Phase 1, Phase 2 and all data for Year 2) for GPS tracking of the male Little Eagle.

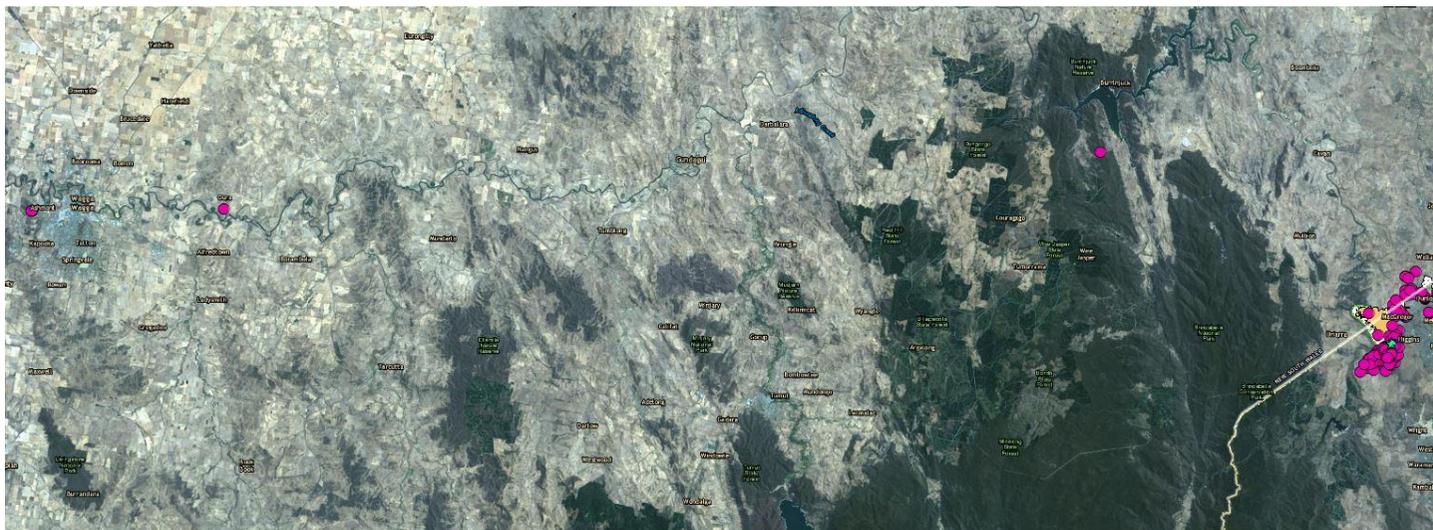


Figure 5. GPS locations showing trip back from Wagga Wagga in August 2016 – note location of fixes along the Murrumbidgee River.

A comparison of breeding and non-breeding range of movement size

In Phase 1 of the study, the range of movement of the male Little Eagle 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 (Brawata and Gruber, 2016).

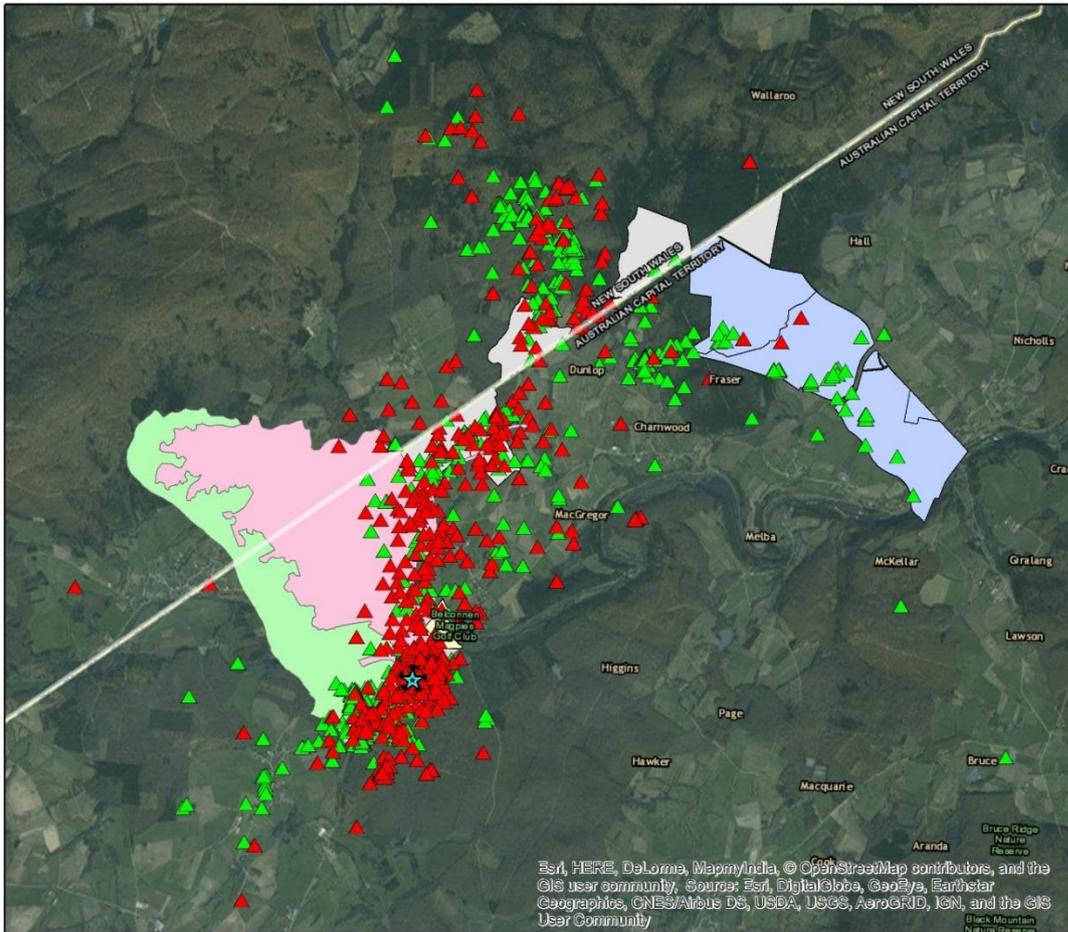
During Phase 2, the extent of the range of movement of the male Little Eagle was very similar to Phase 1. In Phase 2, fewer GPS fixes were taken in the CSIRO lands to the north-east of the nest site, but a few fixes were taken to the south-west towards Uriarra. Fixes were more condensed around the nest site during Phase 2. When fixes taken using all data from year 2 were plotted a distinct pattern of north and south use of the range of movement emerged (Figure 7). During the early part of the season, immediately after returning from Wagga Wagga and prior to Phase 2, the southern area of the range of movement was used, including the Conservation zone and the area surrounding the Molonglo River near the confluence with the Murrumbidgee River south of Strathnairn. After Phase 2 and prior to its journey north, the male Little Eagle focused activity in the mid and northern parts of its range of movement (Figure 7).

Total range of movement was estimated for Phase 1, Phase 2 and all data for year 2 using both the minimum convex polygon method (MCP) and kernel density estimates (KDE) (Figure 11). Results for these analyses are given in Table 3. Taking the generally accepted 90-95th percentile isopleth, results from these methods show the total range of movement of the male Little Eagle to be approximately 47-67km² over Phase 1 of the study, 35 - 41km² over Phase 2 of the study and 48-53 km² when all data from year 2 was accounted for (Table 3).

Core range of movement (generally accepted as the 50th percentile) was greatly reduced between a non-breeding year in Phase 1 of the study (12-21km²) and a breeding year in Phase 2 (2-4km²), even when taking into account all of year 2 data (5-11km²) (Table 3). A greater proportion of fixes located the male Little Eagle in closer proximity to the nest when a chick was present during a successful breeding year.

Table 3. Total range of movement size (km²) for different isopleth (contour) levels of MCP and KDE in Phase 1 (Ph1) and Phase 2 (Ph2) of the study, as well as for all data year 2 (Yr2).

Isopleth	Area km ² (MCP) Ph1	Area km ² (KDE) Ph1	Area km ² (MCP) Ph2	Area km ² (KDE) Ph2	Area km ² (MCP) Yr2	Area km ² (KDE) Yr2
50	21.97	12.38	2.597	3.921	10.63	5.38
55	24.16	14.85	3.247	4.775	11.05	6.622
60	28.18	19.81	4.842	5.858	12.17	8.337
65	31.68	22.28	6.135	7.338	13.91	10.82
70	35.93	27.23	11.51	9.569	17.29	14.06
75	38.21	32.18	13.7	12.46	18.1	18.02
80	43.06	37.14	14.06	16.18	19.86	22.88
85	45.48	44.56	16.73	20.97	40.79	28.91
90	47.52	51.99	35.41	27.73	48.72	37.29
95	50.96	66.84	56.01	40.69	72.56	52.72
100	108.8	151	85.83	109.1	173.9	167.3

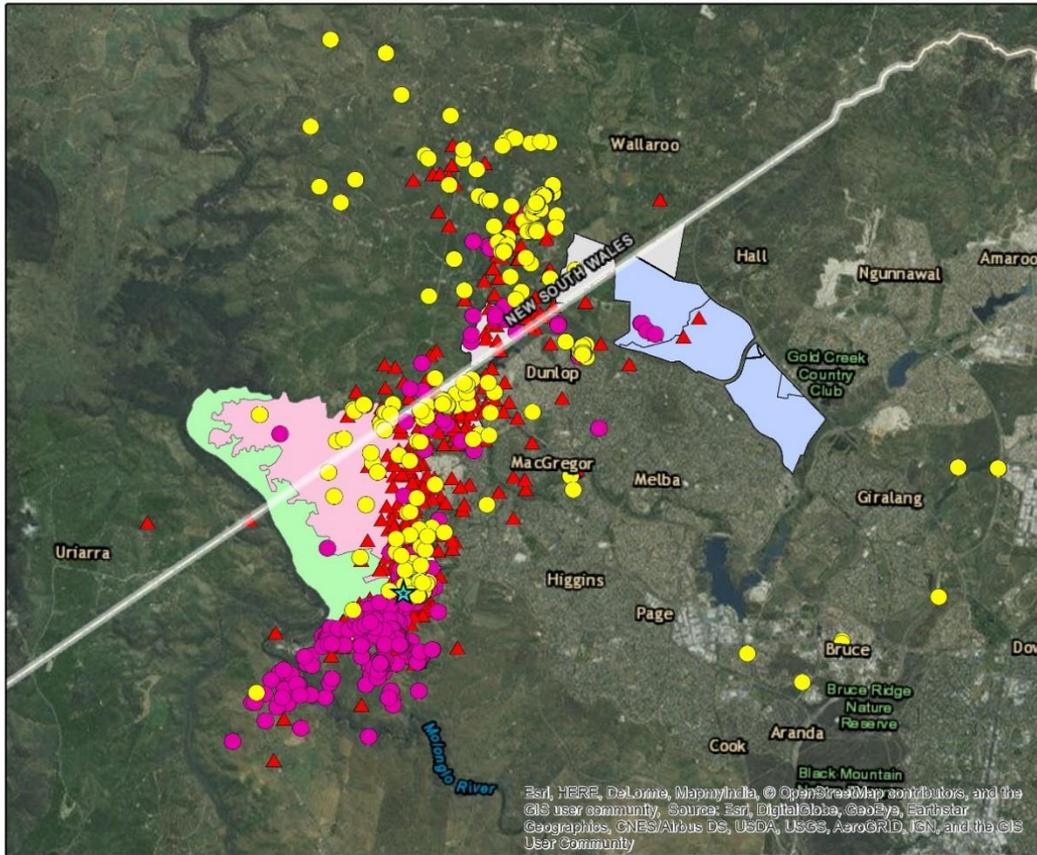


Legend

- ▲ Little Eagle Phase1
- ▲ Little Eagle Phase2
- ★ Strathnairn_nest_location
- Strathnairn_nest_location_200m_buffer
- Deferred development
- Development area
- Conservation zone
- 2017_golf_course_development
- ACT_Border
- CSIRO Lands
- Proposed Offsets ACT/NSW



Figure 6. A similar range of movement between years: map shows the location of the GPS fixes over Phase 1 of the study (October 25th 2015 -January 31st 2016) compared to the GPS fixes obtained during the same time period in the second year of the study (Phase 2: October 25th 2016 - January 31st 2017) in relation to the Strathnairn Little Eagle nest site and identified land use sectors.



Legend

- Little Eagle Wagga
- Little Eagle North
- ▲ Little Eagle Phase2
- ★ Strathnairn_nest_location
- Deferred development
- Development area
- Conservation zone
- 2017_golf_course_development
- ACT_Border
- CSIRO Lands
- Proposed Offsets ACT/NSW

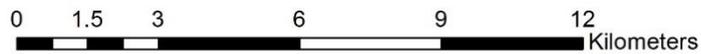
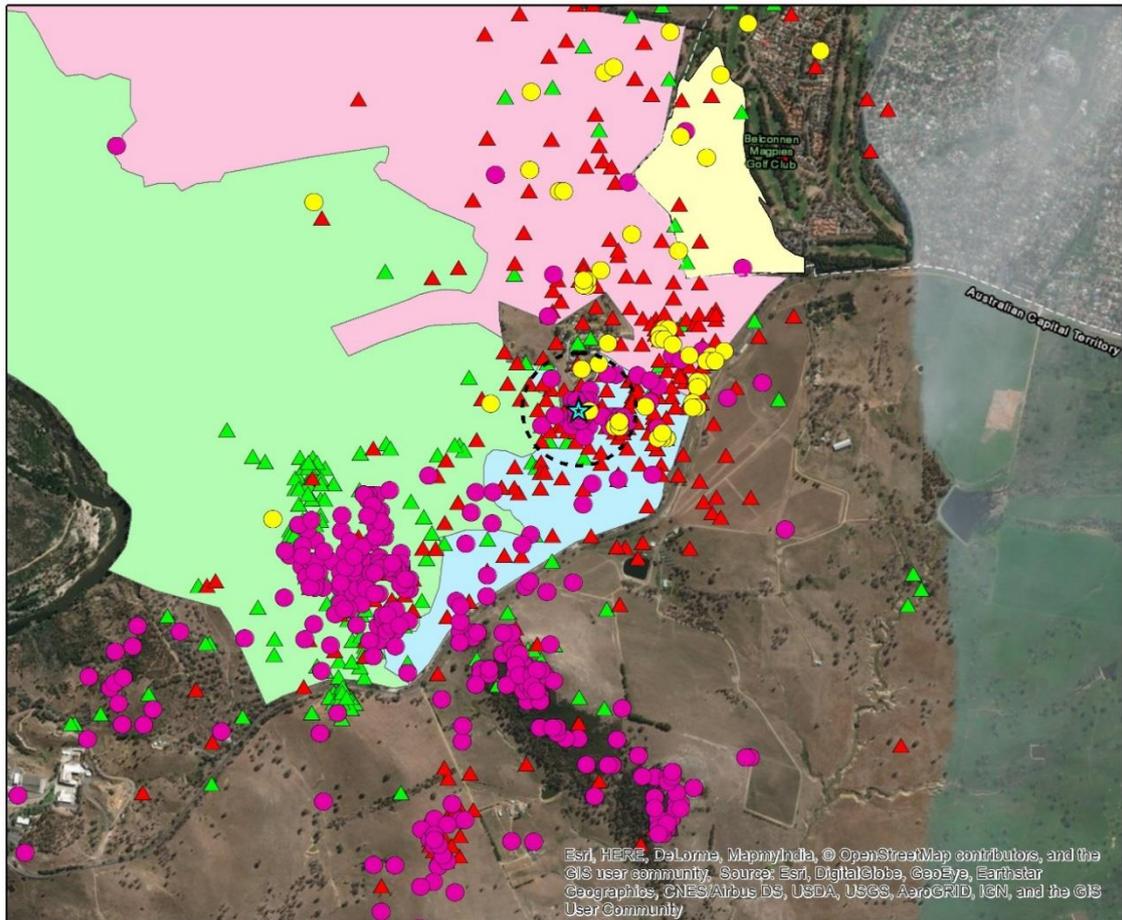


Figure 7. GPS fixes for the male Little Eagle for all data for year 2 (21st August 2016 – 7th March 2017) in relation to the Strathnairn Little Eagle nest site and identified land use sectors. Pink dots indicate data prior to Phase 2 when the male Little Eagle first returned to the ACT from the direction of Wagga, NSW, while yellow dots indicate data collected after Phase 2, but prior to the Strathnairn male Little Eagle journeying north for the winter. These two sets of data (prior and post Phase 2) are hereafter referred to as ‘extra data for year 2’.



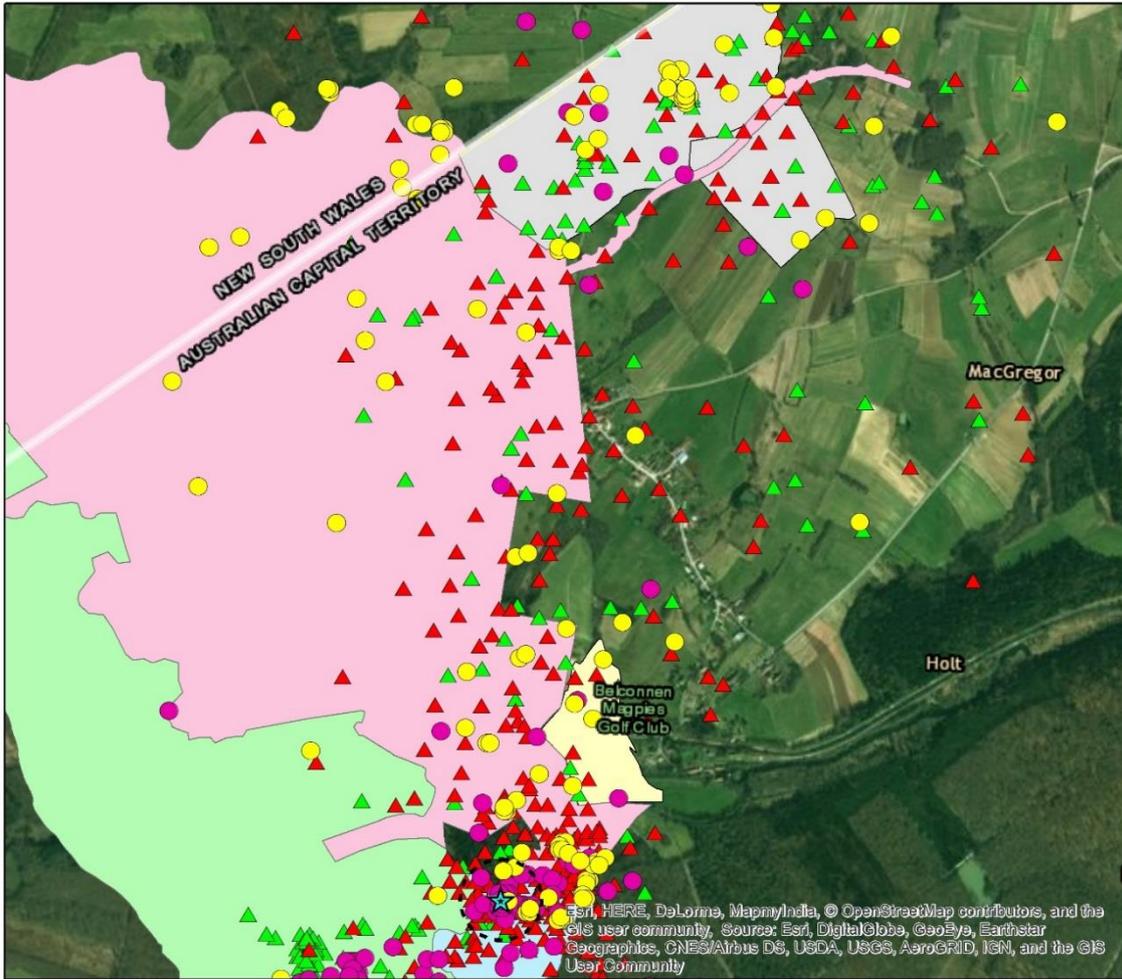
Legend

- ▲ Little Eagle Phase1
- Little Eagle Wagga
- Little Eagle North
- ▲ Little Eagle Phase2
- ★ Straithnairn_nest_location
- ⋯ Straithnairn_nest_location_200m_buffer
- Deferred development
- Development area
- Conservation zone
- 2017_golf_course_development
- ACT_Border
- CSIRO Lands
- Proposed Offsets ACT/NSW



0 0.275 0.55 1.1 1.65 2.2 Kilometers

Figure 8. Map showing the southern area of the movement range of the male Little Eagle during Phase 1, Phase 2 and for extra data for year 2 (both before (Wagga) and after (North) Phase 2).

