Koala Monitoring Program

Yarrabilba Priority Development Area

Annual Report on Koala Health and Movements

2023

Image of female koala 'Ella' being released in the Quinzeh Creek vegetation corridor.
July 2023 Koala Capture / Monitoring Event.

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1. Introduction

This report presents a summary of the findings from the 2023 *Koala Capture / Monitoring Events* that were conducted at the Yarrabilba Priority Development Area, by the Koala Ecology Group in partnership with Austecology.

The *Koala Capture / Monitoring Events* formed an integral part of the overall Koala Monitoring Program for the site and were undertaken during 3-day fieldtrips. The general aim during each fieldtrip was to catch, examine and fit collars to selected koalas, to facilitate a detailed examination of koala movement and health at the site.

This report synthesises the findings from fieldtrips conducted in 2023 and includes a detailed examination of movement and home ranges for collared koalas. These analyses are based on movement data that was collected by 1. Radio-tracking of collared koalas and 2. The LX remote monitoring system, which utilises GPS collars to automatically record the location of collared koalas twice daily.

The report also examines koala health in detail by compiling laboratory test results from examined individuals, and assessing how health has changed among those koalas that were part of the research program in previous years.

2. Methodology

Two *Koala Capture / Monitoring Events* were undertaken in 2023 during March and July, in the final year of the program. Each fieldtrip was three days in duration. The research team comprised three personnel from the Koala Ecology Group (Ben Barth, Bill Ellis, and Sean FitzGibbon).

During each fieldtrip, collared koalas were radio-tracked and habitat searches were conducted to try to locate new/untagged koalas ("cleanskins"), to catch, examine and tag. The nominated target habitat area within EPBCA Offset Area 1 was prioritised for these searches. In 2023, surveys were also conducted with a thermal-imaging drone, to detect koalas based on their heat signature.

When a koala was detected, suitability for capture was assessed. Capture attempts were made using the previously described methods, involving a tree climber and a ground support team implementing the extendable pole "flagging" method (Figure 1).

Captured koalas were restrained in a cloth bag in a cool location before being processed at the site. Processing took approximately 45mins per animal, during which time the koala was briefly anaesthetised (5mins) to facilitate a basic health examination and the collection of body measurements, as well as eye and urogenital swabs for disease testing (Figure 2). Measurements included body weight, head length and width, testes width (males), and an assessment of tooth wear (to age the koala) and body condition (from 1 to 10; 1 = very poor condition, 10 = excellent condition). The pouches of mature females were inspected for the presence of young. Cleanskin koalas were fitted with a coloured ear tag stamped with a unique number, following established protocols (right ear for females and left for males). A small stainless steel numbered tag was inserted in the opposite ear as back-up identification.

A select number of koalas were fitted with collars to enable them to be radio-tracked (during monthly *Koala Monitoring Events*) as well as monitored using the online LX Koala Tracker system. The main advantage of the LX monitoring system is that it provides close to real-time data on the location and activity level of collared koalas (see http://trackkoalas.com.au/ for further information on this koala-specific tracking technology). The LX system was first implemented at the Yarrabilba site in 2018 and since that time the developers have refined the technology to provide improved functionality and reliability.

All collars were manufactured with a rubber weak-link, designed to break should the koala become snagged by the collar (e.g. in vines or outer branches), thereby enabling the koala to free itself. When collared koalas were recaptured, we reassessed the fit of the collar to ensure it was neither too tight nor loose, and that it was still in good working order.

After processing, captured koalas were allowed time to fully recover from anaesthesia (~5min) before being released in the same tree from which they were captured. All procedures were in accordance with our current DES Scientific Purposes Permit and Animal Ethics Certificate.

Figure 1. Attempted capture of a koala using the flagging technioque.

Figure 2. Image showing how a swab sample is taken from the eye of an anaesthetised koala.

3. Results & Discussion

During 2023, a total of seven tagged, independent koalas were observed at the study site during the six-month program (Table 1). The sex ratio amongst the tagged koalas was skewed towards females, consisting of 5F:2M. Two of the tagged koalas (Ella and Douglas) were caught and examined during 2023. The total number of koalas that have been caught, examined and tagged at the site since 2017 is 32 individuals (Table 1).

In addition to the tagged koalas that were observed at the site, there were nine records of untagged koalas (aka. 'cleanskins') throughout 2023. Because these koalas had not been fitted with ear tags, it was not possible to distinguish between individuals. It is possible that some of these records would have been the result of the same individual being observed on more than one occasion.