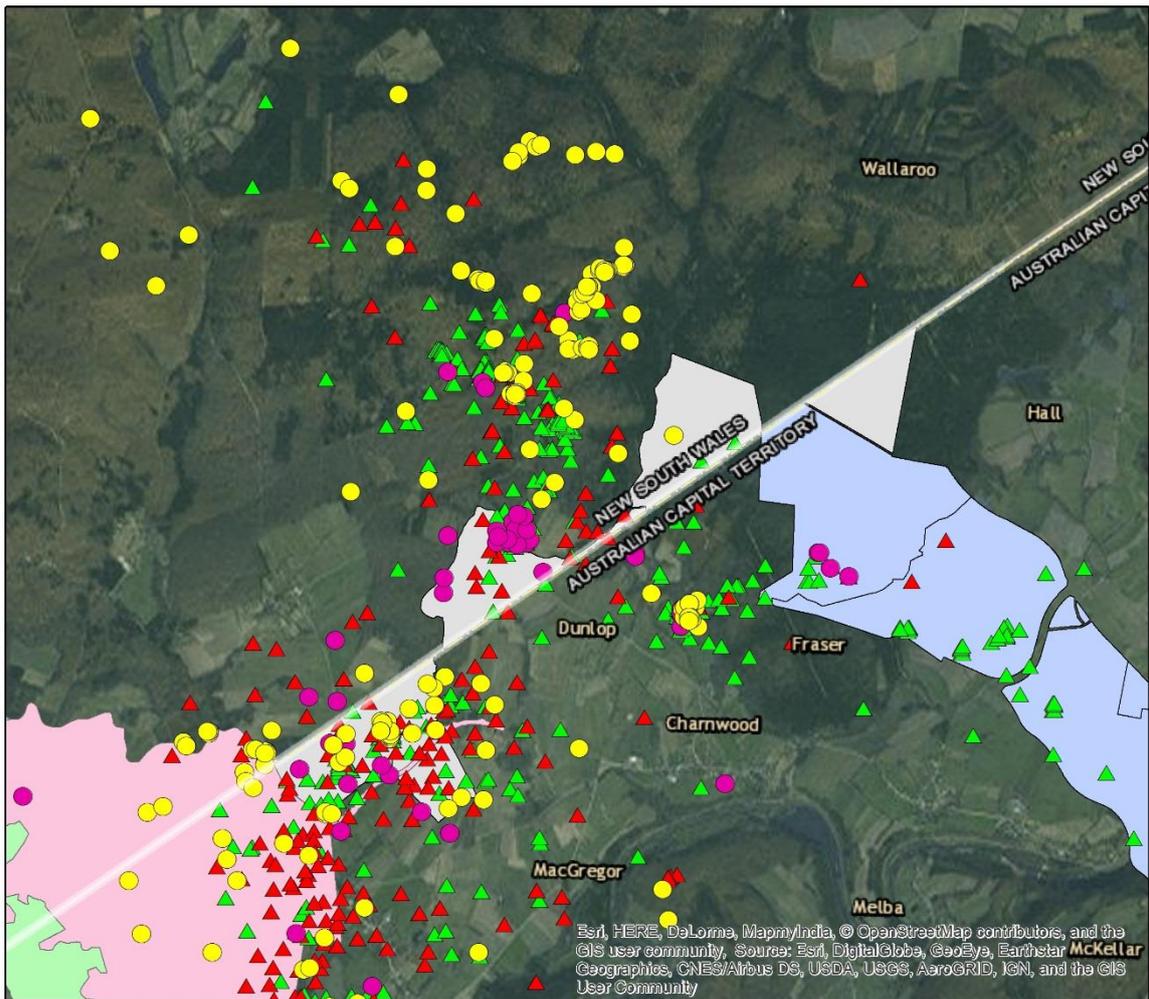


Legend

- ▲ Little Eagle Phase1
- Little Eagle Wagga
- Little Eagle North
- ▲ Little Eagle Phase2
- ★ Straithnairn_nest_location
- ⋯ Straithnairn_nest_location_200m_buffer
- Deferred development
- Development area
- Conservation zone
- 2017_golf_course_development
- ACT_Border
- CSIRO Lands
- Proposed Offsets ACT/NSW



Figure 9. Map showing use of the eastern section of the Development area used by the male Little Eagle during Phase 1, Phase 2 and for extra data for year 2 (both before (Wagga) and after (North) Phase 2).



Legend

- ▲ Little Eagle Phase1
- Little Eagle Wagga
- Little Eagle North
- ▲ Little Eagle Phase2
- ★ Straithnairn_nest_location
- ⋯ Straithnairn_nest_location_200m_buffer
- Deferred development
- Development area
- Conservation zone
- 2017_golf_course_development
- ACT_Border
- CSIRO Lands
- Proposed Offsets ACT/NSW

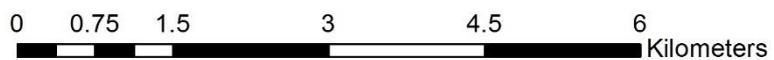


Figure 10. Map showing the northern area of the movement range of the male Little Eagle during Phase 1, Phase 2 and for extra data for year 2 (both before (Wagga) and after (North) Phase 2).

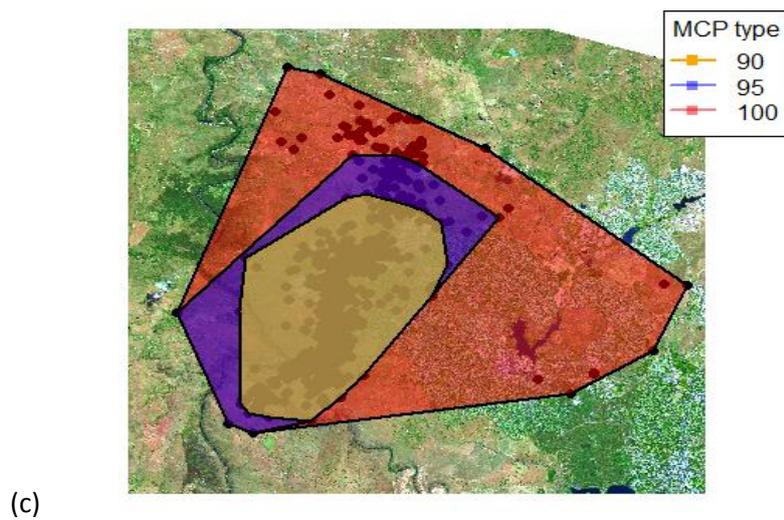
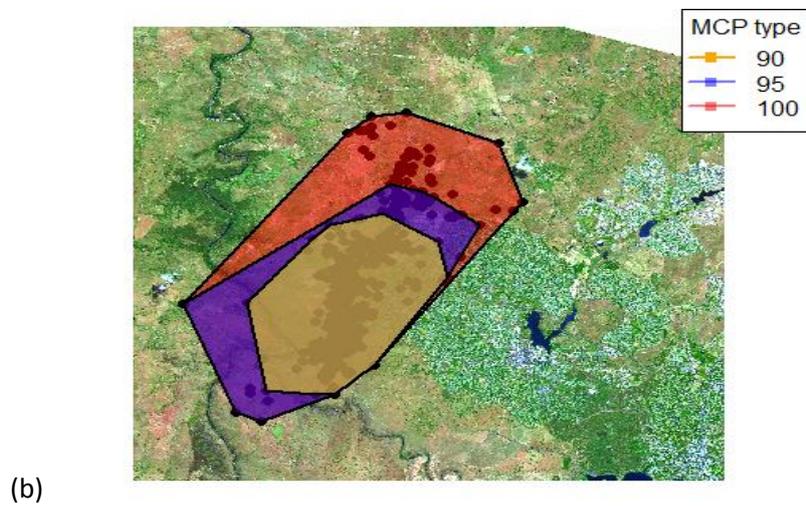
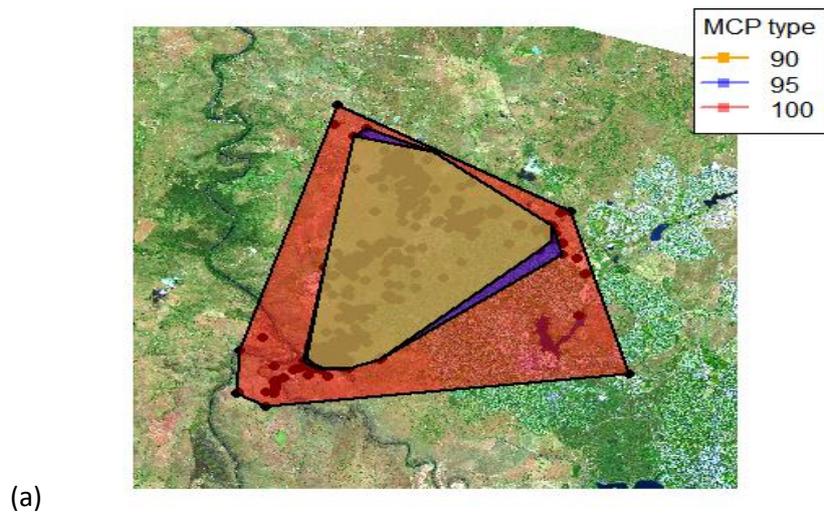


Figure 11a-c. Range of movement of the male Little Eagle captured at Strathnairn using minimum convex polygon (MCP), showing 90, 95 and 100% isopleths for Phase 1 (a) Phase 2 (b) and for all data year 2 (c).

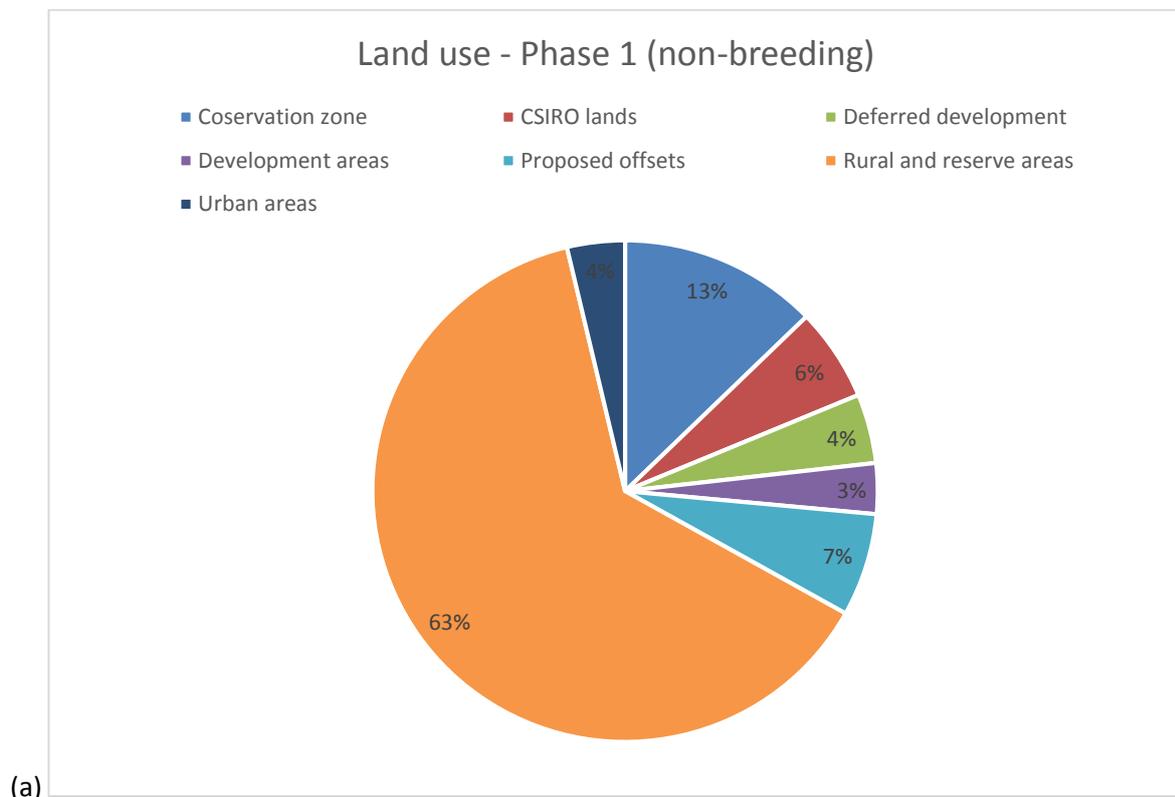
A comparison of breeding and non-breeding sector use

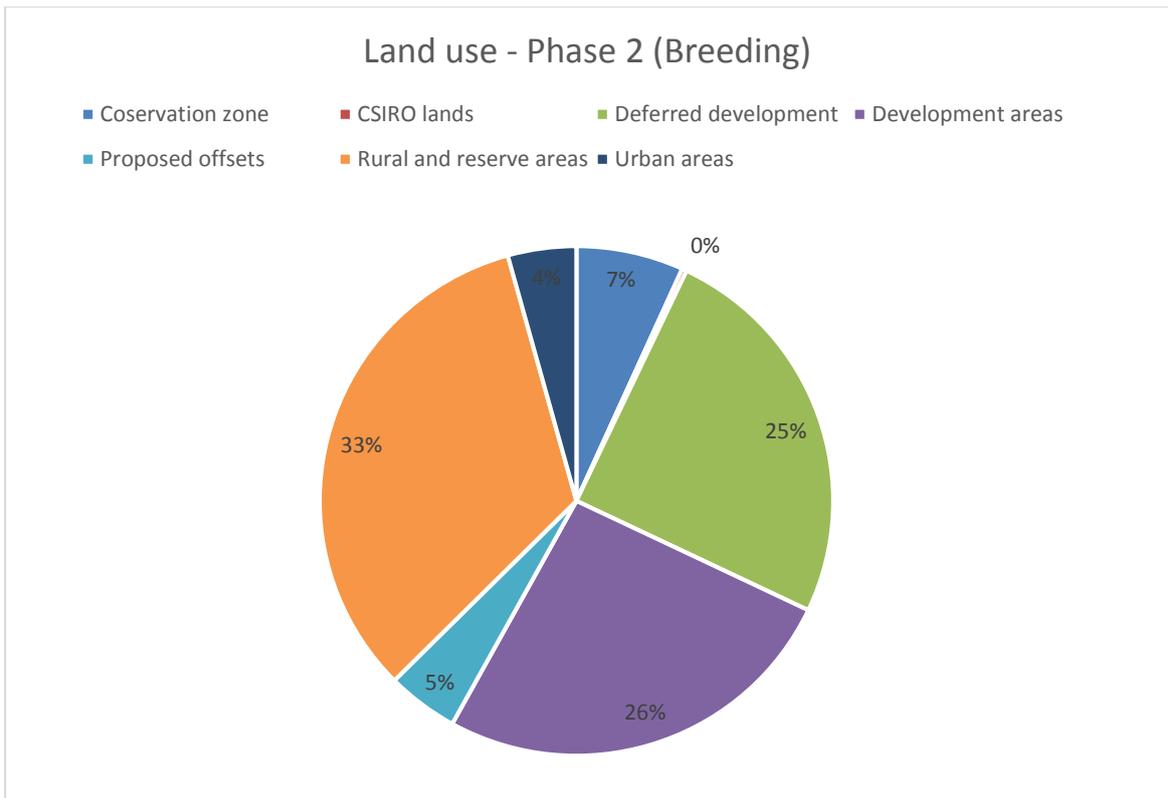
We compared the proportion of GPS fixes of the male Little Eagle that were taken in different land use sectors during Phase 1 and Phase 2 of the study, and also examined sector use using all data from year 2. Land use sectors are described on page 10 and shown in Figure 3 of this document.

During the non-breeding Phase 1 of the study most of the fixes of the male Little Eagle were taken within Rural and reserve areas (63%). The next largest sector used was the area allocated as a Conservation zone (13%), followed by Proposed offset areas (7%) and CSIRO lands (6%). Less than 5% of fixes were taken within each of the sectors of Development areas, Deferred development, and Urban areas (Figure 12a).

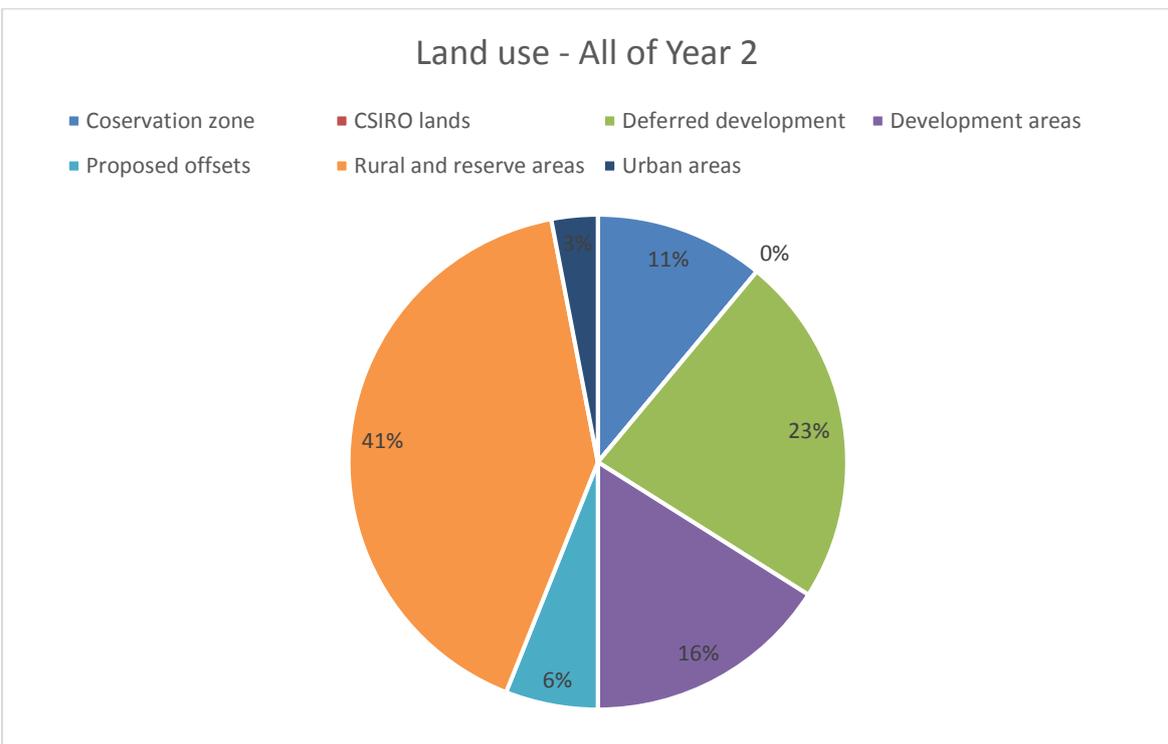
The location of GPS fixes for the male Little Eagle in relation to land use sectors during Phase 2 differed to that of Phase 1. During breeding in Phase 2, most of the fixes of the male Little Eagle were taken within Rural and reserve areas (33%), the Development area (26%) and Deferred development (25%). Only 7% of GPS fixes were taken within the Conservation zone, 5% in Proposed offset areas, 4% in Urban areas and only 3 fixes were taken in CSIRO lands (Figure 12b).

For all data for year 2, Rural and reserve areas were again used the most (41%), followed by the Deferred development (23%), Development area (16%), (Conservation zone (11%), Proposed offset areas (6%) and Urban areas (3%) with only 6 fixes were taken in CSIRO lands (Figure 12c).