Because of the reduced (six month) monitoring period in 2023, and the focus on retrieval of LX collars and base stations in the second (final) fieldtrip in July '23, relatively little information was collected on population demography, health and reproductive output compared to previous years of the program. For example, two of the females (Emily and Marlee) that were collared in 2023 weaned young in late 2022. These females may have concieved new young in late 2023 during the main breeding period (Sept-Oct), but they were not monitored during the second half of the year. For this reason, it is not possible to examine the annual level of reproduction. Similarly, little can be drawn on population demography or health in 2023, due to the very low number of catches and health assessments. .

Several of the tagged koalas that were observed in 2023 have been resident at the site for several years. The female Zara was first caught and tagged in mid-2018, and we have observed her produce several young over the past five years. The female Nyunga was first caught and tagged on the site in 2019. Two of the females (Emily and Marlee) collared in 2023 are the offspring of Jean, which was one of the first mature females tagged at the site, in October 2017. Emily was weaned in 2017 and Marlee in 2019.

Table 1. Details of the 32 koalas that have been tagged at the study site since May 2017. Koalas that were sighted in 2023 are shaded grey.

UQ #	Name	Sex	Wt (kg)	Age 1st capture	Left ear tag	Right ear tag	1st capture date	Latitude, Longitude	Notes
13007	Heath	M	3.65	2+	Orange F10	Yellow H10	17/05/2017	-27.811349, 153.106215	
13008	Bomber	M	9.10	6+	Light Blue 621	Pink 886	18/05/2017	-27.812197, 153.107219	
13009	Caitlin	F	5.74	4	Pink 866	Yellow H6	18/05/2017	-27.821973, 153.131331	
13486	Jean	F	5.56	3-6	metal UQ800	Orange F15	9/10/2017	-27.812155, 153.108676	
13487	Emily	F	1.07	1	metal UQ724	metal UQ789	9/10/2017	-27.812155, 153.108676	Jean's offspring
13488	Cain	M	8.07	2-4	Royal Blue G8	metal UQ796	9/10/2017	-27.813243, 153.103977	
13489	Scarlet	F	4.81	1-3	metal UQ753	Royal Blue G14	10/10/2017	-27.811097, 153.104962	
13490	Sue-Bob	F	5.66	5-10	-	Orange F20	10/10/2017	-27.812209, 153.106371	
13495	Kobe	F	5.06	3-6	Metal UQ175	Yellow C20	20/03/2018	-27.813724, 153.116915	
13304	Zara	F	6.17	4-8	Maroon A16	Yellow C4	6/06/2018	-27.809703, 153.103454	
13496	Squeak	F	0.85	<1	Metal UQ956	-	8/10/2018	-27.809757, 153.102653	Zara's offspring
13497	Lindsay	M	5.80	2-4	Yellow C10	Metal UQ958	10/10/2018	-27.817012, 153.109601	
12341	Kevin	M	2.15	~18 mths	Light Blue B5	Metal UQ991	4/03/2019	-27.811086, 153.104432	Sue-Bob's offspring
12342	Meghan	F	5.02	3-6	Metal UQ965	Light Blue B3	5/03/2019	-27.818168, 153.108580	
13508	Lucky	M	7.40	2-4	Yellow C19	Red A19	27/05/2019	-27.809771, 153.103803	
13509	Nyunga	F	3.24	1-3	Metal UQ955	White T7	28/05/2019	-27.815716, 153.115121	
13518	Marlee	F	-	<1	Metal UQ118	-	1/08/2019	-27.812705, 153.108693	Jean's offspring
13307	Lilly	F	5.55	4-8	Green E9	White T3	19/11/2019	-27.823554, 153.108909	
13308	Wooten	M	1.40	<1	UQ170	-	20/11/2019	-27.823554, 153.108909	Lilly's offspring
13533	Millie Mae	F	7.26	4-8	Metal UQ158	Green Q18	21/11/2019	-27.809418, 153.099941	
13557	Kamala	F	2.47	1	Metal UQ940	Green Q12	10/11/2020	-27.813689, 153.113378	Nyunga's offspring
13269	Bilba	F	2.08	1	Metal UQ329	Blue B18	10/11/2020	-27.8107054, 153.103070	Zara's offspring
13558	Gladys	F	4.93	2-4	Metal UQ939	Maroon A2	11/11/2020	-27.8110245, 153.1056022	
13564	Ella	F	5.23	3-6	Metal UQ934	Grey blue R10	19/04/2021	-27.811320, 153.106273	