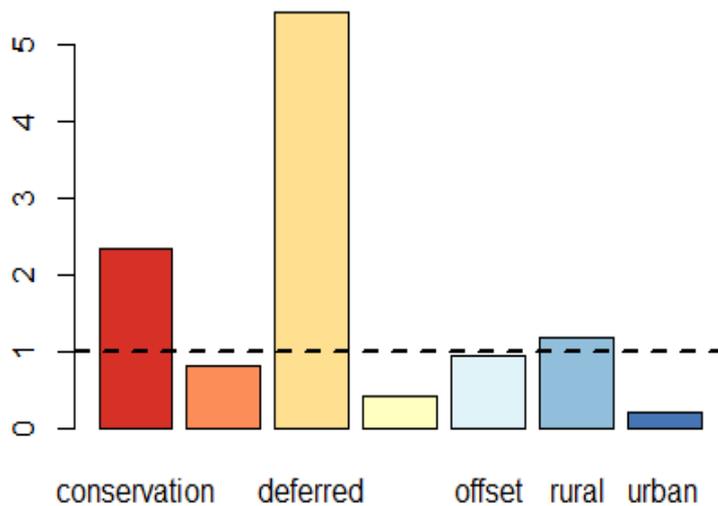
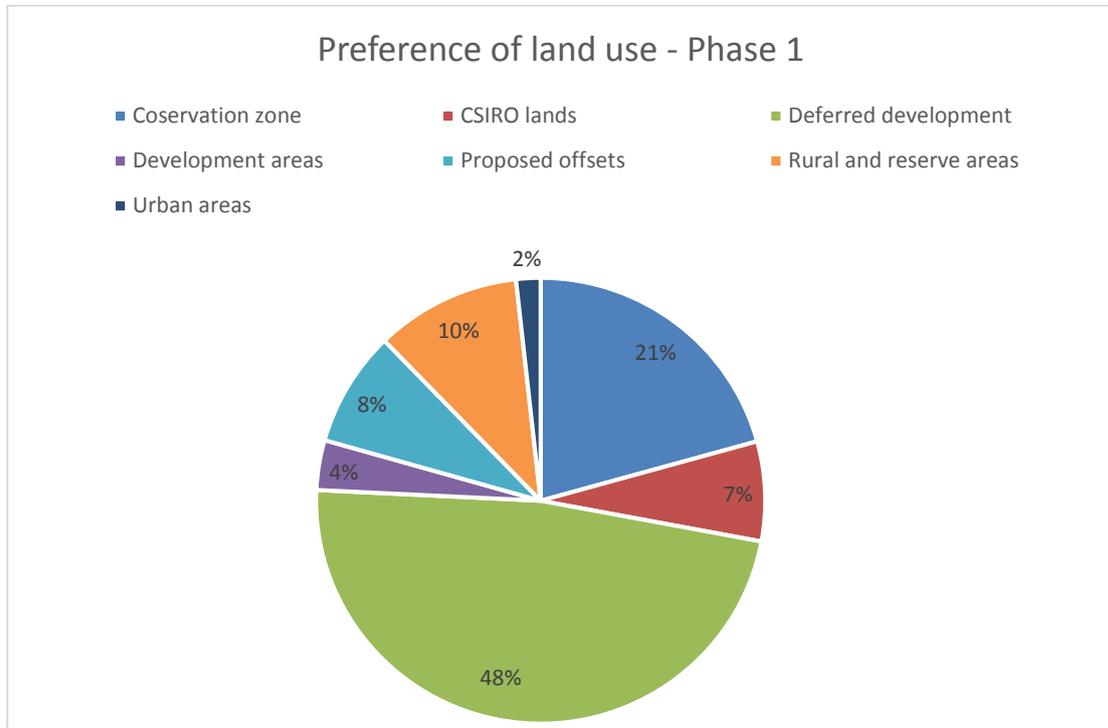
(b)



(c)

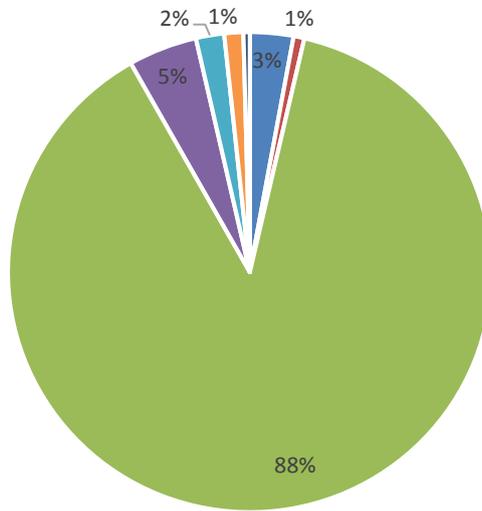
Figure 12a-c. Overall use of by the male Little Eagle of different sectors within the range of movement for Phase 1 (a), Phase 2 (b) and using all data from year 2 (c) of the study.

When we considered the availability of different land use sectors (the amount of land available to be used by the bird), we found a preference for the Deferred development area during Phase 1, Phase 2 and all of year 2. In particular, during the second year when breeding, there was a very strong preference for the Deferred development area. There was also a preference for the Conservation zone during Phase one of the study (Figure 13a-c).

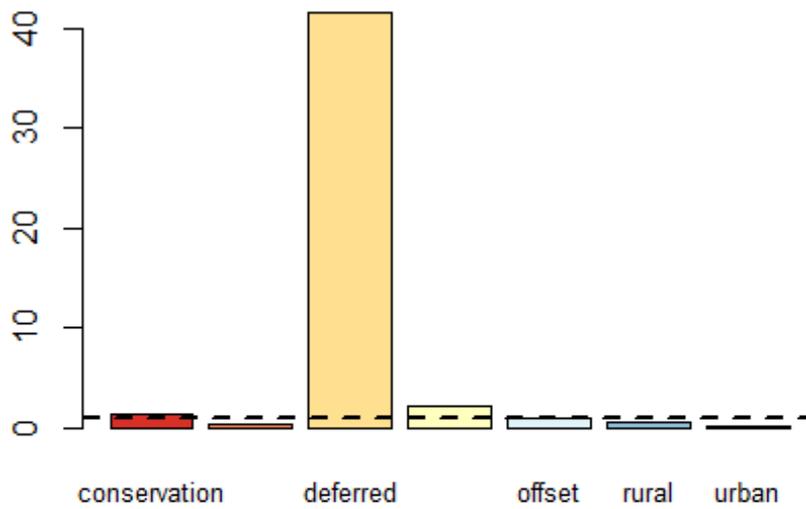


Preference of land use - Phase 2

- Coservation zone
- CSIRO lands
- Deferred development
- Development areas
- Proposed offsets
- Rural and reserve areas
- Urban areas



(c)



(d)

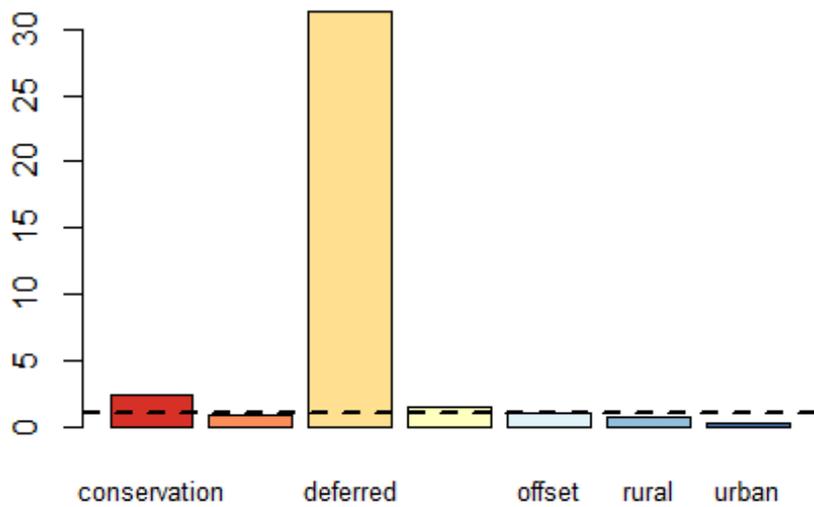
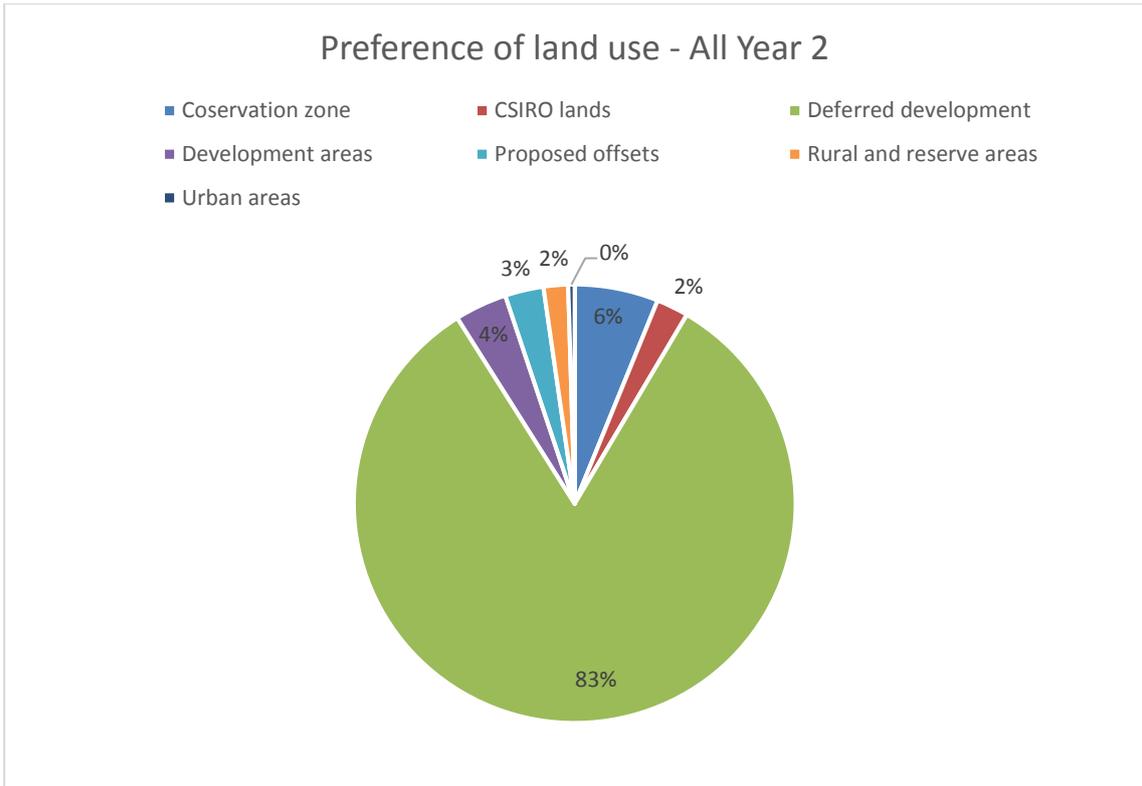


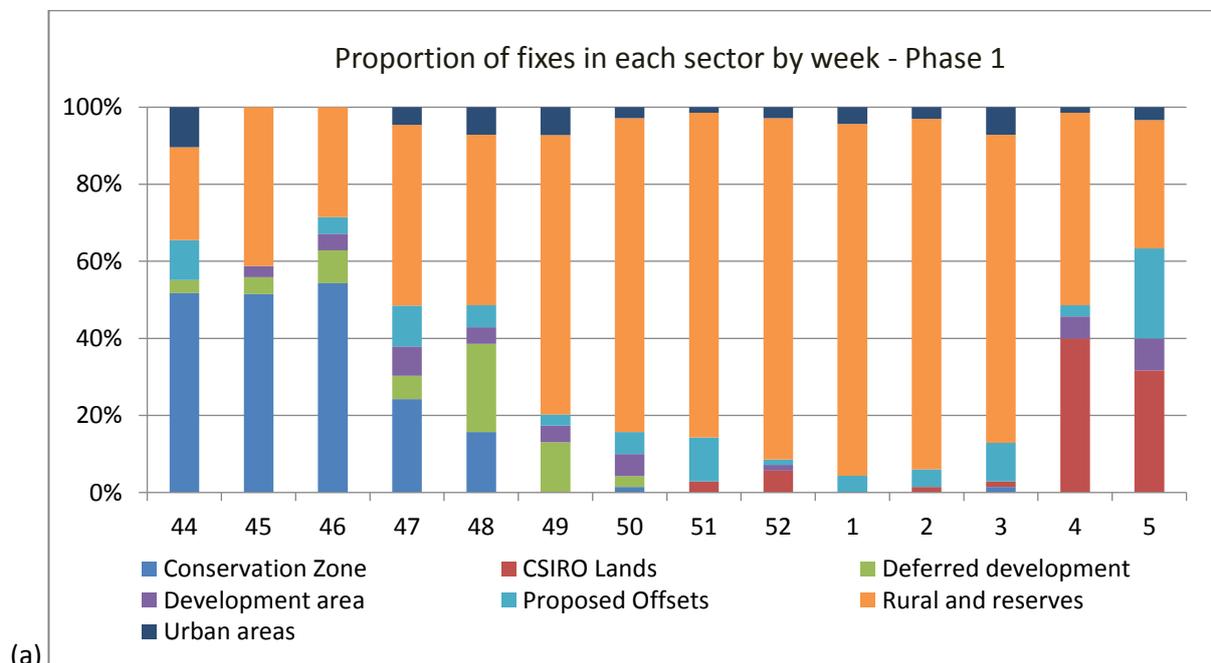
Figure 13a-f. Use of land use sectors by the male Little Eagle in comparison to availability (preferred use) for Phase 1 (a, b), Phase 2 (c, d) and using all data from year 2 (e, f) of the study. Dashed line on bar graphs indicates where preference = availability, and therefore no preference or avoidance of the land use is shown.

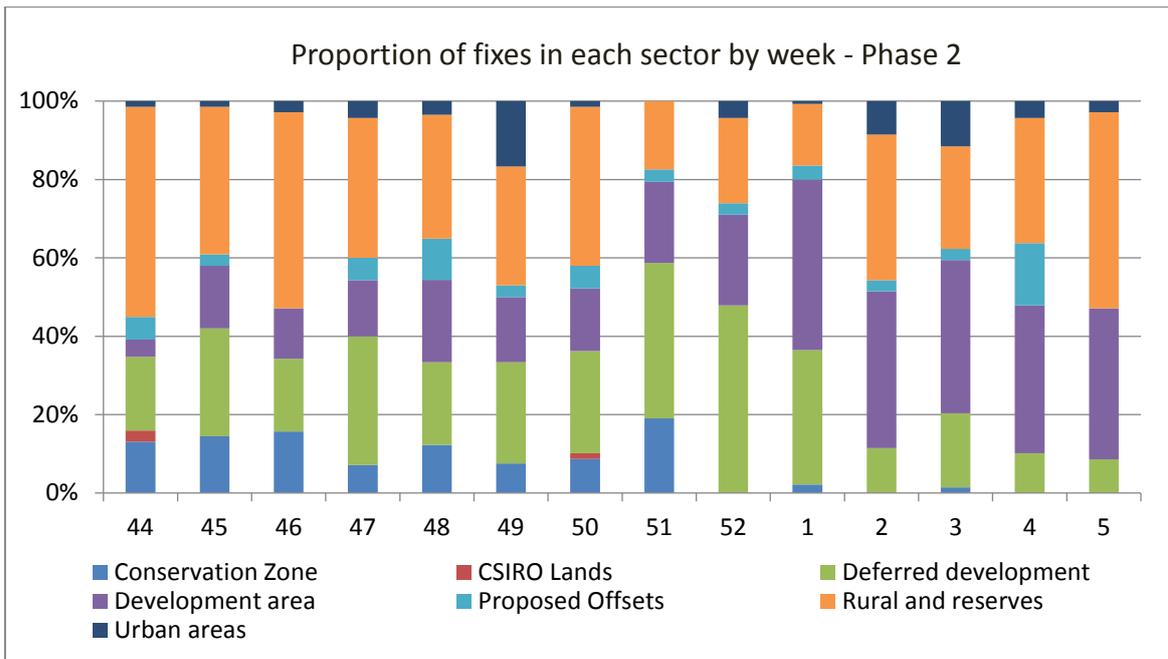
When the proportion of fixes in each sector was examined by week, the differences between the amount of fixes taken within each land use sector during Phase 1 and Phase 2 (weeks 44 to 5) were highlighted.

During Phase 1 the Conservation zone contained the most GPS fixes in the first three weeks (late October to mid-November), after which there was an increase in the amount of fixes within Rural and reserve areas from week 48. Rural and reserve lands contained by far the majority of GPS fixes from week 49 (early December) through to week 3 (mid-January). During late January (weeks 4 and 5) there was an increase in the amount of fixes taken in the CSIRO lands (Figure 14a).

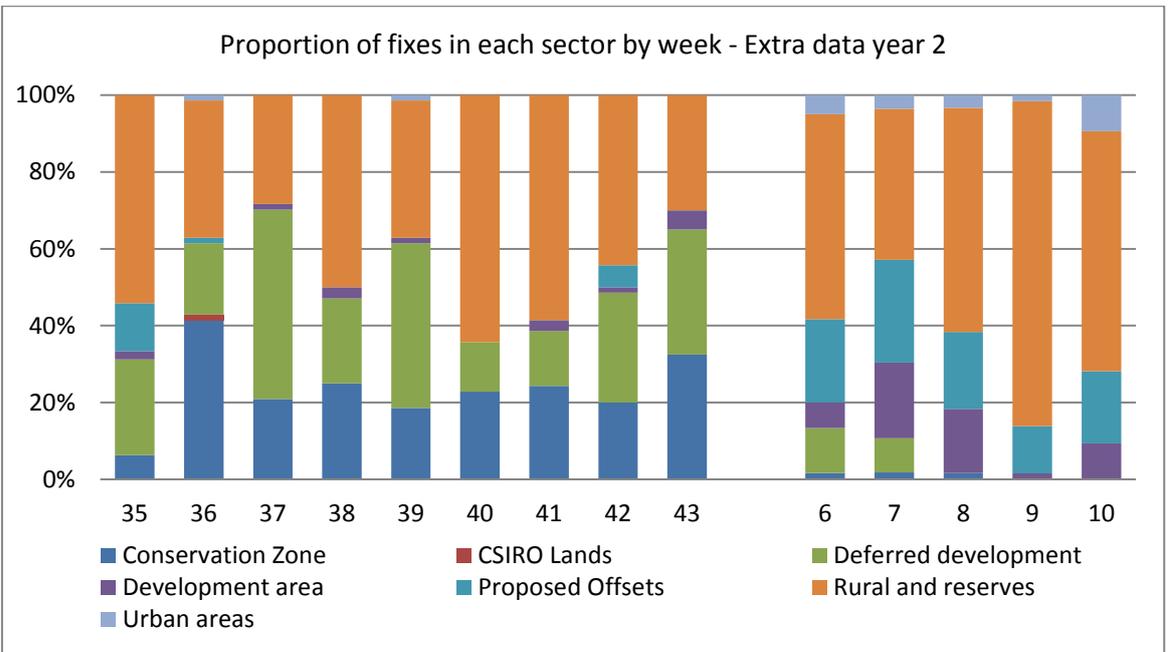
In contrast, during the same period for Phase 2 of the study, the amount of fixes taken within land use sectors remained relatively constant, and split between Rural and reserve lands, the Deferred development and the Development area (Figure 14b). There was a distinct change from fixes being found consistently within the Conservation zone up until from the end of December (week 52), to very few found in this sector after this time (Figure 14b).

When we examined the extra data for year 2, we could see the number of GPS fixes in Conservation zone was higher between weeks 36 and 43 (prior to and during breeding), but lowered as the summer progressed, with very few fixes taken in the Conservation zone after week 6. There was a decline in the number of fixes taken within the both the Deferred development and Development area after Phase 2 during week 6 (mid-February), when the male Little Eagle then increased his use of the Proposed offsets and Rural and reserve areas prior to his migration north (Figure 14c).