13565	Banjo	M	2.54	1	Maroon A3	Metal UQ987	20/04/2021	-27.810577, 153.103908	
13316	Jana	F	5.28	5-10	Metal UQ114	Light Blue B16	21/04/2021	-27.815245, 153.110754	
13328	Amelia	F	0.74	<1	Metal UQ917	-	22/11/2021	-27.811498, 153.104591	Gladys' offspring
13334	Clancy	M	5.55	2-4	Brown I12	UQ534	14/02/2022	-27.812775, 153.101376	
13332	Miso	F	3.09	1-3	Metal UQ916	Orange (no #)	15/02/2022	-27.811673, 153.103339	
13333	Larabee	M	4.12	1-3	Orange front / light blue back	Metal UQ952	16/02/2022	-27.811099, 153.103760	
13354	Brumby	F	2.95	1-3	Metal UQ576	Light blue front / red back (no #)	12/07/2022	-27.811747, 153.104272	
13373	Douglas	M	5.80	2-4	Red 7894		15/11/2022	-27.816287, 153.117667	

3.1 Summary of Koala Health (2023)

Overview

Although four koalas were monitored with collars in 2023, only two of these were caught and given a basic physical health examination. The other two individuals dropped their collars and so were not recaptured for collar removal during the July ’23 fieldtrip.

The health examinations involved checking the eyes and urogenital orifice for signs of inflammation or infection (e.g. staining of the rump), which is often caused by the bacteria *Chlamydia*. A physical examination was also conducted to check for signs of poor health (e.g. fungal infection, lesions) and to determine body condition score.

Ocular and urogenital swabs collected during the fieldtrips were sent for laboratory testing to determine if any of the sampled koalas were positive for *Chlamydia*. The laboratory used a quantitative polymerase chain reaction (PCR) test, which amplifies any chlamydial DNA that is present on the swab samples; this is the gold-standard method of testing for chlamydial infection.

Table 2 provides details on the visual health and swab test results for the two koalas that were examined in 2023. Where possible, Table 2 also shows the equivalent health information and test results for the same koalas, from previous years.

Table 2. Details of health and swab test results for koalas examined in 2023 (blue highlight) and previous years (grey highlight, where data available).
UGT = urogenital tract; BCS = body condition score (1 = very poor condition, 10 = excellent condition).

Koala	Examination date	Visual signs of disease / condition notes	Left eye swab	Right eye swab	UGT / penile swab
Ella	17/7/2023	No overt disease (BCS 7)	negative	negative	negative
Ella	12/7/2022	No overt disease (BCS 7)	negative	negative	negative
Ella	19/4/2021	No overt disease (BCS 7)	negative	negative	negative
Douglas	18/7/2023	No overt disease (BCS 7)	negative	negative	negative
Douglas	15/11/2022	Overt disease, left eye (BCS 4)	positive	negative	positive

The results show neither of the two koalas examined in 2023 returned a positive swab test result (Table 2). The female koala Ella also tested negative in 2021 and 2022, and displayed no overt signs of disease. The male koala Douglas was first caught in November 2022, at which time he presented with an inflamed and weepy left eye. His left eye and penile swab tested positive for Chlamydia and the infection was successfully treated with antibiotics at Australia Zoo Wildlife Hospital. He was released back at the site in January 2023, and it is pleasing that he continued to test negative for *Chlamydia* six months after his return.

Details and health profiles of examined koalas

This section provides greater detail on the health and physical condition of the two koalas that were examined in 2023.

Female 13564 'Ella'

This female koala was first caught in April 2021 and was estimated to be between 3-6 years old. At the time she had a large, semi-independent offspring, which was sitting in a separate part of the tree and was not caught.

At first capture Ella weighed 5.2kg and the physical examination suggested she was in good health (body score 7/10). She had no signs of chlamydial infection or disease. Swabs collected from each eye and the urogenital sinus were sent for laboratory PCR analysis and later returned negative test results, indicating that no *Chlamydia* DNA was detected (Table 2). Ella was fitted with ear tags and an LX collar (A5-549). She carried the same collar until July 2023, when it was removed at her final capture.

Ella was also recaptured in July 2022 to enable a health check and to replace the VHF transmitter on the collar. At that time Ella was not carrying a pouch young but she was known to have weaned a young in early 2021 and then again in early 2022. Ella was monitored via the LX online mapping webpage throughout 2022 and 2023. She undertook some incredibly large and unusual movements in late 2022 and early 2023, which are examined in more detail in Section 3.2.

During the final fieldtrip in July 2023, Ella was recaptured and given another health check (Figure 3). She appeared to be in good condition (body score 7/10) and as stated, the collected swab samples tested negative for *Chlamydia*. Her pouch was empty. We removed the tracking collar from Ella and then released her at the point of capture (Figure 4).

Figure 3. Female koala 'Ella' at her final examination and collar removal, July 2023.

Figure 4. Dr Bill Ellis releasing female 13564 'Ella' in the Quinzeh Ck corridor, July 2023.

Male 13373 'Douglas'

This male koala was first captured at the study site in November 2022, from habitat adjacent to the south side of the powerline easement. He weighed 5.8kg and was in poor condition (body score 4/10). It was immediately apparent that Douglas had an infection in his left eye, which appeared weepy and had crusty exudate around the eyelid. He was taken immediately to Australia Zoo Wildlife Hospital (AZWH) for treatment.

Detailed veterinary examination revealed that Douglas had further health issues, including the formation of pustules around his prostate. He was put on a course of antibiotics and required an extended period of treatment to resolve his health issues. He was eventually cleared for release by the AZWH veterinary team in early January 2023 (Figure 5). Douglas was returned to the Yarrabilba study site fitted with an LX collar so that his movements and activity level could be closely monitored via remote data uploads. Further detail regarding Douglas's movements are provided in Section 3.2.

Figure 5. Male koala 13373 ‘Douglas’ at the end of his treatment at Australia Zoo Wildlife Hospital, just prior to being returned to the Yarrabilba study site (January 2023). Note, the shaved area on his forearm facilitated blood collection and administration of medicines and fluids.

During the final fieldtrip in July 2023, Douglas was recaptured and his health examined (Figure 6). He appeared to be in good condition (body score 7/10) and showed no signs of disease. As stated above, the collected swab samples tested negative for *Chlamydia*. The LX tracking collar was removed and Douglas was released at the point of capture.

Figure 6. Male koala 13373 ‘Douglas’ at his final recapture to remove the tracking collar.

Conclusion

In 2023, only two koalas were caught and examined during the reduced monitoring period. Both koalas appeared healthy and tested negative for *Chlamydia*. The female Ella was not carrying a pouch young when examined in July ’23, however, she may have conceived a young later in the year, beyond our monitoring period.

Although neither of the two examined koalas returned a positive swab test result when sampled in 2023, we are aware that there is still at least a low level of chlamydial infection within the general koala population at the study site. In support of this, two other tagged koalas (Nyunga and Larabee) were spotted during 2023 and visual examination with binoculars suggested that both had slightly stained rumps. Sometimes this slight staining can be due to tree bark or to koalas sitting on fresh scats, but it is often indicative of chlamydial infection of the urogenital tract/bladder. Further, Austecology conducted extensive searches for koalas on the study site in November 2023, which resulted in numerous koalas being sighted, some of which were noted to have inflamed or crusty eyes/conjunctiva (L. Agnew pers. comm.). These observations may have been indicative of chlamydial infection.

These instances of overt disease are evidence of at least a low level of chlamydial infection within the population, but it is not possible to estimate infection rate due to inadequate testing of a representative sample. It should also be remembered that some koalas may appear healthy and free of overt disease, yet still be infected with *Chlamydia*.

3.2 Summary of Koala Movement (2023)

Overview

At the start of 2023, four koalas were fitted with LX collars. Three individuals (Emily, Marlee, Ella) had been fitted with collars during 2022 and continued to carry them in 2023. The fourth individual, a male named Douglas, was released at the site in mid-January 2023 after being treated at Australia Zoo Wildlife Hospital (see Section 3.1).

All four koalas were fitted with LX Koala Tracker collars. This collar system was designed specifically for use on koalas (see http://trackkoalas.com.au/ for more information). Each collar contained a GPS device and a 3-axis accelerometer, enabling location and activity level to be remotely monitored via the online LX platform. Collars were programmed to record location and activity data every 2-4 hours. These data were transmitted to the online platform via solar-powered base stations deployed up tall trees at the study site. In addition, collars contained a standard VHF transmitter that enabled koalas to be routinely radio-tracked.

As with all GPS devices, logged locations can be inaccurate for reasons such as poor GPS satellite reception (e.g. due to heavy cloud or thick canopy) or unfavourable satellite geometries (e.g. satellites low on the horizon). Because of this, not all of the locations (i.e. fixes) that were logged on the collars were suitable for use in analyses, due to the unacceptably high location error for some fixes (determined from the HDOP value assigned to each fix). Only those fixes with an estimated accuracy of approximately 20m or less were retained for mapping and analytical purposes. These retained data points were used to plot movements, examine habitat use, and estimate home ranges for the monitored koalas (Figures 7 - 25).

All collars incorporated a weak-link made from a rubber o-ring. The weak-link was designed to either break or stretch if the koala became snagged by the collar, thereby enabling the koala to free itself.

The four collared koalas were monitored for varying durations in 2023. All four were still carrying collars when we conducted the first fieldtrip in March. However, by the end of April two individuals (Emily and Marlee) had dropped their collars, presumably as a result of the collars becoming snagged. The other two koalas (Ella and Douglas) continued to carry their collars until the final fieldtrip in July, at which time they were recaptured for collar removal and health assessments (see Section 3.1).

Collar deployments in 2023 resulted in detailed movement datasets for each of the four monitored koalas. Table 3 lists the number of fixes that were obtained for each individual and presents various other metrics, including estimates of home range size using two common techniques (further detail provided below). The same techniques were used to examine koala home ranges in all previous annual reports for the study site. Home range estimates and movement metrics were calculated in the online software "ZoaTrack" after raw data were imported (see https://zoatrack.org).