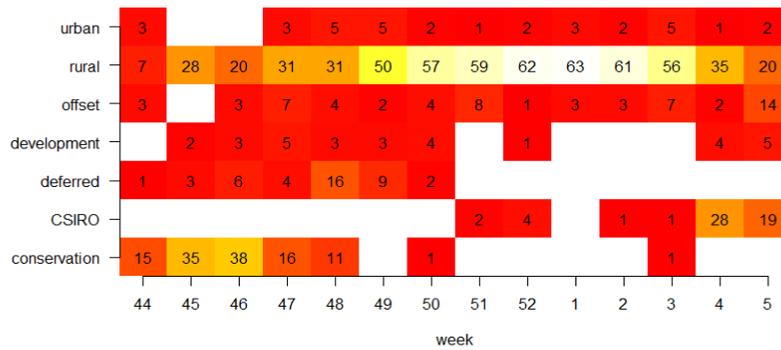
(b)



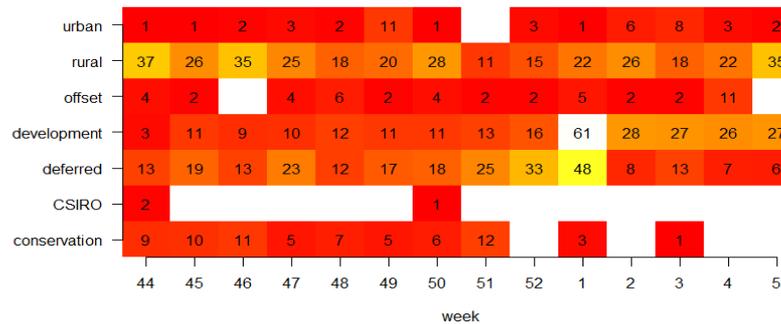
(c)

Figure 14a-c. Change in the proportion of fixes in each sector by week for Phase 1 (a), Phase 2 (b) and extra data for year 2 (c).

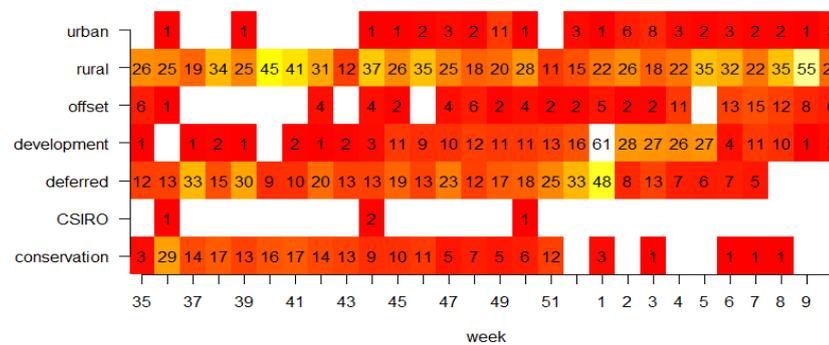
The same patterns in the change of sector use are shown in heat maps of activity for Phase 1, Phase 2 and all data for year 2 (Figure 15a-c). Phase 1 of the study shows higher use of the Conservation zone switching to concentrated use of Rural and reserve areas between week 47 to week 4 (Figure 15a), while Phase 2 (Figure 15b) and all data for year 2 (Figure 15c) shows higher use of Rural and reserve areas as well as the Deferred development area across the whole time period and the Development area between weeks 1-5 (Figure 15c).



(a)



(b)



(c)

Figure 15a-c. Heat map of activity showing the number of fixes in each sector by week for Phase 1(a), Phase 2 (b), and all of Year 2 (c).

A comparison of breeding and non-breeding movements by month and week.

When the range of movement was examined by month, during Phase 1 there was a clear shift of movement from the southern area of the range of movement around Strathnairn in month 11 (November 2015) to the northern and eastern areas of the range of movement, around the areas of Hall, Wallaroo and the property of Jaramalee in January 2016 (Figure 16a). This marked shift in focus of range of movement activity did not occur during Phase 2 of the study. During Phase 2, the male Little Eagle continued to use all parts of the range of movement from October 2016 - January 2017 (Figure 16b). This may likely be due in part to a need to be closer to the nest and chick in a successful breeding year.

When all data from year 2 was examined by month, month 9 (September 2016) showed a very high number of fixes around the Strathnairn nest site, including use of areas to the southwest (Figure 17). This coincides with the period just prior to and during breeding. The male Little Eagle did not start to use the more northern areas of its range of movement until February 2017 (month 2), just prior to its journey away from the area in early March 2017 and after the young had fledged (January 2017) (Figure 17).

When range of movements were examined at the weekly scale, the shift of the occupied areas northwards over time during the non-breeding Phase 1 can more clearly be seen (Figure 18a), which does not occur during the breeding event of Phase 2 (Figure 18b). When all data for year 2 was examined by week, there was a clear concentration of points around the nest tree from early September (week 37), through to mid-October (week 43), just prior to Phase 2. The final week prior to the male Little Eagle flying north (week 10) showed an increase in wide ranging movements across the whole area (Figure 19).



Photograph of Strathnairn Little Eagle fledgling in flight, courtesy Stuart Rae.

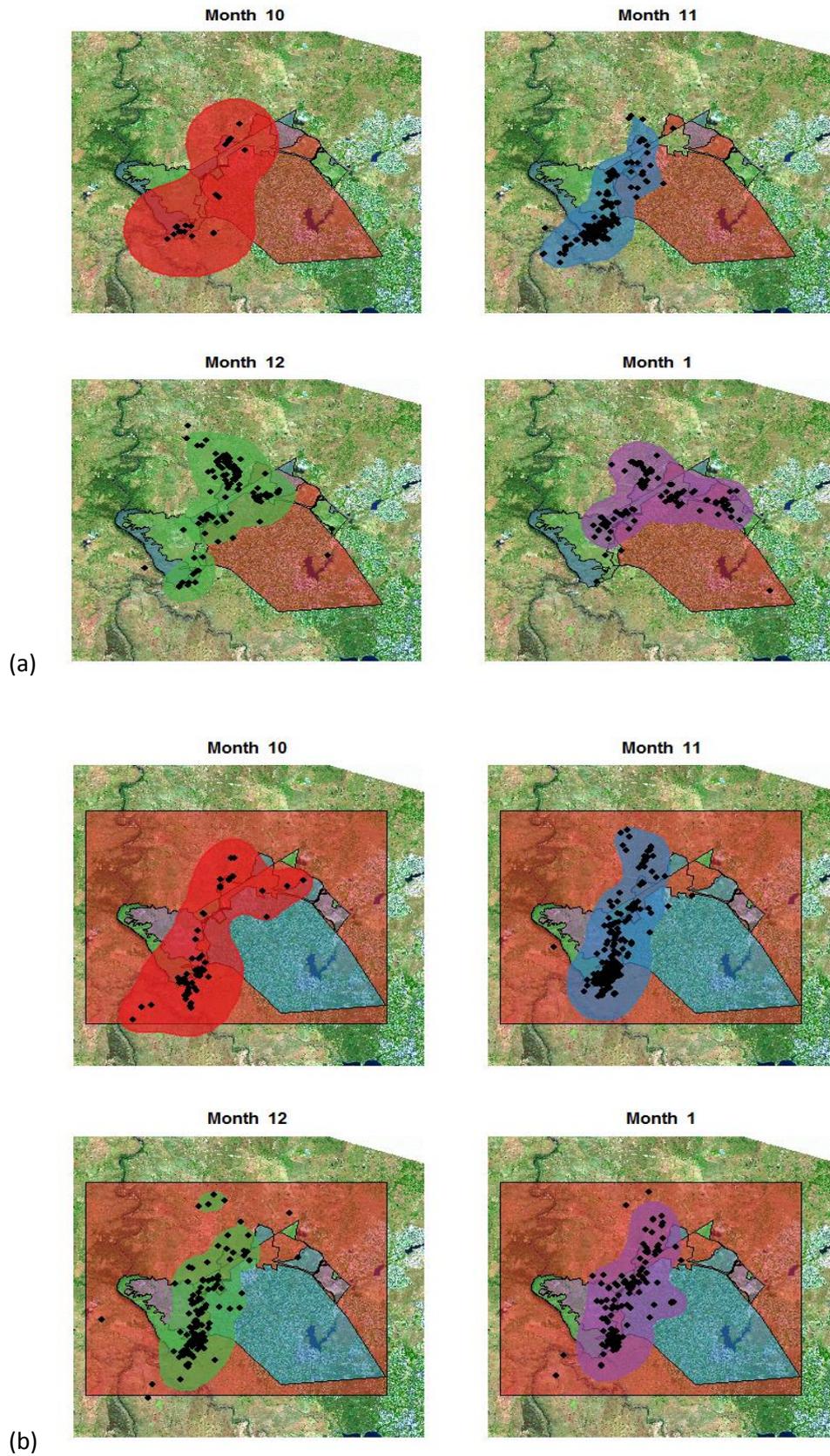


Figure 16a-b. Range of movements of the male Little Eagle during Phase 1 (a) and Phase 2 (b), by month. Large error (over estimation of range of movement) in Month 10 is likely the result of less fixes obtained in this month in both phases.

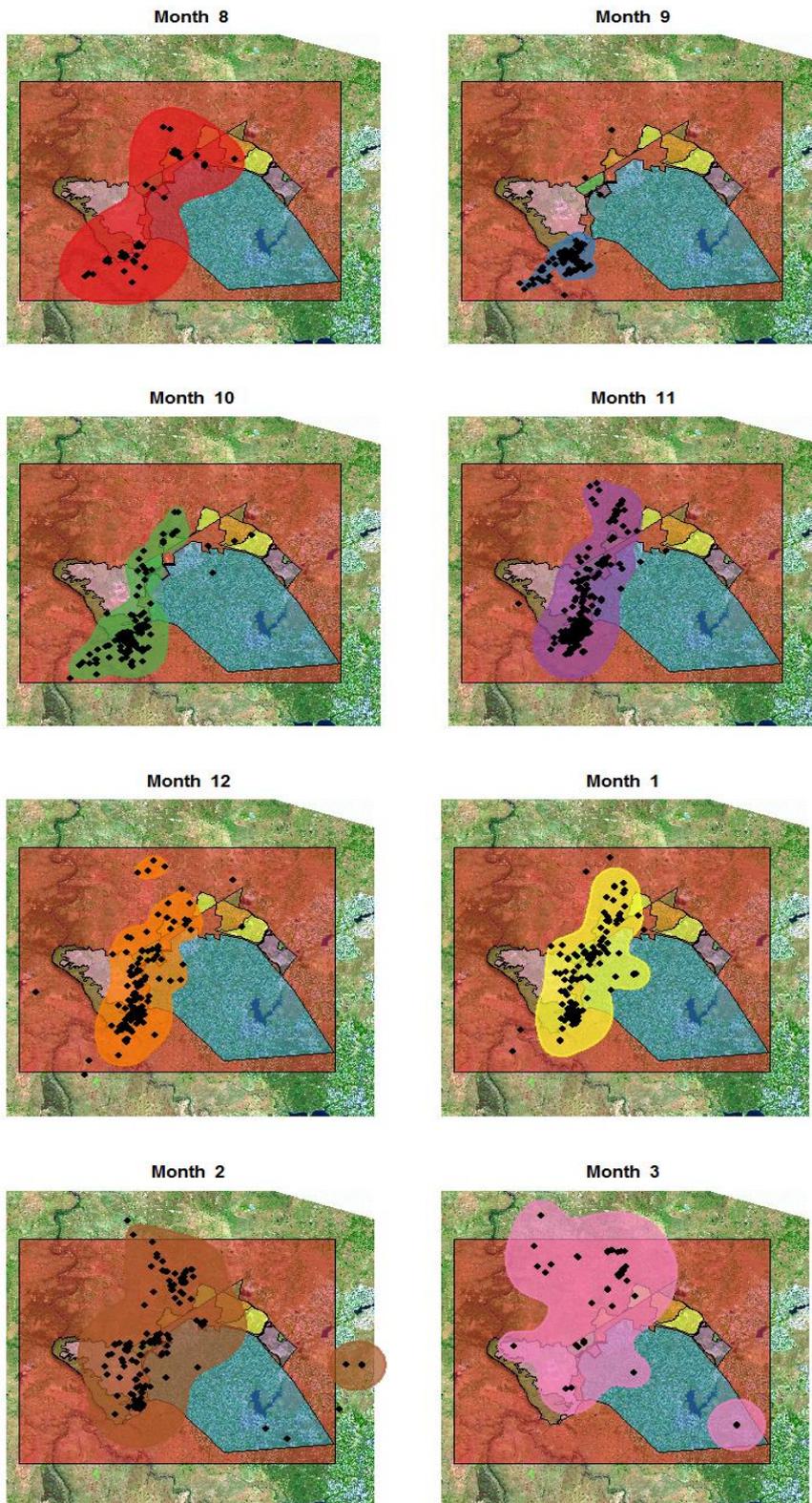
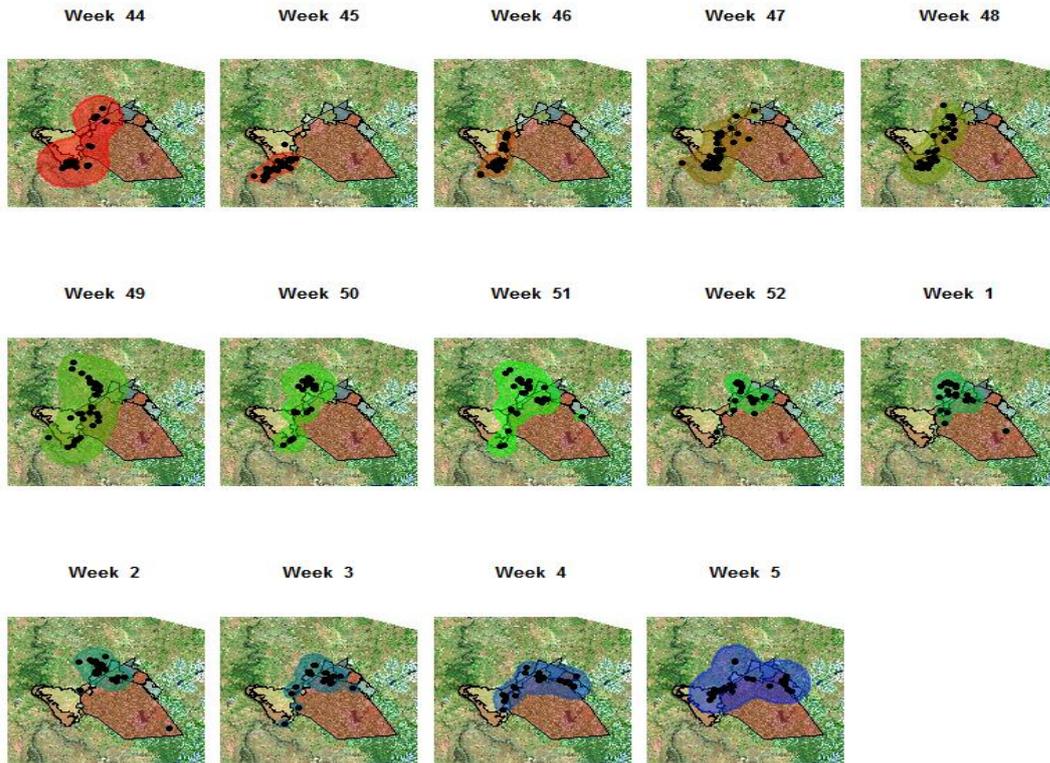
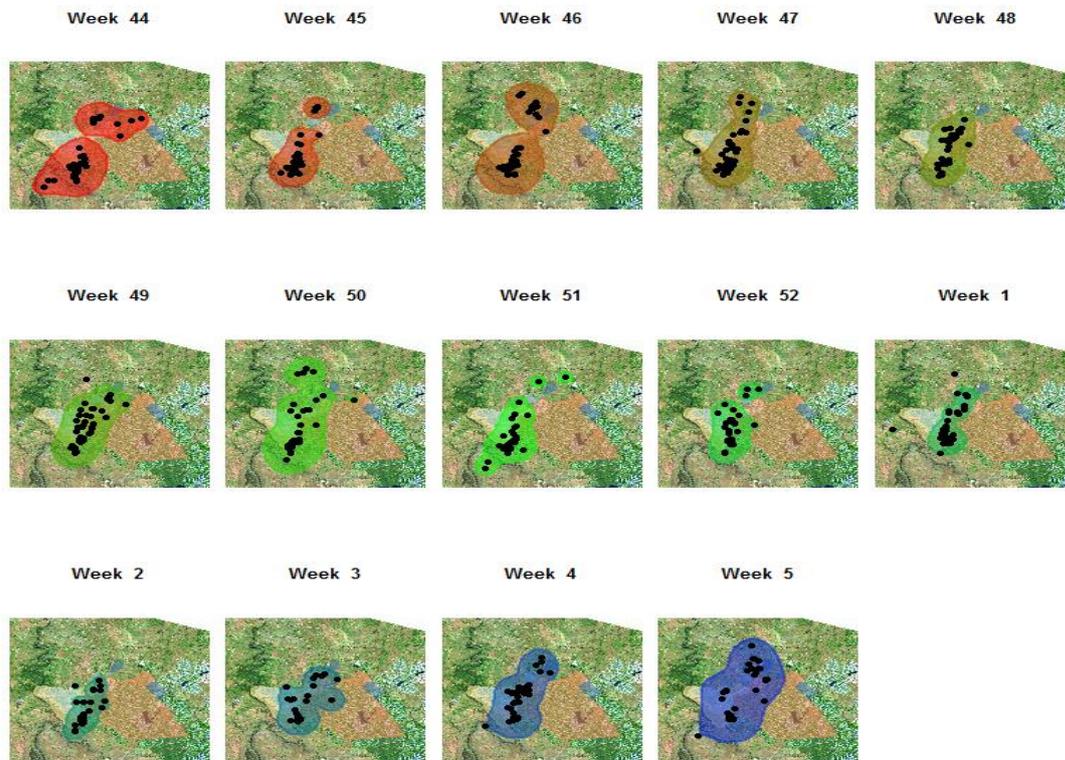


Figure 17. Range of movements of the male Little Eagle using all data from year 2 (20th August 2016 – 7th March 2017). Large error (over estimation of range of movement) in Month 3 is likely the result of less fixes obtained in this month (only seven days).



(a)



(b)

Figure 18a-b. Range of movements of the male Little Eagle, by week. Note the shift in movements to the northern end of the study area over time during Phase 1 (a) that did not occur during Phase 2 (b).

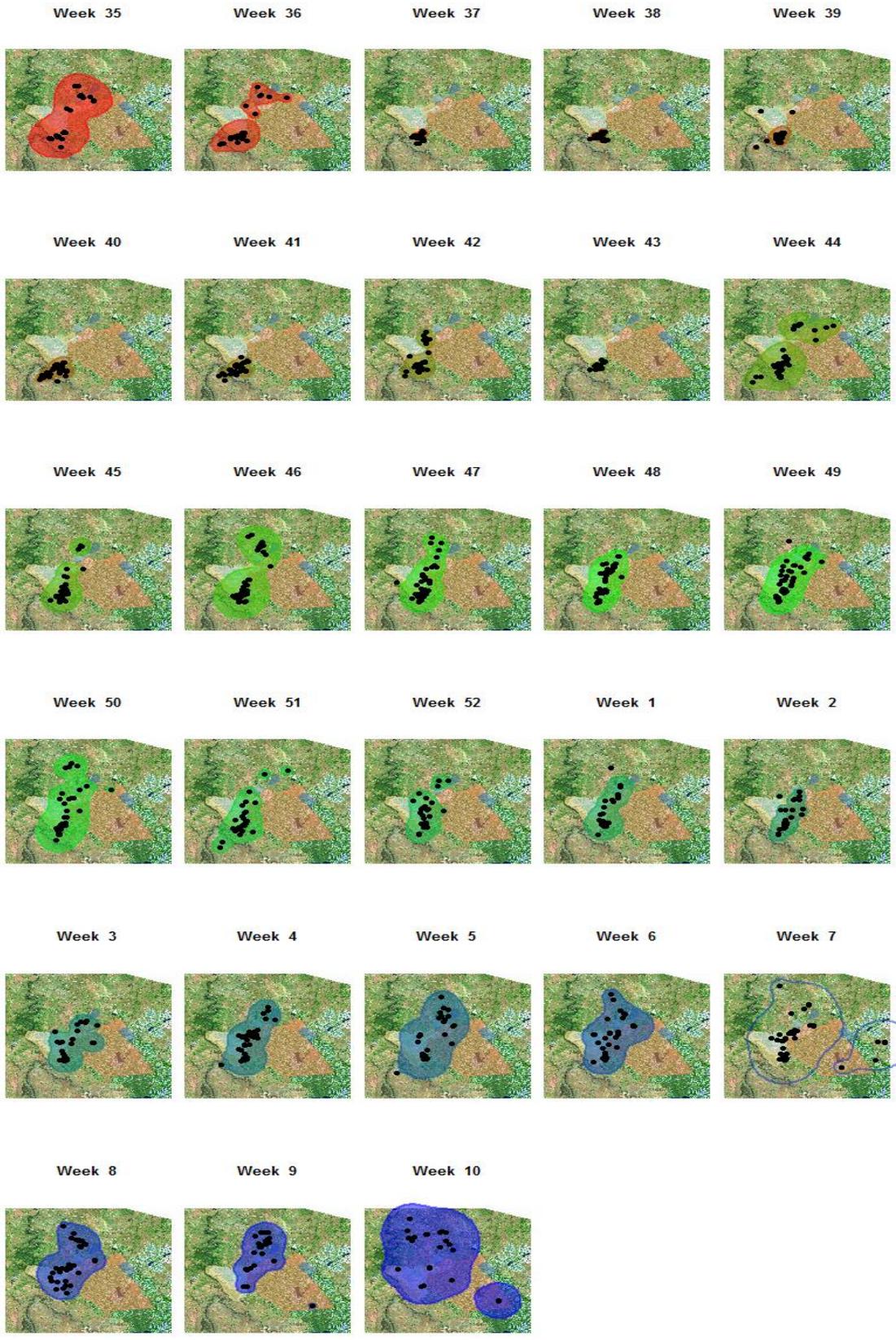


Figure 19. Range of movements of the male Little Eagle, by week, for all data year 2. Note the condensed activity around the nest tree at Strathnairn between week 37 and week 43.