The mean number of fixes (± standard error) per koala during the 2023 monitoring period was 802 ± 67 fixes; Euclidean distance travelled while collared ranged from 4.3km (Emily) to 7.4km (Douglas). However, these data were collected over widely variable time periods for each koala (range 99 – 197 days). To enable a fair comparison of movement rates between individuals, the total distance travelled while collared was divided by the number of days collared, to produce a metres-moved-per-day statistic. Somewhat surprisingly, the females Emily and Marlee had the highest rates of daily movement, at 43.5m and 45.0m per day, respectively. Although Ella undertook some extremely large daily movements, these were offset over her total monitoring period (197d) by many days of relatively small movements.

Table 3. Details of movement datasets and home range estimations for koalas collared in 2023.

Koala name	No. fixes	No. days	Avg. no. fixes / day	Euclidean distance (m)	Avg. distance travelled / day (m)	MCP 95% (ha)	KUD 50% (ha)	KUD 95% (ha)
Ella	927	197	4.7	6408	32.5	128.3* (12.2)	7.4* (2.1)	98.7* (22.7)
Douglas	904	188	4.8	7357	39.1	43.8	14.8	59.0
Emily	655	99	6.6	4307	43.5	9.3	1.5	9.9
Marlee	722	113	6.4	5084	45.0	5.9	1.3	7.4
mean ± std error	802 ± 67	149 ± 25	5.6 ± 0.5	5789 ± 679	40 ± 2.8	17.8 ± 8.8*	4.9 ± 3.3*	24.8 ± 11.9*

MCP = minimum convex polygon (home range estimator)
KUD = kernal utilisation distribution (home range estimator)
* Two home range estimates were calculated for Ella 1. Using full dataset, and 2. Using subset of data, excluding exploratory movements (shown in brackets). Means and standard errors were calculated using the subset home range estimates.

Methods of home range estimation

Home range sizes were estimated using two common techniques: 1. minimum convex polygon (MCP) home range estimator, and 2. kernal utilisation distribution (KUD) home range estimator.

Otherwise known as a convex hull, the MCP home range estimate uses the smallest convex area that contains all the specified location data. This was one of the earliest methods developed for examining home ranges and is sometimes criticised for the extent of non-habitat that can be included in ranges, especially in heavily fragmented landscapes. It is common to use the 95% MCP, which excludes the furthest outlying 5% of locations, on the basis that these may have been atypical/exploratory movements that do not constitute part of the home range.

The 95% KUD home range estimate defines the outer boundary of the area where the koala would be expected to be found 95% of the time. The 50% KUD estimate is generally used to determine core home range areas. The fixed kernel density estimator is a non-parametric method of home-range analysis, which uses the utilisation distribution to estimate the probability that an animal will be found at a specific geographical location. This fixed method of kernel smoothing ignores the temporal sequence whereby locations were obtained, and assumes that all locations from that individual are spatially autocorrelated. This means that the location of an individual koala at a particular point implies an increased probability that the koala frequents neighbouring locations as well. The kernel utilisation distribution accurately estimates areas of high use by the focal animal, providing that the level of smoothing is appropriate.

Koala habitat use and home ranges

Very detailed movement datasets were obtained for the four collared koalas (>650 fixes ea.). The smallest datasets were those for Emily (n=655 fixes) and Marlee (n=722 fixes), both of which dropped their collars during April 2023. All datasets consisted of a sufficient number of fixes to examine home ranges.

Movements plots (Figures 8 – 13) show that the four collared individuals made extensive use of the site. As in previous years, most movements were concentrated along the creeklines and associated riparian vegetation. But some koalas also utilised habitat away from the creeklines. Emily and Marlee used much of the habitat between the two branches of Quinzeh Creek in the north of the site. Many of Emily's recorded locations fell in the area dominated by acacia and eucalypt regrowth (Figure 9); this area has been well-utilised in previous years by numerous koalas, including Gladys (F), Bilba (F), Cain (M), Kevin (M), Sue-Bob (F), and Zara (F) (see figures in previous annual reports). It is highly likely that additional uncollared koalas utilised this area of short regrowth vegetation in 2023.

Douglas's movement plot shows his activity was centred slightly east of Emily and Marlee, but still focused along Quinzeh Creek (Figure 11). The most striking aspect of his movements is that he made numerous crossings of the powerline easement. A large proportion of his recorded fixes were in the fauna corridor north of the powerline easement and south of Yarrabilba Drive. Interestingly, the trajectory plot for Douglas suggests that he often crossed the fence on the south side of the powerline easement at the same point. Further, the data suggests that he often utilised the same tree beside the fence, either before or after crossing the easement (see inset in Figure 11).

The home range estimates for Emily and Marlee were similar in size and location, sharing a high degree of spatial overlap. Their estimated home range sizes ranged between 5.9ha and 9.9ha for both estimation techniques (Table 3). Their home ranges consisted almost entirely of forested habitat, other than the 95%KUD polygon for Emily which included a small portion of cleared land on the western polygon boundary (Figures 15, 16, 21, 22). The core home range areas for these two female koalas, determined from the 50% KUD polygon, were almost identical in size (1.5ha v 1.3ha).

Douglas had a substantially larger home range area, covering 44ha using the 95%MCP estimator, and 59ha using the 95%KUD polygon. Both polygons encompassed a large portion of non-habitat in the form of cleared land, parklands, and industrial estate (Figures 17 & 23). This was due to the general shape of the area utilised by Douglas (an "L" shape), and also the fact that he utilised habitat at the edges of the fauna corridor and other forested areas at the study site. As such, both home range estimators included considerable areas of non-habitat. This was most exaggerated in the 95% KUD polygon (Figure 23). This highlights a drawback of some home range estimation techniques, which can incorporate large areas of non-utilised space, especially in highly fragmented landscapes. Almost all of Douglas's core area (50% KUD) was in forested habitat, and comprised three discrete areas totalling 14.8ha (Figure 23).

The female Ella undertook some incredibly large and unusual movements in 2023 (Figure 12). These movements were a continuation of some even larger movements that she undertook in 2022 (Figure 13). Ella was first collared at the study site in April 2021. We collected a large movement dataset in 2021 (>1300 fixes) and the plots of her home range showed that she occupied a small, stable home range (estimated at 4.7ha using 95% MCP and 5.5ha using 95% KUD - see 2021 annual report). Ella weaned a young in early to mid-2021 and then quickly conceived again, as she was carrying a large back young in February 2022. She continued to occupy the same small home range area for the first half of 2022. She had weaned the second young by the time she was recaptured in early July 2022 (no new pouch young present).

Approximately one month later, on the 11th August 2022, Ella commenced her large and unusual movements (Figure 13). She departed her home range area to the east and her GPS uploads show that for two nights she tracked along the mesh fence on the southern side of the powerline easement. On the 14th August '22, she crossed the easement and moved northwards into the Quinzeh Creek fauna corridor. She crossed Yarrabilba Drive (exact path unknown), continued along the creek corridor and then in early September, she reached the extensive forest area that is the Wickham Timber Reserve. Over the next month she travelled a large circle (>7km) in a clockwise direction (Figure 13). Notably, Ella rarely stayed more than one night in any area during this extraordinary journey. On one night (4th / 5th Sept) she covered more than 2km. It is difficult to know what motivated these large and relatively rapid movements.

Ella's circular pathway led her back to the Quinzeh Creek corridor, to habitat she had previously used. She remained in the same area for a short while. In November 2022, Ella crossed back over Yarrabilba Drive and the powerline easement. The uploaded GPS locations strongly suggest that she transited through the cleared development area to the south of the fauna corridor, and then walked across Yarrabilba Drive, through further cleared development area, and then across the easement (rather than following the vegetated corridor).

Remarkably, after covering a huge distance over several months, Ella briefly returned to her former home range area for approximately one week, in late November 2022. She then tracked back east and crossed the powerline easement for the third time, retracing the movement path that she took when she first left her home range area (Figure 13).

In early January 2023, Ella undertook further exploratory movements through developed areas and habitat fragments north of Yarrabilba Drive. By early February, her movements had settled and the GPS uploads suggested that she had finally established a new home range area in the Quinzeh Ck corridor immediately south of Pineview Rd. It was in this area that Ella was recaptured and her collar removed in July 2023.

Ella's 2023 home range area was estimated using two approaches. Firstly, the full 2023 movement dataset was used to derive home range estimates using the MCP and KUD techniques (Figures 18 & 24). Secondly, we recalculated these estimates after excluding all locations recorded prior to 5th

February 2023, as these movements were regarded as exploratory (Figures 18 & 25). This assessment was based on a plot of the data using the Google Earth Timeslider function, which displays the sequence of movements through time (using the timeslider bar). The static plot of the timeslider file is shown in Figure 13. When the exploratory movements were excluded, Ella's 2023 home range area reduced from 128ha to 12ha using the 95% MCP, and from 99ha to 23ha using the 95% KUD technique (Table 3). The movement dataset collected for Ella over 2.3yrs highlights that even mature koalas can undertake large dispersal movements and complete shifts in the location of their previously well-established home range areas.