A comparison of breeding and non-breeding flying vs. roosting behaviours

The term “roosting” is used for stationary fixes defined as having zero flying speed, while flying points were the remainder. We were unable to definitively distinguish between flying and foraging, nor distinguish between roosting fixes where the male Little Eagle was inactive or actively searching for prey.

When examined by week, the number of flying fixes decreased in summer during both Phase 1 and Phase 2 (Figure 20a, b), and the number of roosting fixes increased. During Phase 2 the estimated hatching time for the chick was around week 44, after which there was an increase in flying time (Figure 20b). When all data for year 2 was examined, the proportion of flying fixes was also lower during weeks 35-40, before increasing between weeks 40 and 50 (Figure 20c).

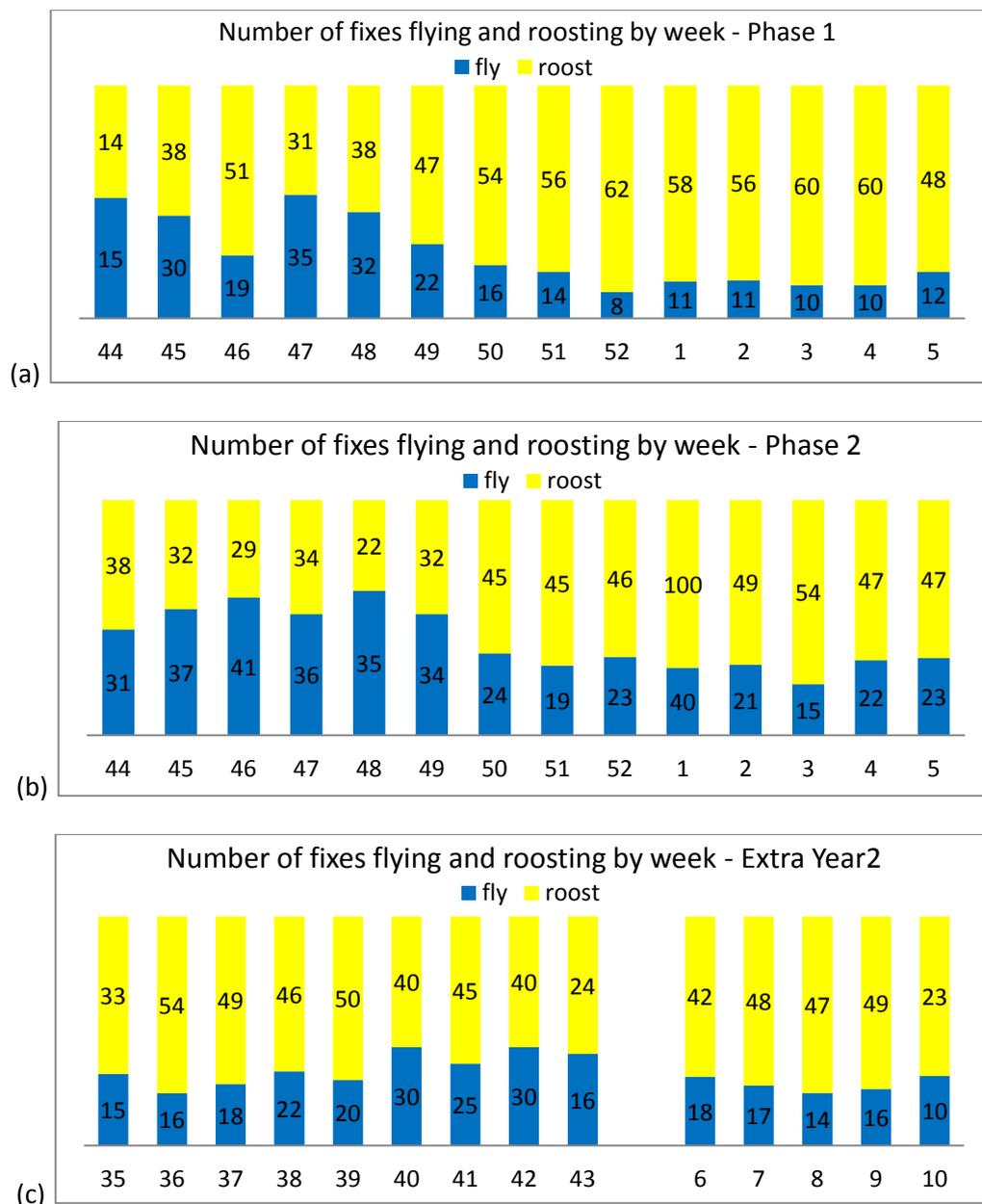


Figure 20a-c. The number of flying and roosting fixes by week for Phase 1 (a), Phase 2 (b) and using extra data for year 2 (c).

When the time of day for roosting and flying activity was examined, similar patterns emerged for Phase 1 (Figure 21a), Phase 2 (Figure 21b) and when all data for year 2 was examined (Figure 21c). Most flying occurring between 9am and 5pm for all three periods, however, there was noticeably more flying fixes in Phase 2 and all data year 2 compared to Phase 1 for these same time period (9am – 5 pm) (Figure 21).

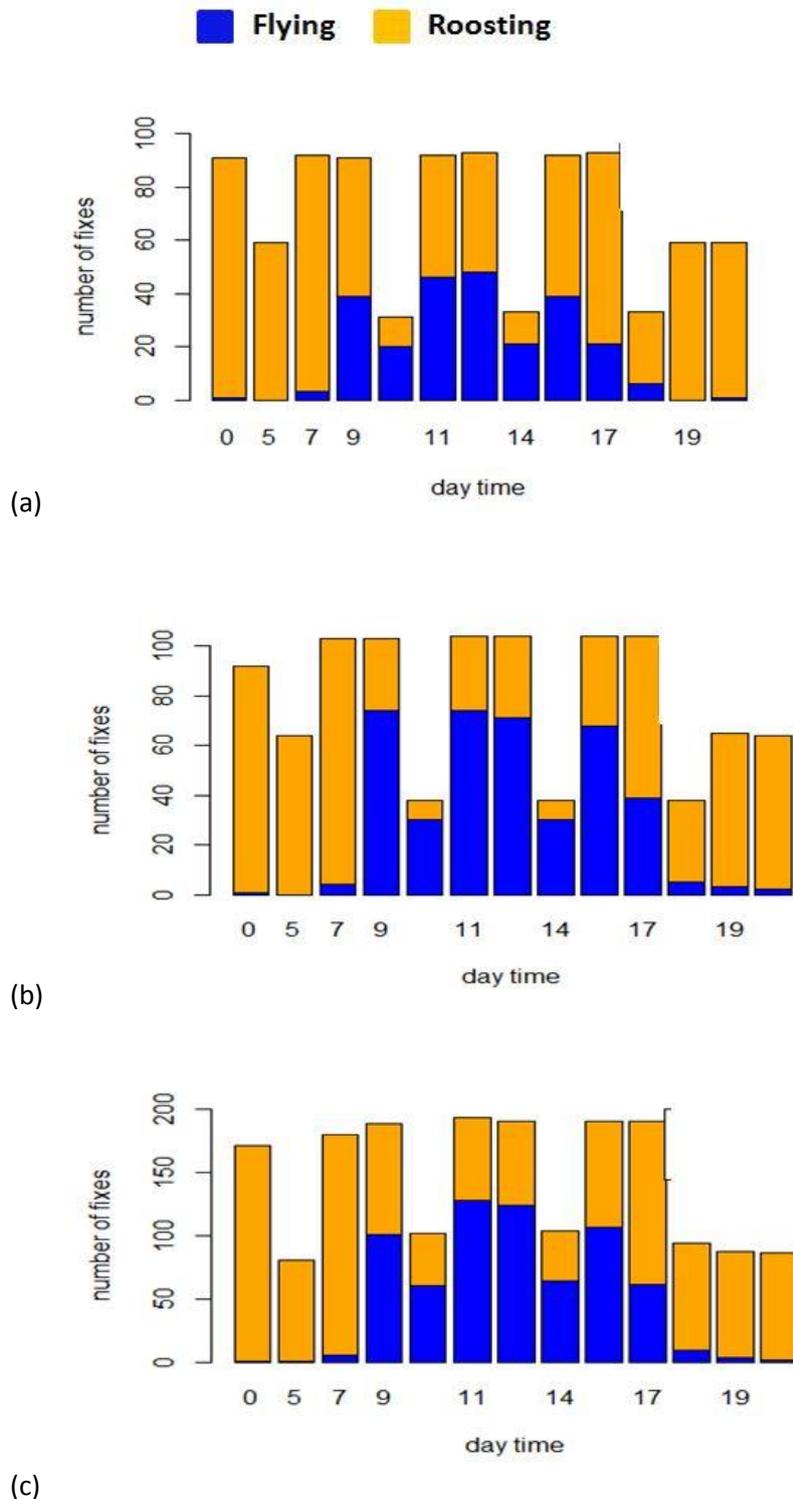


Figure 21a-c. Roosting and flying behaviours by time of day for Phase 1 (a), Phase 2 (b) and all data year 2 (c) (AEST).

Flying and roosting fixes were mapped for Phase 1, Phase 2 and all data for year 2 (Figure 25 and 26). Flying and roosting fixes were more condensed over the southern half and middle sections of the range of movement during Phase 2 (breeding), while, in contrast, Phase 1 (non-breeding) showed more flying and roosting fixes in the northern half of the range of movement (Figure 25a, b and 26a, b). When all data for year 2 were examined, these wide ranging movements across both the north and into urban areas of Canberra also occurred (Figure 25c and 26c), but they occurred approximately a month later than during Phase 1.

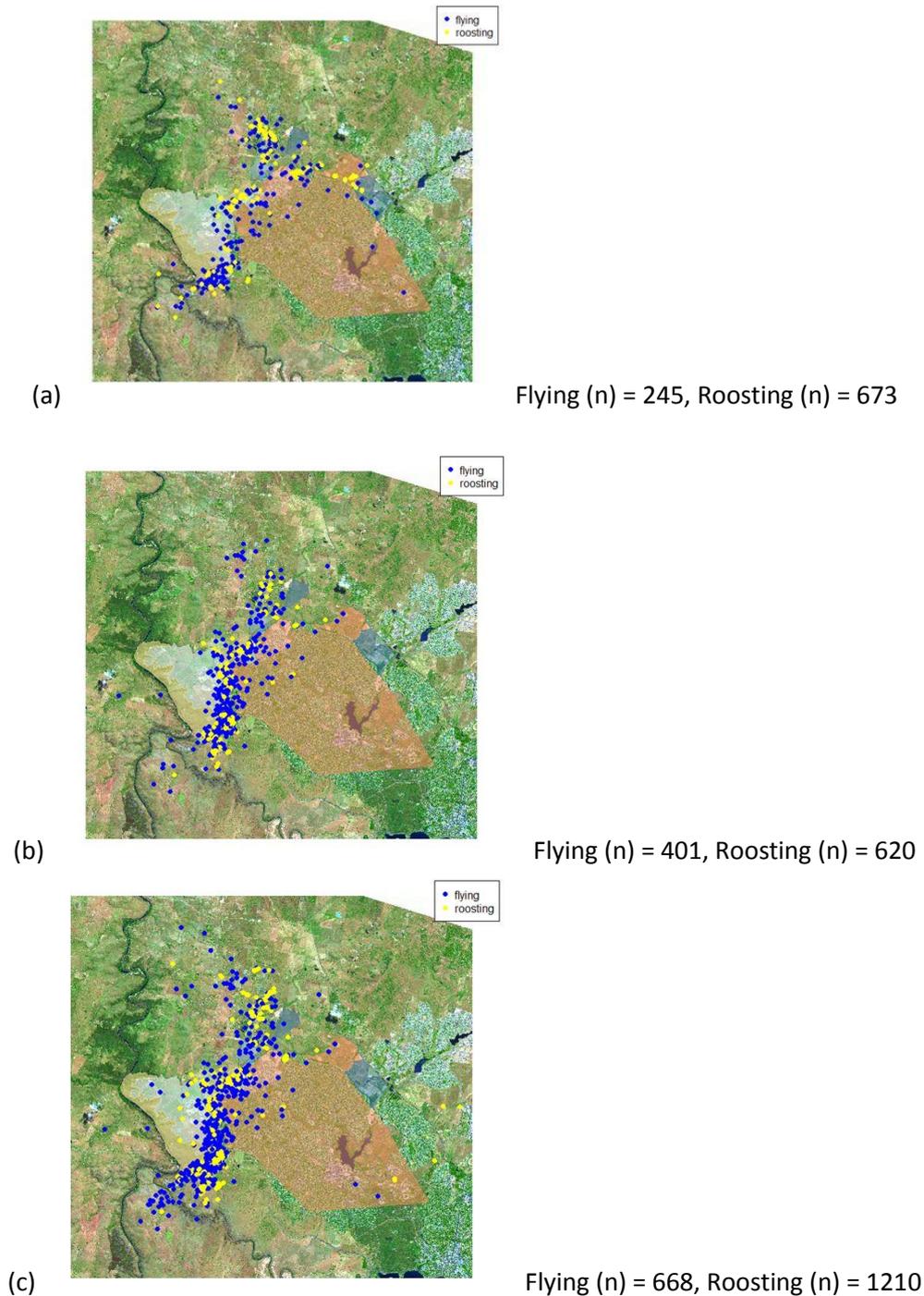


Figure 22a-c. Total flying and roosting GPS fixes for the male Little Eagle for Phase 1 (a), Phase 2 (b) and all data year 2 (c)

Consistent patterns that emerged through Phase 1, Phase 2 and for all data for year 2 was the use of Conservation zone and area surrounding the nest tree, the northern area around the NSW border and the distinct flight path up through the eastern side of the proposed Development area through Proposed Offset areas that linked the north and the south of the range of movement (Figure 23a-c).

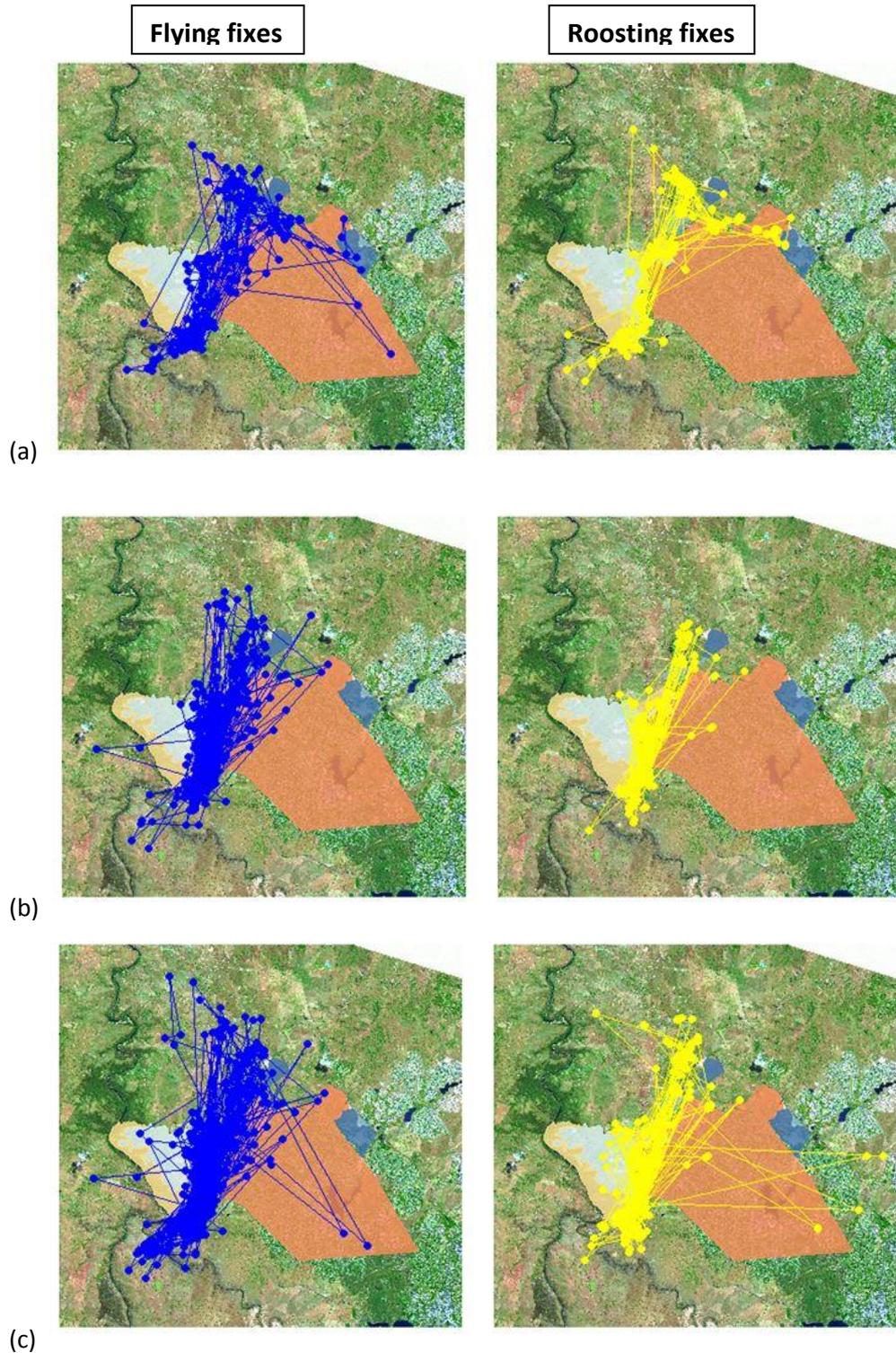


Figure 23a-c. Total flying and roosting GPS fixes for the male Little Eagle for Phase 1 (a), Phase 2 (b) and all data year 2 (c), showing movement links between consecutive fixes.