Conclusion

In 2023, detailed movement datasets were collected for four koalas using LX collars and by radio-tracking. These data showed that the examined koalas made extensive use of the vegetated creeklines and areas adjacent to them. Core home ranges were focused on riparian areas along Quinzeh Creek. However, koalas are highly mobile and can traverse virtually any type of urban landscape element, including roads, residential and industrial estates, and large stretches of bare ground. This is especially true of dispersing or transitory individuals, as demonstrated by Ella during the 2022 and 2023 monitoring periods.

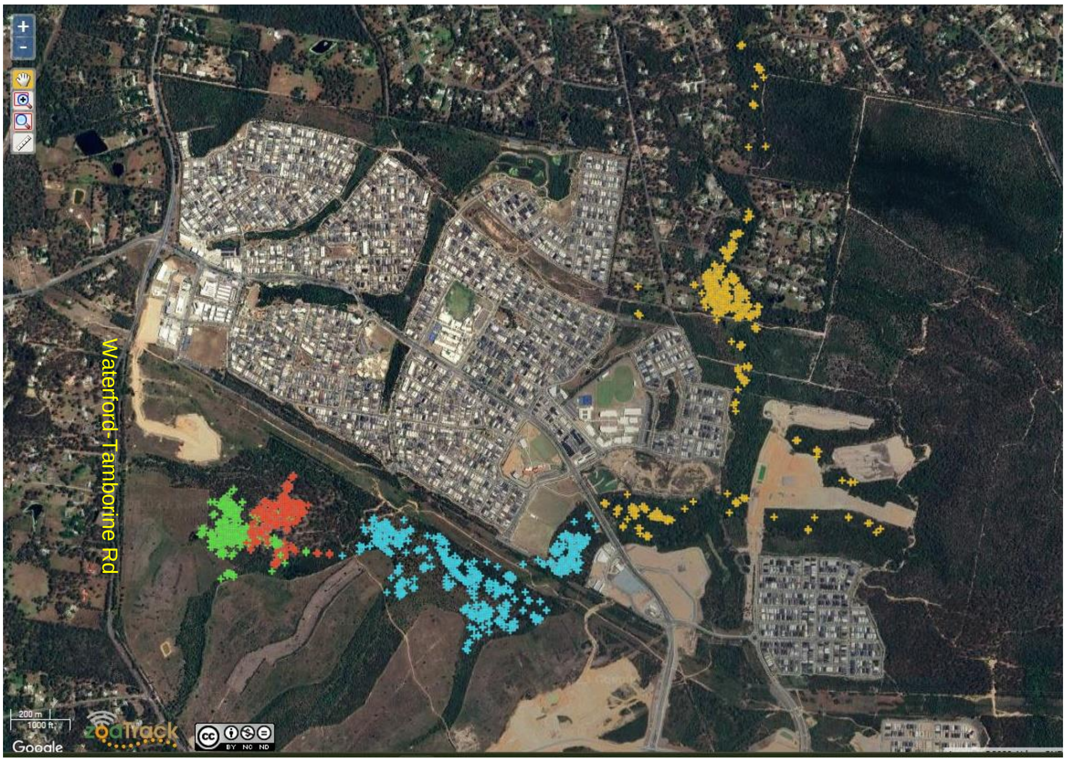

Figure 7. Plot of recorded locations for the four koalas collared at the Yarrabilba study site in 2023.
Colour key: Emily (green), Marlee (red), Douglas (blue), Ella (orange).