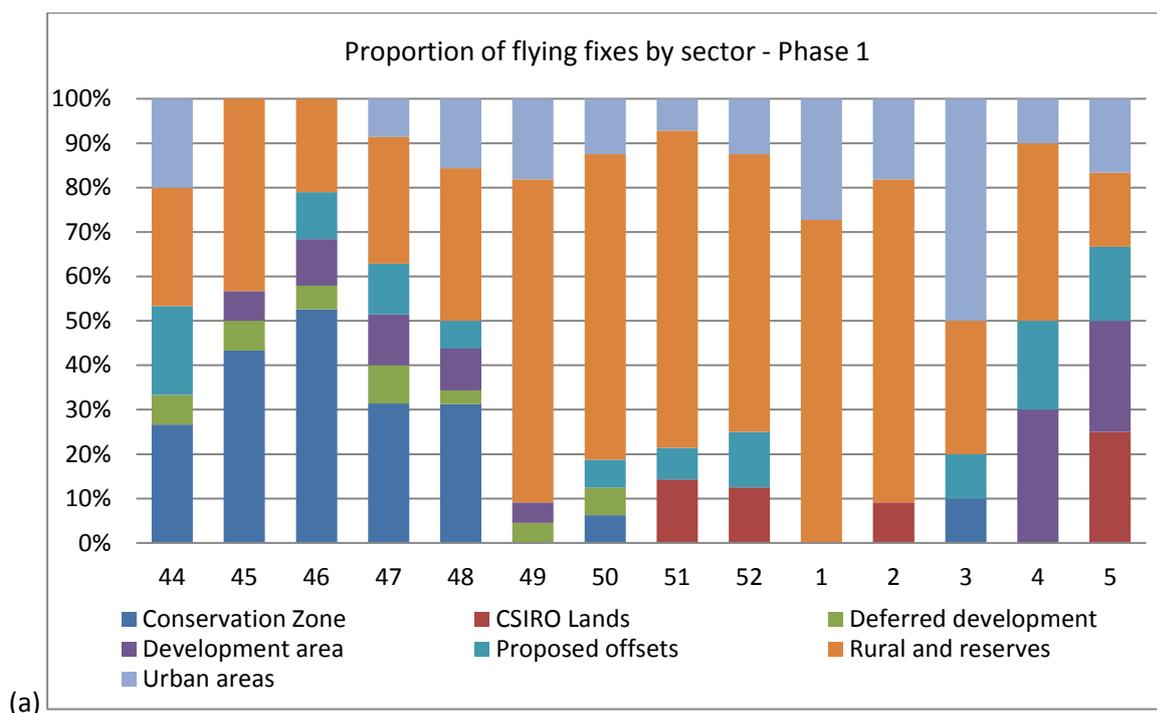
A comparison of breeding and non-breeding flying vs. roosting behaviour, by sector

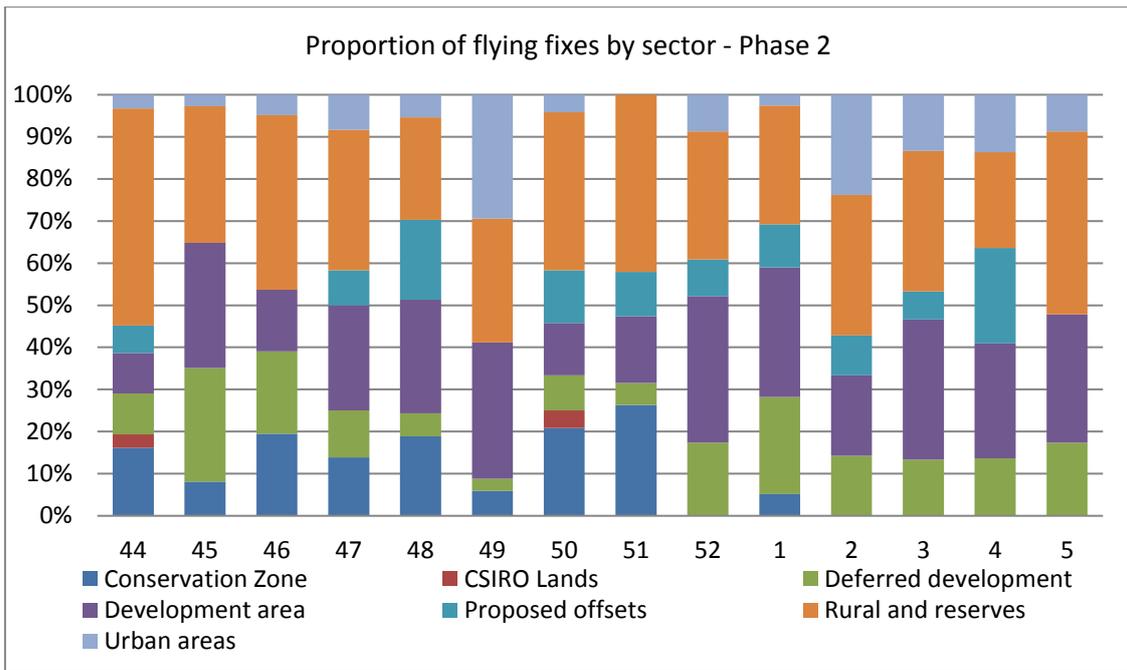
The number of roosting and flying fixes in each sector was examined for Phase 1, Phase 2 and using all data for year 2.

During Phase 1 the Conservation zone was used for both roosting and flying weeks 44-48, after which there was an increase in flying and roosting in Rural and reserve lands (Figure 27a, 28a). There was increase flying in CSIRO lands from week 51, and roosting from week 4 (Figure 27a, 28a).

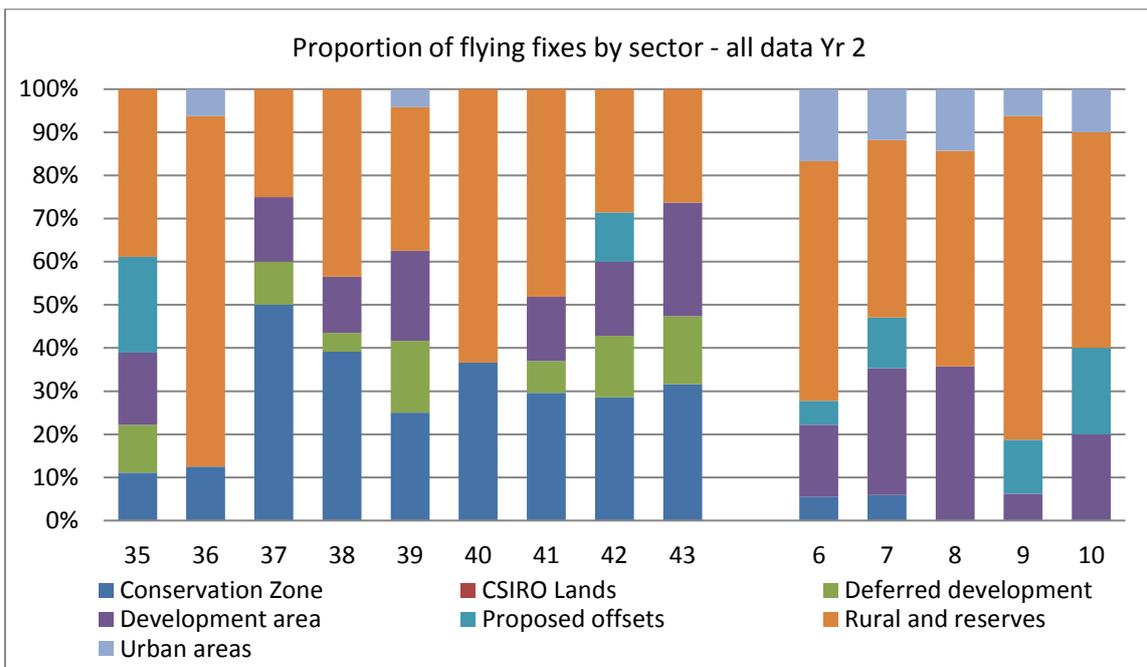
Across the entire Phase 2, most flying fixes were spread across Rural and reserve lands and the Development area, with flying fixes also taken in the Conservation zone up to week 51, after which more flying fixe were taken in the Deferred development area (Figure 26b). In comparison, most roosting fixes were taken in the Deferred development area, suggesting that the male Little Eagle roosted more often in close proximity to the nest when young were present, followed by Rural and reserve lands (Figure 28b). The amount of roosting fixes taken in the Development area during Phase 2 increased after week 1 (Figure 27b).

During the period for of extra data for year 2, most flying fixes were taken in Rural and reserve areas and the Conservation zone up until week 43. This coincides with the early breeding period. Between weeks 6 and 10, most flying fixes were taken in Rural and reserve areas and the Development area (Figure 27c) just prior to the bird leaving on its journey north. Roosting fixes were concentrated in Rural and reserve lands, the Deferred development and Conservation zone up until week 43 (Figure 28c), while between weeks 6-10 roosting fixes were concentrated in Rural and reserve areas and Proposed offsets just prior to the male Little Eagle leaving the ACT and flying north (Figure 28c). Most fixes in Urban areas were taken while the Little Eagle was flying in all three periods (Figure 26 and 28).



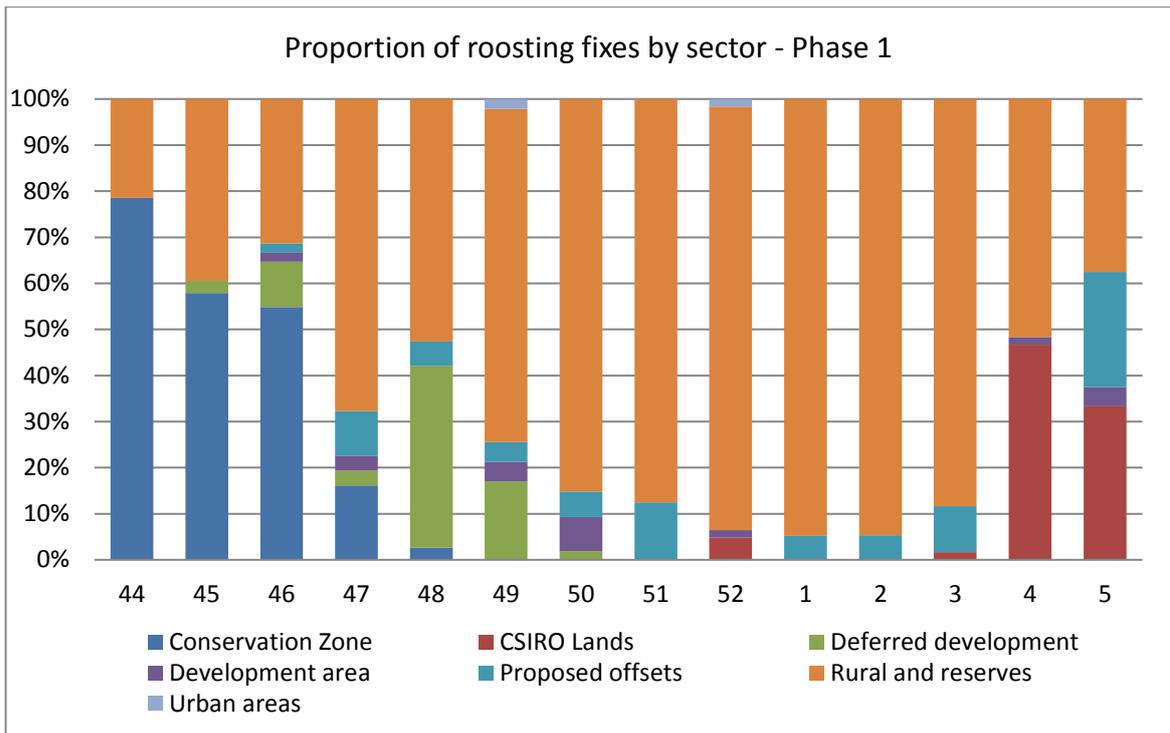


(b)

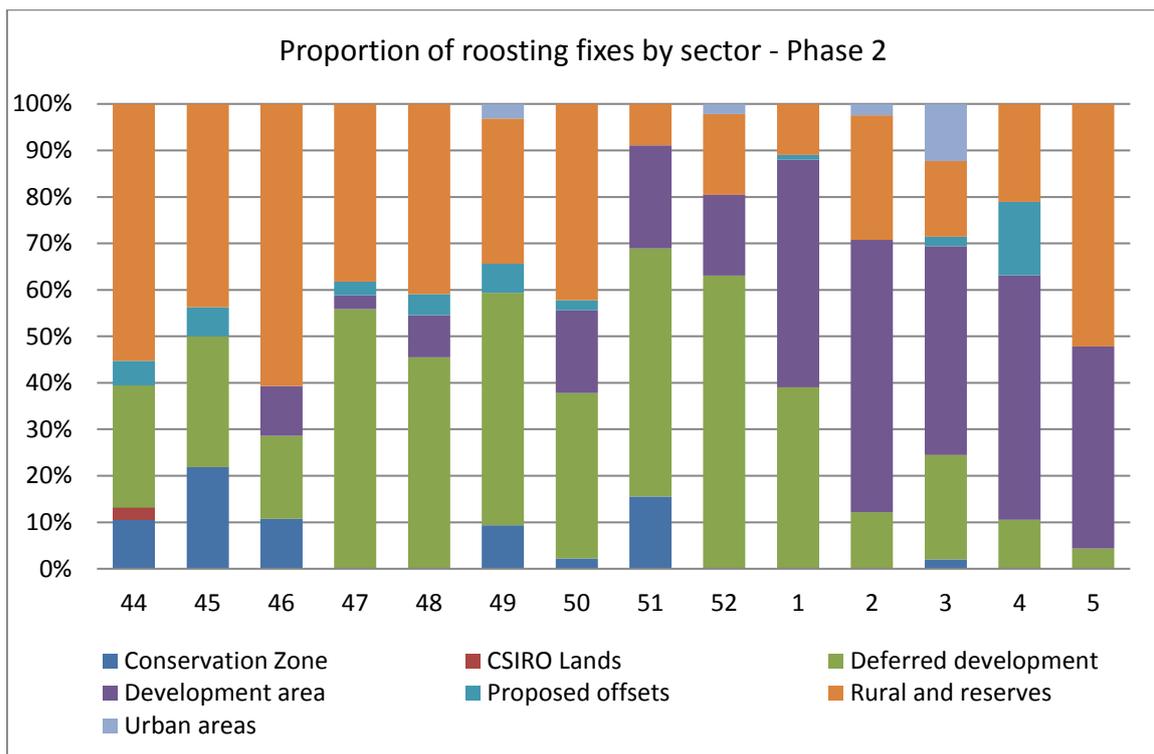


(c)

Figure 24a-c. Proportion of flying fixes, by land use sector, for Phase 1 (a), Phase 2 (b) and using extra data for year 2 (c).



(a)



(b)

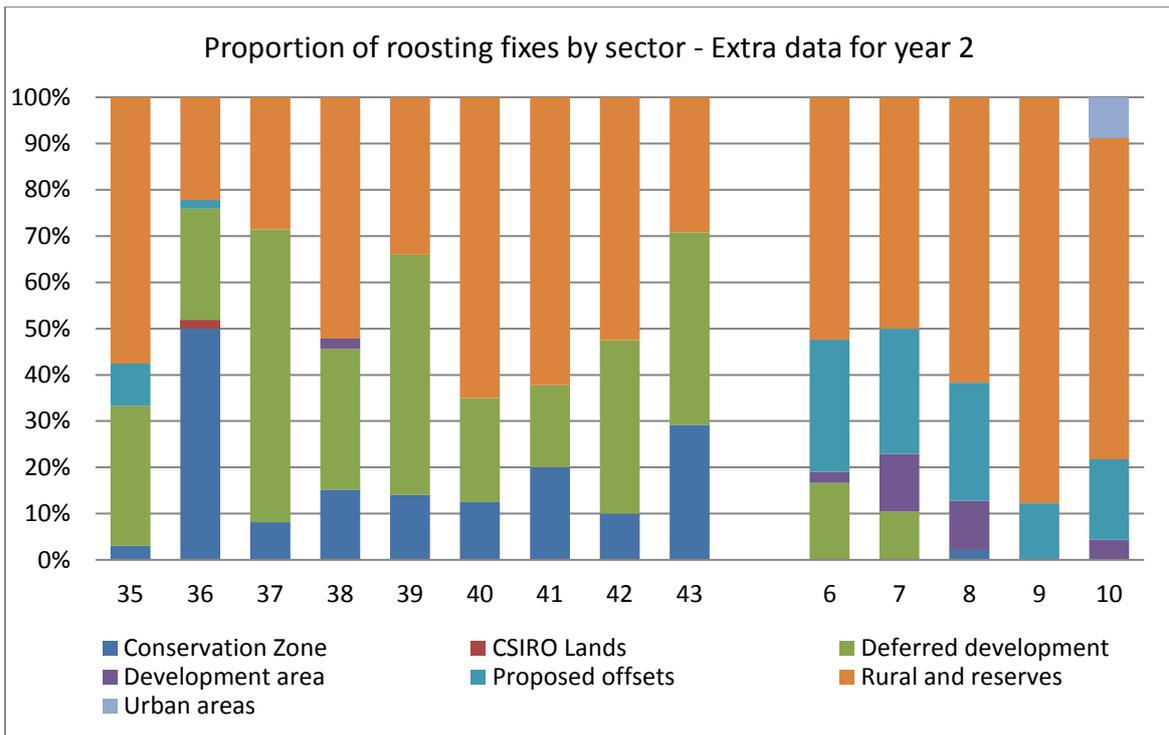


Figure 25a-c. Proportion of roosting fixes, by land use sector, for Phase 1 (a), Phase 2 (b) and using extra data for year 2 (c).

There was marked differences in the estimated area of flying and roosting fixes between Phase 1, Phase 2 and for all data for year 2 (Figure 29). An estimated flying area of movement of 91.6 km² for Phase 1 was much larger than found for Phase 2 or for all data for year 2 (60 km² and 66.77 km² respectively). The estimated are for roosting was also much larger during Phase 1 (66.57 km²) than in Phase 2 (30.51 km²) (Figure 29). A similar pattern was found for core flying and roosting range of movement, with a reduction in estimated area between Phase 1 and Phase 2, and between Phase 1 and when all data for year 2 was examined (Figure 30). However, the overall use of the same core area for both roosting and flying remained similar between breeding and non-breeding years.

The total range of movement for roosting and flying behaviours was greatly reduced between Phase 1 and Phase 2 (Figure 26a, b). During Phase 2, roosting and flying fixes were more condensed in Conservation zone, Deferred development areas and the eastern side of the Development area (Figure 26b). Core flying and roosting areas during Phase 2 were also much more restricted than in Phase 1 and focused around the nest tree at Strathnairn in the Deferred development area (Figure 27a, b).

When all data for year 2 was examined, the pattern of roosting and flying for both total (95% kernel) and core range of movements (50% kernel) remained similar to Phase 2, with only a very small increase in total range of movement for flying (Figure 26c) and core range of movement for roosting (Figure 27c). The total range of movement for roosting for all data year 2 was larger than for Phase 2. (Figure 26c).

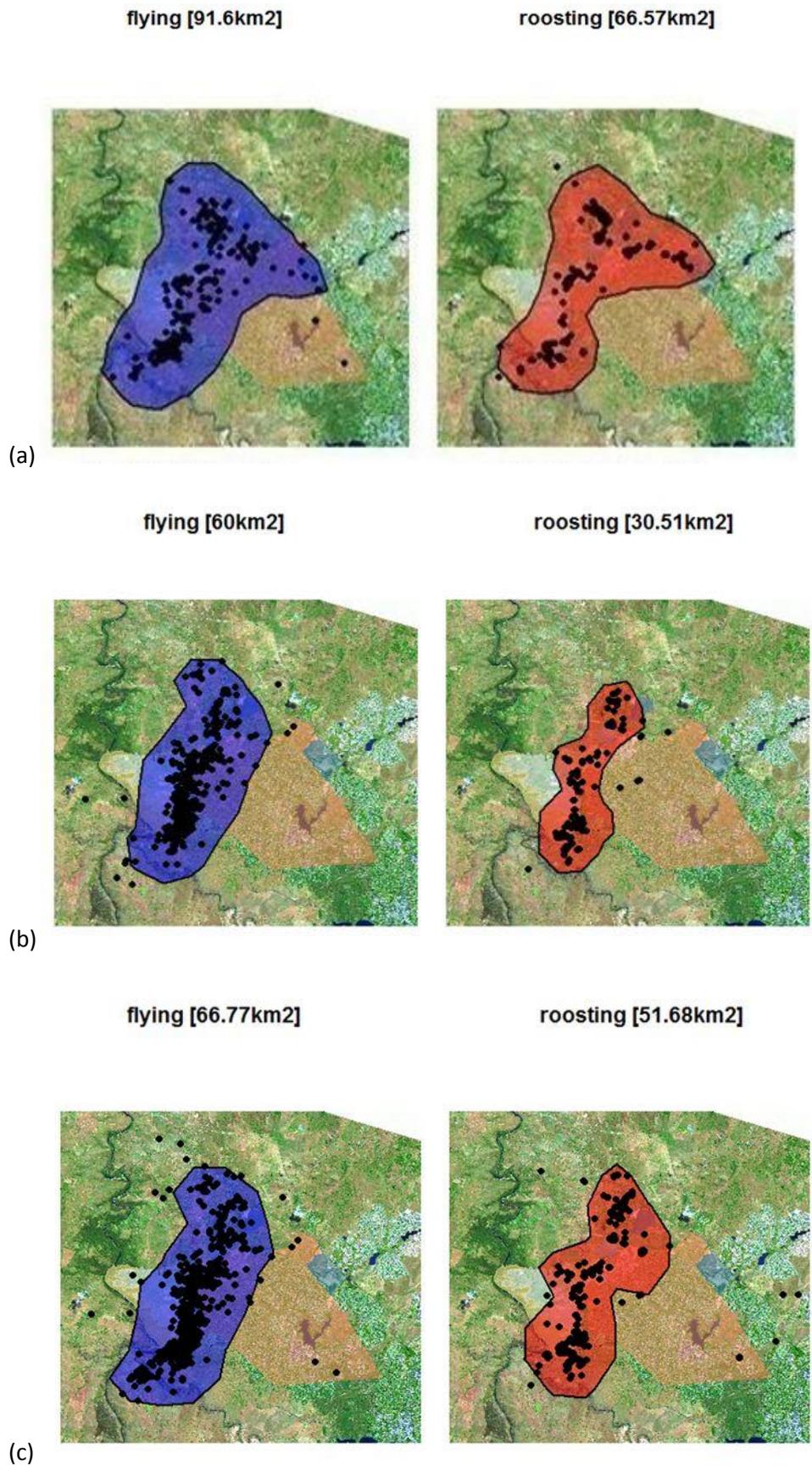


Figure 26a-c. Total (95% kernel) flying and roosting range of movement of the male Little Eagle, for Phase 1 (a), Phase 2 (a) and for all data for year 2 (c).

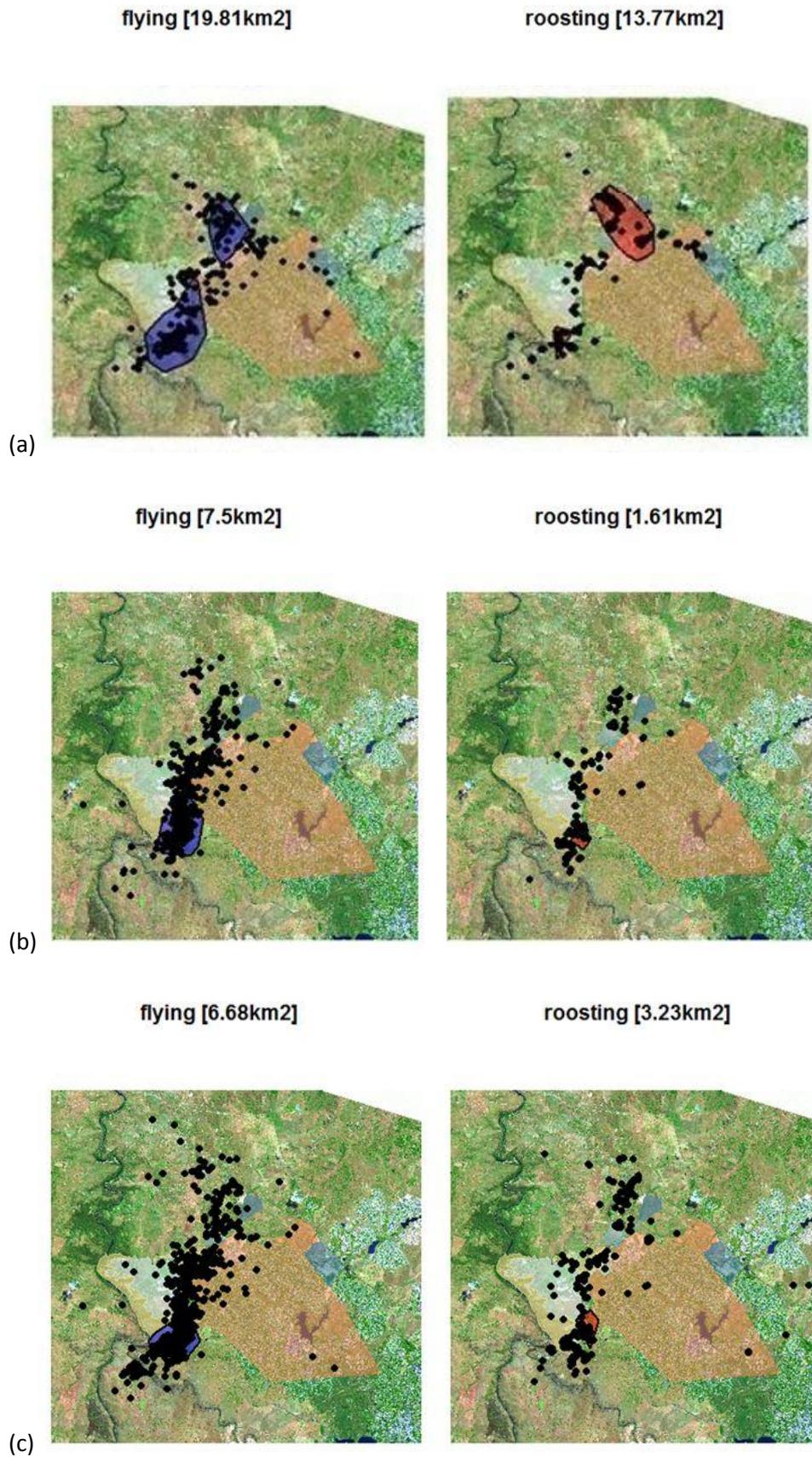


Figure 27a-c. Core (50% kernel) flying and roosting range of movement of the male Little Eagle, for Phase 1 (a), Phase 2 (a) and for all data for year 2 (c).

A comparison of breeding and non-breeding day vs. night locations

During Phase 1 of the study, 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 mainly during the day (Figure 28a). During Phase 2 and for all data for year 2, day and night fixes were found throughout the range of movement, with a higher concentration of both day and night fixes around the nest tree at Strathnairn and in the southern and eastern sections of the range of movement (Figure 28b, c).

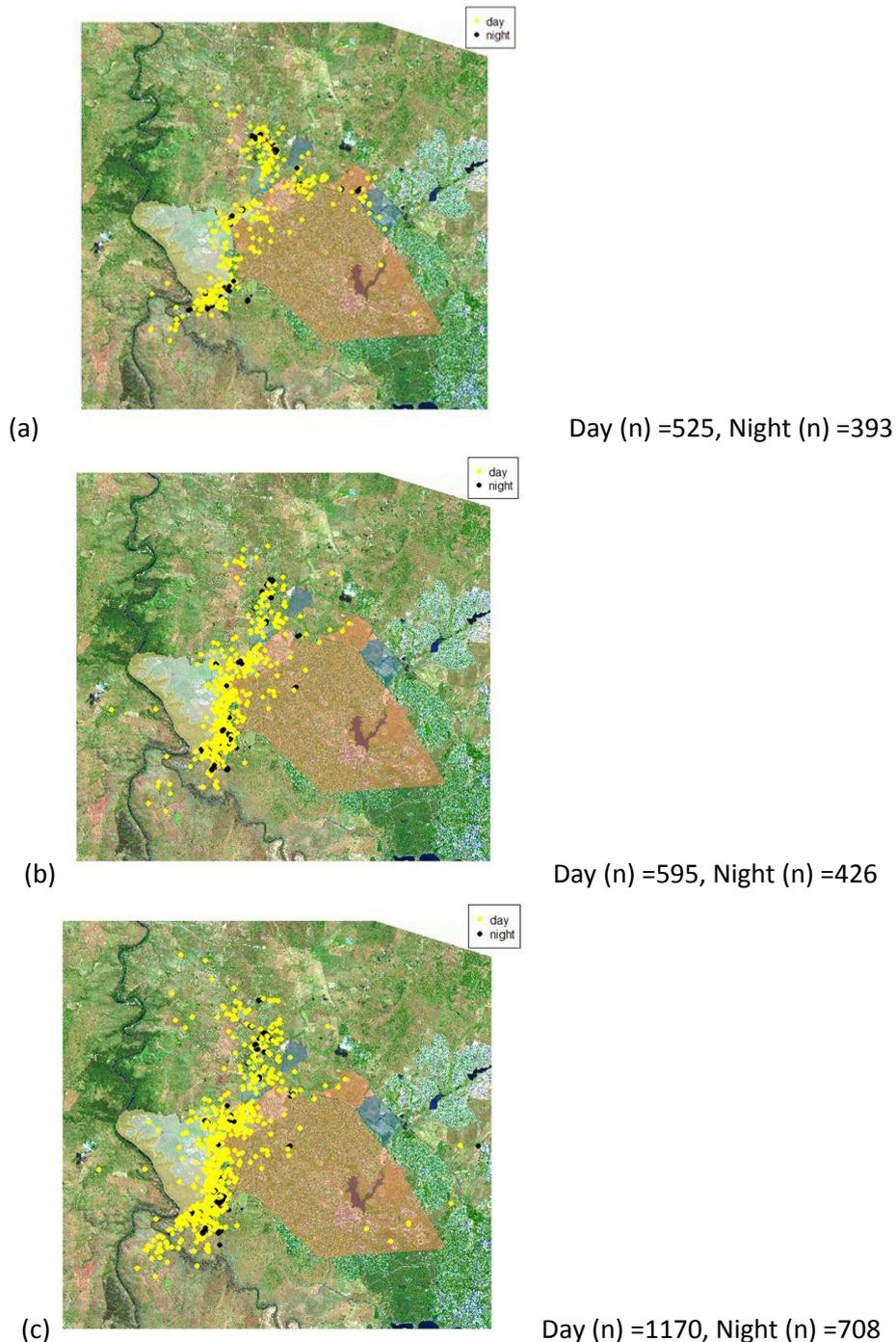


Figure 28a-c. The location of day and night fixes for the male Little Eagle during Phase 1 (a), Phase 2 (b) and using all data for year 2 (c), where day fixes were taken between 9am and 5pm AEST.

The influence of nearby urban development on movements

In 2016 earthworks commenced for an urban development located approximately 600m north-east of the nest tree. This area was formerly part of a golf course. These earthworks continued throughout Phase 2 of the study while the Strathnairn little Eagle pair was breeding. Very few fixes were found within the golf course earthworks area for both Phase 1 (n=3) and Phase 2 (n=4), however there was a large number of fixes within close proximity to the earthworks, particularly during Phase 2. Prior to earthworks commencing, in Phase 1 there were 9, 23 and 56 fixes within 200m, 400m and 600m of the golf course respectively. During Phase 2 there were 40, 195 and 432 fixes within 200m, 400m and 600m of the golf course respectively which were collected when earthworks were active.

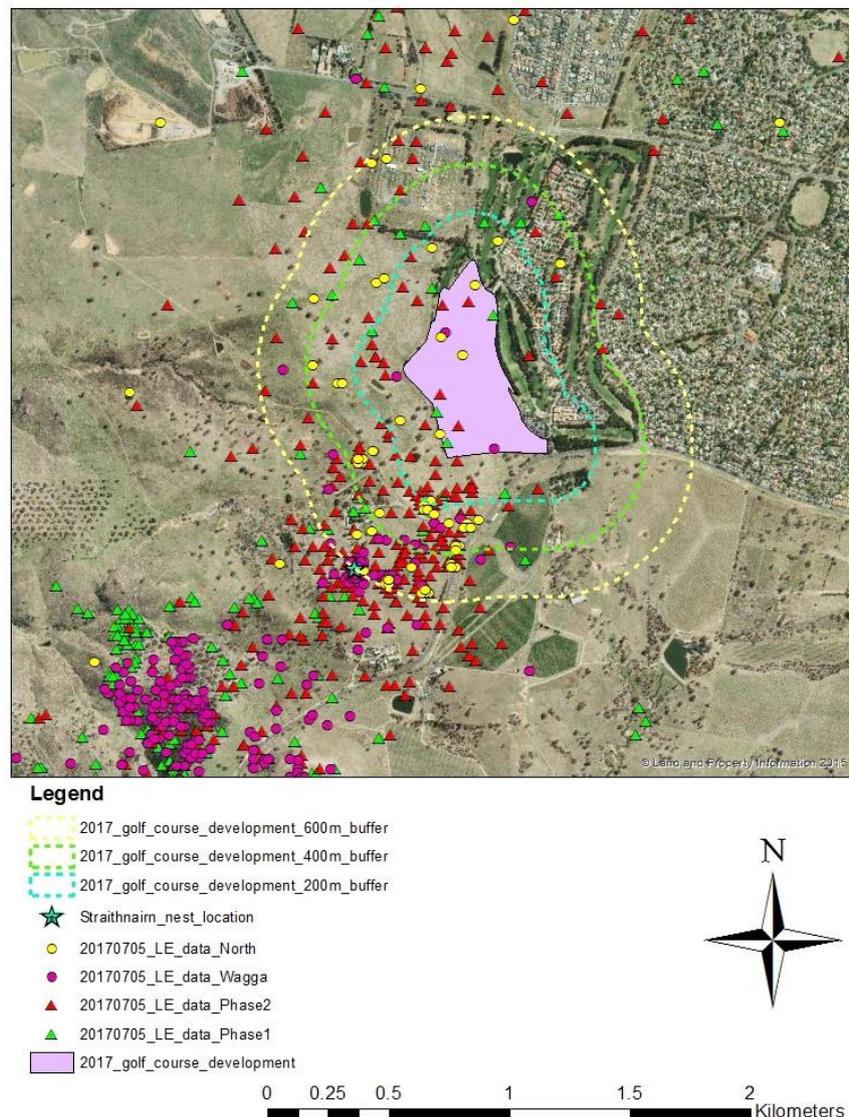


Figure 29. Map showing GPS fixes from Phase 1, Phase 2 and extra data for year 2 within a 200m, 400m and 600m of the golf course earthworks, which were conducted during Phase 2 of the study.

Winter migratory movements: a journey north

On March 8th 2017, the male Little Eagle left the ACT and headed north-west into NSW towards the townships of Cootamundra and Temora (Figure 30). It continued this northwest journey for eighteen days (8th – 25th March 2017), until it arrived at what appeared to be its winter range of movement grounds at Kalala Station near the townships of Birdum and Daly Waters, Northern Territory; a total journey of approximately 2800km (Figure 31). On the 24th May 2017 the GPS unit again stopped transmitting data, at which point the male Little Eagle was still residing in the Daly Waters area. No further transmissions have been received since.

During this period the Little Eagle flew a maximum distance of approximately 490km in one day (10th March 2017) and a minimum distance of 10km (20th March 2017)(Figure 32). While the male Little Eagle continued its journey north-west over the 18 day period, there was a four day period between the 17th and 20th of March where distance travelled per day lowered, and the bird appeared to rest in Leichhardt River region, north of the townships of Cloncurry and Mt Isa, Queensland (Figure 33) before resuming its journey north to Kalala Station (Figure 34).

The average travelling speed recorded for the male Little Eagle on the journey north was 20km/hr, with a maximum speed of 127km/hr recorded on the 28th March 2017. A maximum soaring altitude was recorded at 8390m above sea level on the 23rd March 2017 (speed 21km/hr), followed by 3120m meters above seas level on the 28th March 2017 (speed 127km/hr) and 2800 meters above sea level on the 24th March 2017 (speed 31km/hr). All other altitude readings were below 1780m. When hourly readings for altitude were examined, a pattern appeared of increasing altitude readings after 2pm, suggesting that the male Little Eagle may have been using the afternoon thermals to travel (Figure 35).

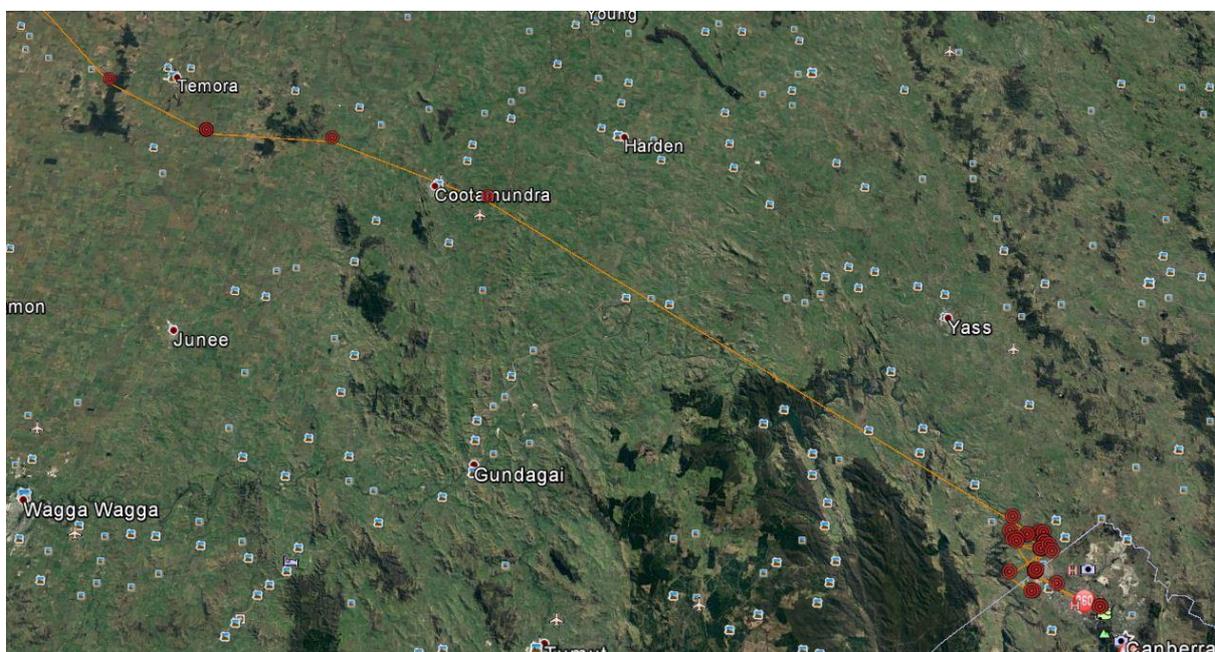


Figure 30. Google earth image showing the flight path of the male Little Eagle as it left the ACT and commenced on its northern journey in March 2017.



Figure 31. Map showing the total north western movements of the male Little Eagle from West Belconnen (ACT) to Kalala Station, near Daly Waters (NT). The journey took place over eighteen days between the dates of 8th – 25th March, 2017.

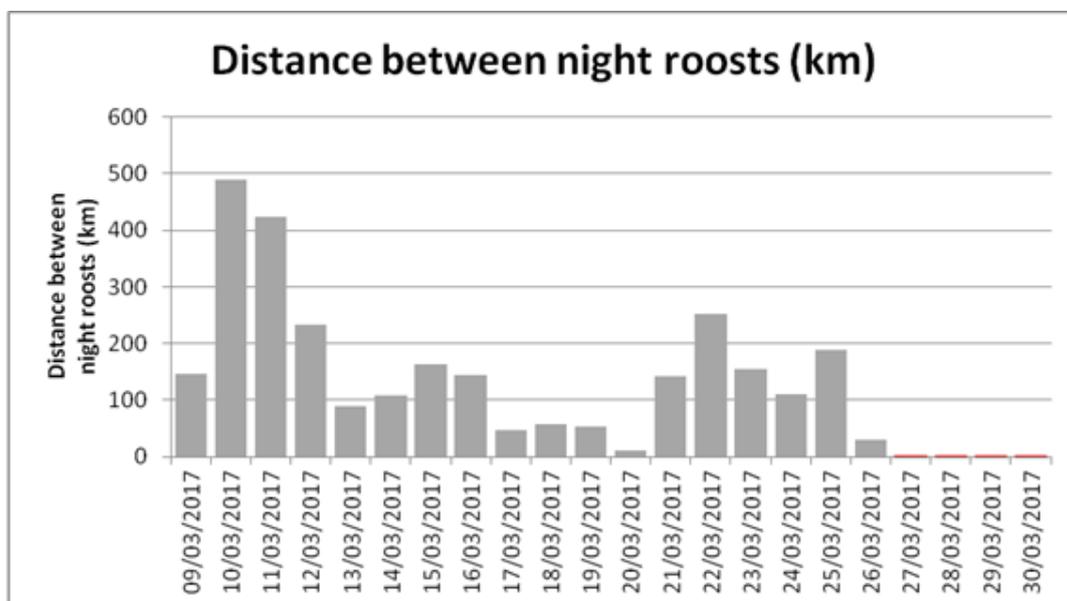


Figure 32. Graph showing distance between night roosts from the 8th March – 30th March 2017. Grey bars indicate movement towards at Kalala Station, NT, while red bars indicate dates that the male Little Eagle resided in what was found to be his winter range of movement. Graph provided by Sam Reid, Conservation Research, ACT Government.

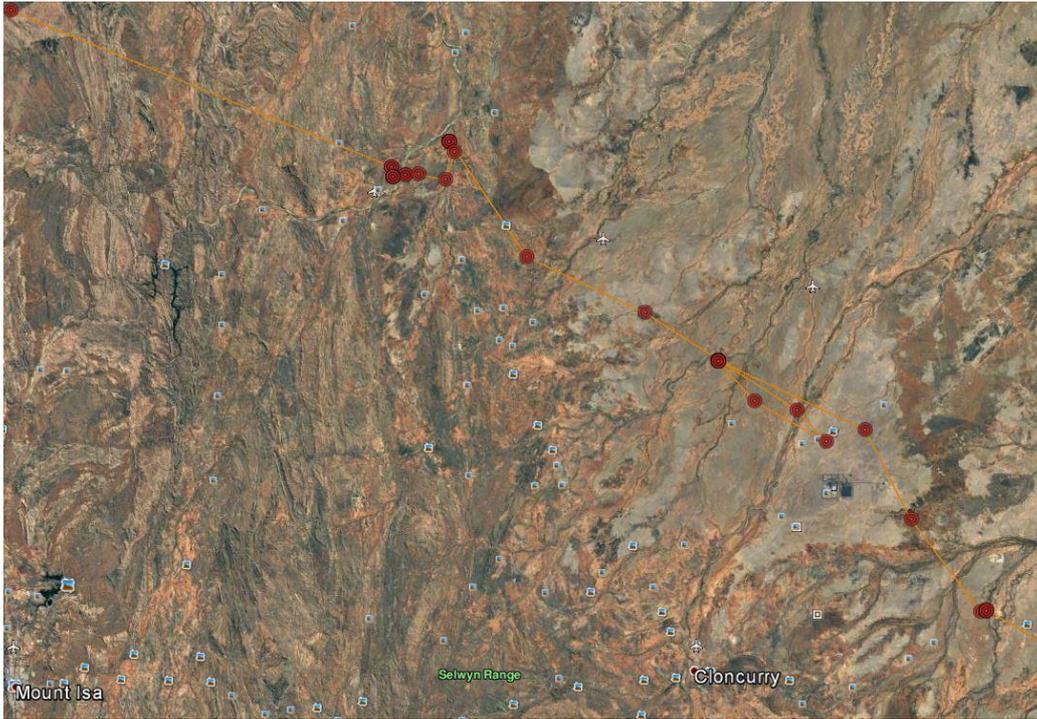


Figure 33. Map showing the GPS fixes of the male Little Eagle as it rested in the region of the Leichhardt River, north of the Selwyn Range, Queensland.



Figure 34. Kalala station, a pastoral lease near the townships of Birdum and Daly Waters NT, was where the male Little Eagle finally settled. Photo of raptor soaring in the vicinity of where the male Little Eagle settled in for the winter, courtesy Amanda Murphy, Kalala station.

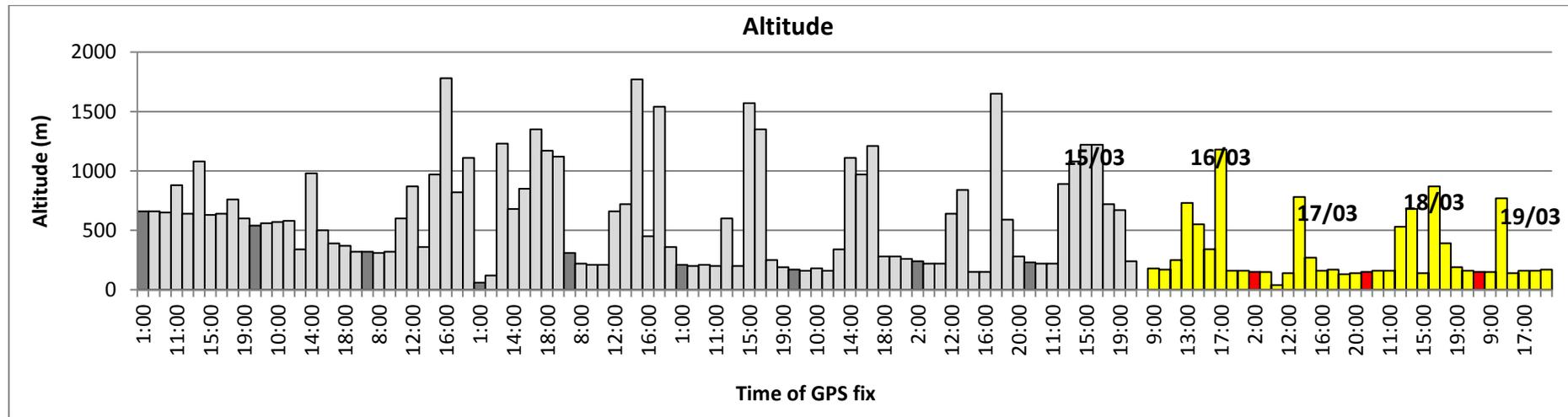
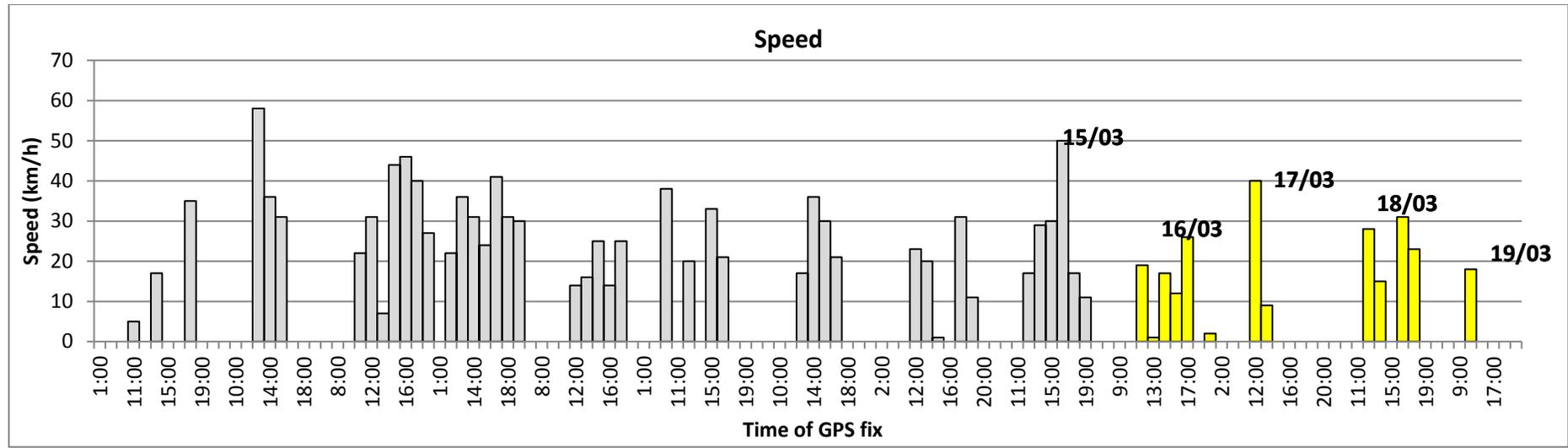


Figure 35. Graphs showing temporal changes in speed and altitude across a daily period as the male Little Eagle travelled north. Dates shown are 7th March - 19th March 2017. Yellow/red bars indicate day and night periods for latter dates. Graph provided by Sam Reid, Conservation Research, ACT Government.

At the end of the journey north, on the 26th March 2017, the male Little Eagle appeared to settle in to a discrete range of movement at Kalala Station, a remote cattle pastoral property near Birdum and Daly Waters, Northern Territory. The vegetation type in the area is predominantly Eucalypt open forests and woodlands (alternatively known as Eucalypt savannah), which are comprised of open wooded areas over a grassland understory (Figure 34).

Between the period of 26th March 2017 and 24th May 2017 (last day of transmission) the male Little Eagle resided in a small range of movement of approximately 30km² (Figure 36). Due to transmitter failure it is unknown as to whether this winter range of movement expanded past this date, whether the Little Eagle changed its winter range of movement location, or at what period the male Little Eagle returned south and journeyed back towards the ACT for the spring.

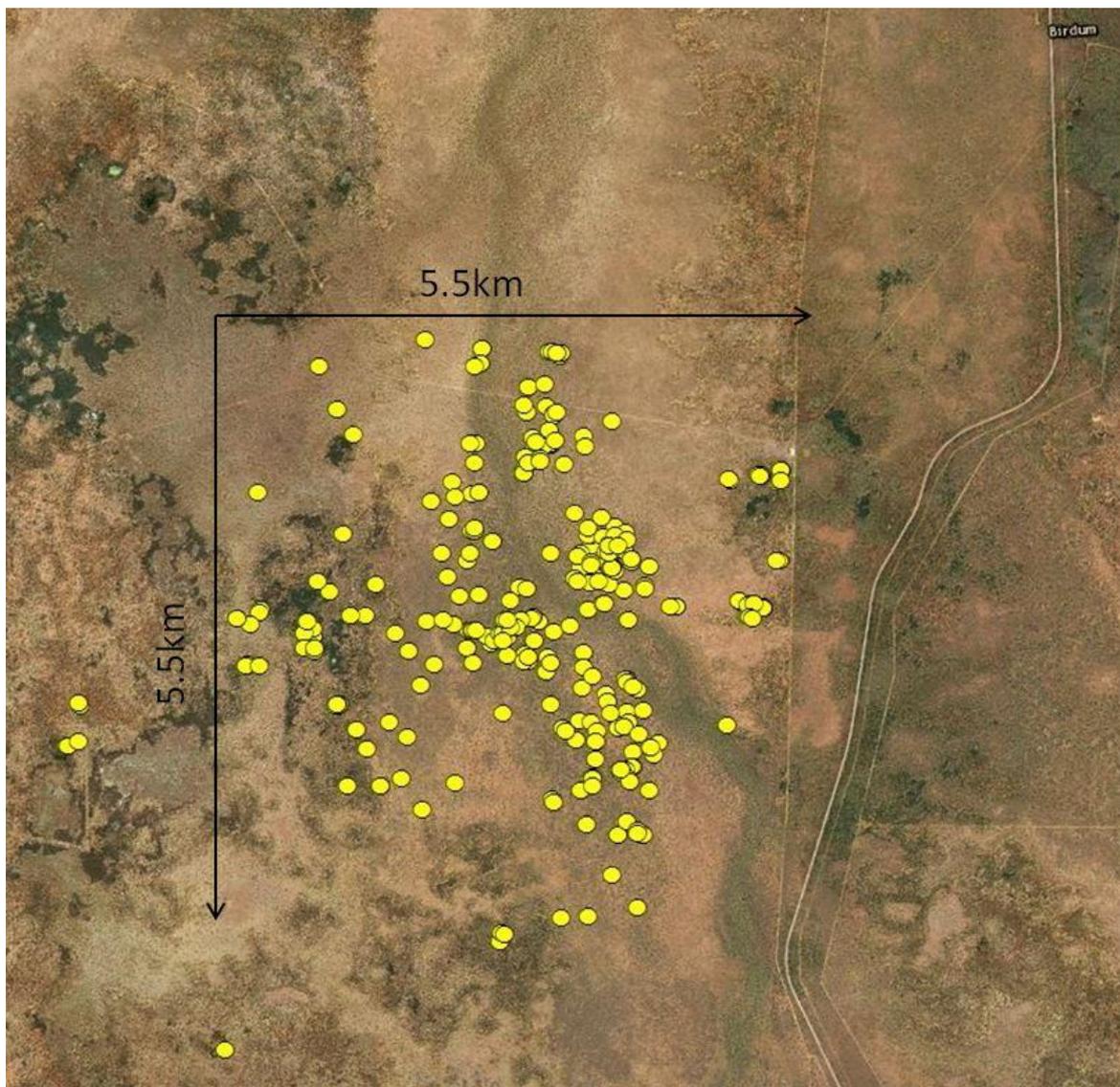


Figure 36. Map of GPS fixes showing the known winter range of movement of the male Little Eagle at Kalala Station, near Birdum, NT. GPS fixes were acquired between 26th March 2017 and 24th May 2017.

Project Outcomes and Recommendations

This study forms part of a larger research project on Little Eagle ecology and breeding in the ACT. The research aims to inform management seeking to maintain a viable population of the Little Eagle in the ACT region, in addition to adding to our knowledge of the eagle's general ecology through understanding range of movement and movement behaviours. This report compared the movements of a male Little Eagle during both an unsuccessful and successful breeding year. It also reported on the northwards migratory movements of the male Little Eagle to its winter range of movement.

In Phase 1 of the study, a non-breeding year, the range of movement of the male Little Eagle 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 (Brawata and Gruber 2016).

During Phase 2, which included a successful breeding event, the extent of the range of movement of the male Little Eagle was very similar to Phase 1, but was more focused on the core area and many fixes were within close proximity to the nest tree. During Phase 2 the northern areas of the range of movement across in NSW were not used as extensively, and when they were used, this occurred later in the season. Very few GPS fixes were taken in the CSIRO lands to the north-east of the nest site in Phase 2; instead fixes were condensed around the nest site in the Deferred development. While there is increased fixes around the nest location, more focus on the core area and less adventurous outliers in the breeding year, the male Little Eagle used much the same core areas are between breeding and non-breeding years.

Core areas for both flying and roosting were more restricted during Phase 2 than in Phase 1. When all data from year 2 was considered, it was found that during the early part of the season prior to Phase 2 the southern area of the range of movement was used. During this period the Conservation zone was used frequently, which then shifted to a higher use of the Deferred development area during Phase 2. After Phase 2 and prior to its journey north, the male Little Eagle focused its' activity in the mid and northern parts of its range of movement.

The commencement of earthworks in a former golf course located approximately 600m north-east of the nest tree provided an opportunity to examine the response of the male Little Eagle to major earthworks in close proximity (within 600m) of the nest. The large number of fixes found within 600m of the earthworks, including the increase in the number of fixes within 200m and 400m, during the successful breeding event of Phase 2 suggests that the male Little Eagle maintained close proximity to the nest tree and successfully bred despite earthworks being conducted.

Furthermore, a consistent pattern emerging when examining Phase 1, Phase 2 and all data for year 2 is the use of the southern area around the nest tree in the Deferred development, the northern area around the NSW border, and the distinct flight path up through the eastern side of the proposed Development area through the Proposed Offset areas that link the northern and the southern areas of the range of movement (Figure 37). These areas provided large trees for roosting and shelter as well as foraging habitat.

Maintaining an adequate amount of open woodland habitats, with mature trees for roosting close to foraging areas, is likely to be critical for breeding success. This report confirms the importance of mature trees and open woodland habitat throughout the southern and eastern sections of the Development area and Deferred development, as recommended in Brawata and Gruber (2016). Retaining of large mature trees in this area is likely to allow the passage of adults and younger birds to northern roosting and foraging areas.

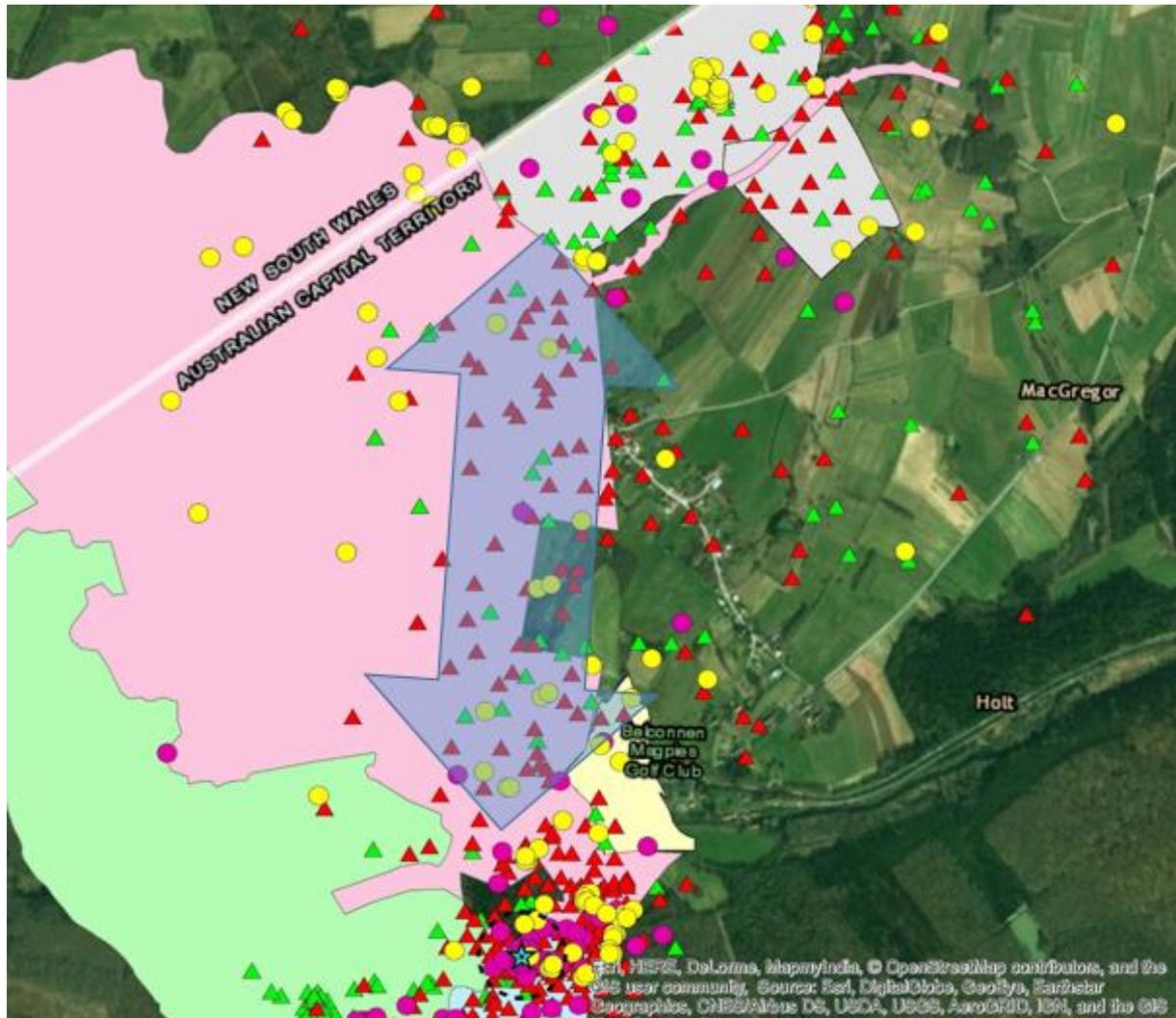


Figure 37. Map showing pattern of GPS fixes located along the eastern side of the Development area, indicated by a blue arrow.

The need to maintain this habitat has become even more apparent in light of the new data from a successful breeding season presented in this report. The fledgling was observed on a number of occasions using mature trees in close vicinity of the nest tree (S Rae *pers. comm.*), to which the parents would return with prey. In addition, taking into account the need of the fledglings to have open woodland for dispersal and to learn to forage close to the nest, the Deferred development area and the eastern fringe of the Development area provides a corridor of habitat for this Little Eagle pair and their young.

During both breeding and non-breeding years, the Conservation zone to the south-west of the nest tree was primarily used early in the season, with few fixes recorded in the area from summer onwards. In the second year of the study during August and September there was also intensive use of the Molonglo corridor, near the confluence with the Murrumbidgee River. The reason that this area is not utilised during other months is unknown. As such, if the Strathnairn nest is still used post development, it is uncertain whether foraging activities and movement will focus more towards the south and the conservation zone as the remaining foraging area close to the nest.

This study represents the first GPS tagging of a Little Eagle, and is one of the few GPS studies of raptors in Australia. In addition to addressing some of the knowledge gaps that exist on breeding and non-breeding range of movement, this study also captured the first known winter migratory movements of a Little Eagle. This highlights the importance of cross-border management of the species and increasing our understanding of the role the ACT region plays in the ecology of the species on a national scale.

This study has revealed important information on the movements and behaviour of a male Little Eagle. In future, research on the activity patterns of female Little Eagles and/or juveniles may shed more light on how the region is used for foraging and dispersal. 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 range of movement. 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, and indeed on a national scale, in the long term.

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