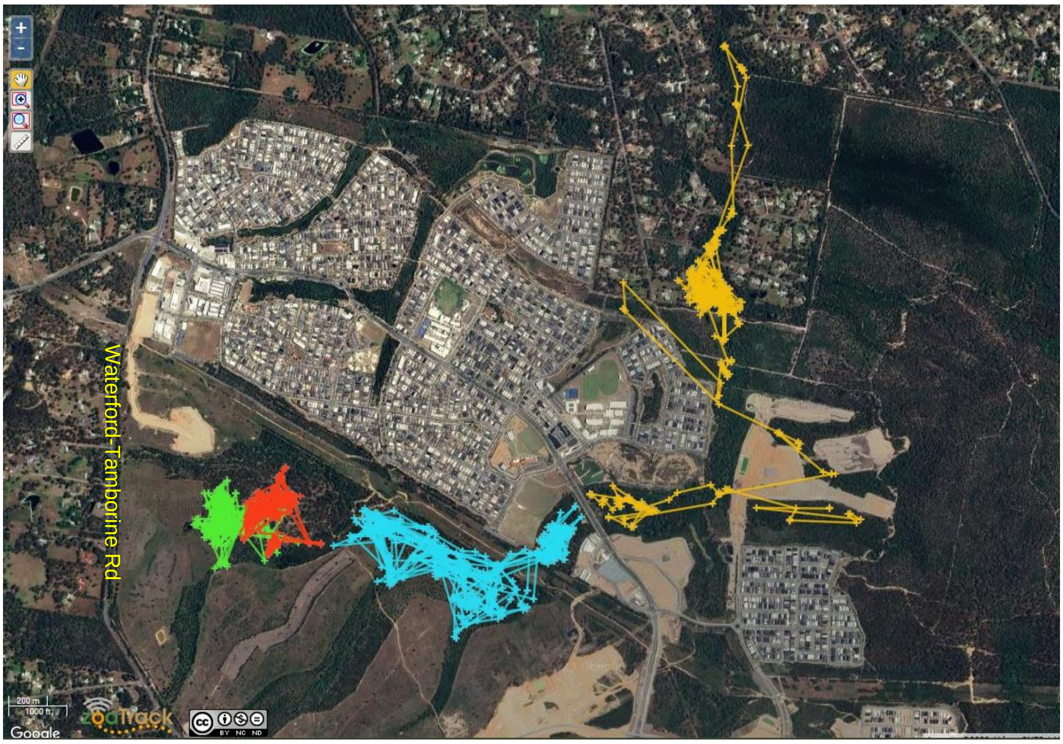

Figure 8. Plot of locations with consecutive fixes joined by trajectory lines, for the four koalas collared at the Yarrabilba study site in 2023. Lines do not necessarily indicate exact movement pathways.
Colour key: Emily (green), Marlee (red), Douglas (blue), Ella (orange).

Figure 9. Plot of movements for Emily.

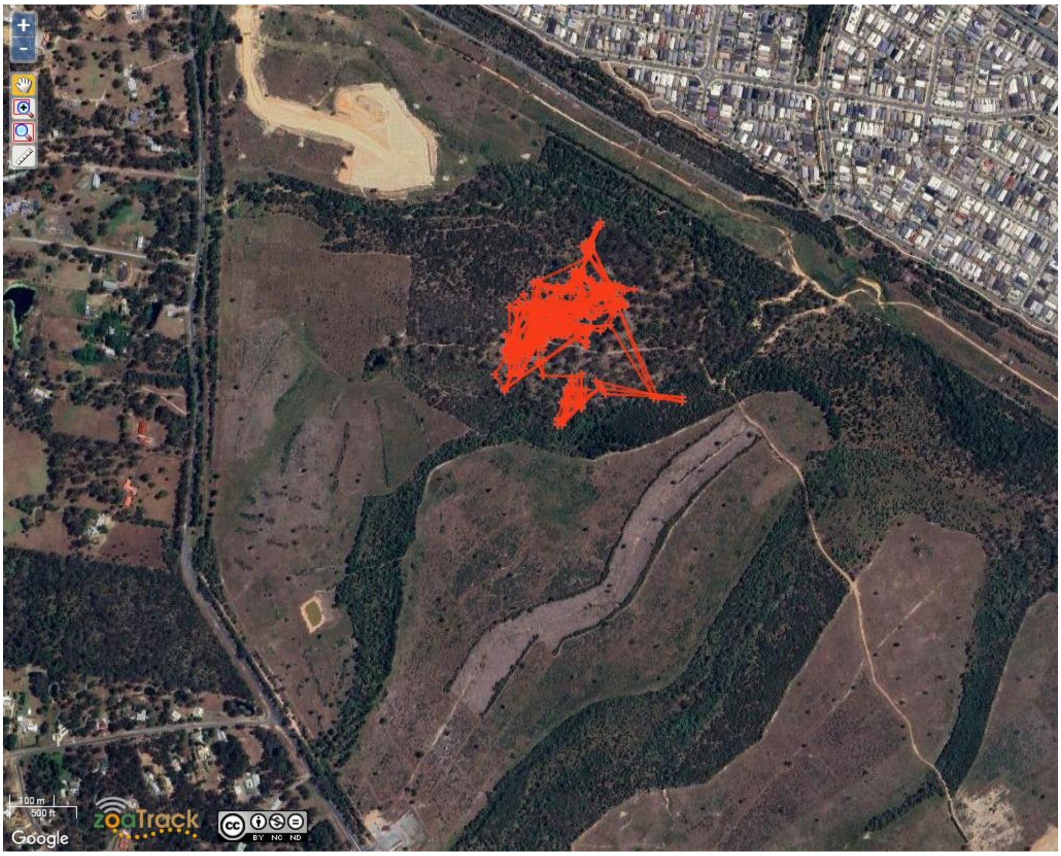

Figure 10. Plot of movements for Marlee.

Figure 11. Plot of movements for Douglas. Inset shows zoomed view of movements across the easement and the concentration of fixes in one area on the southern side, suggesting repeated use of the same tree.

Figure 12. Plot of movements for Ella.

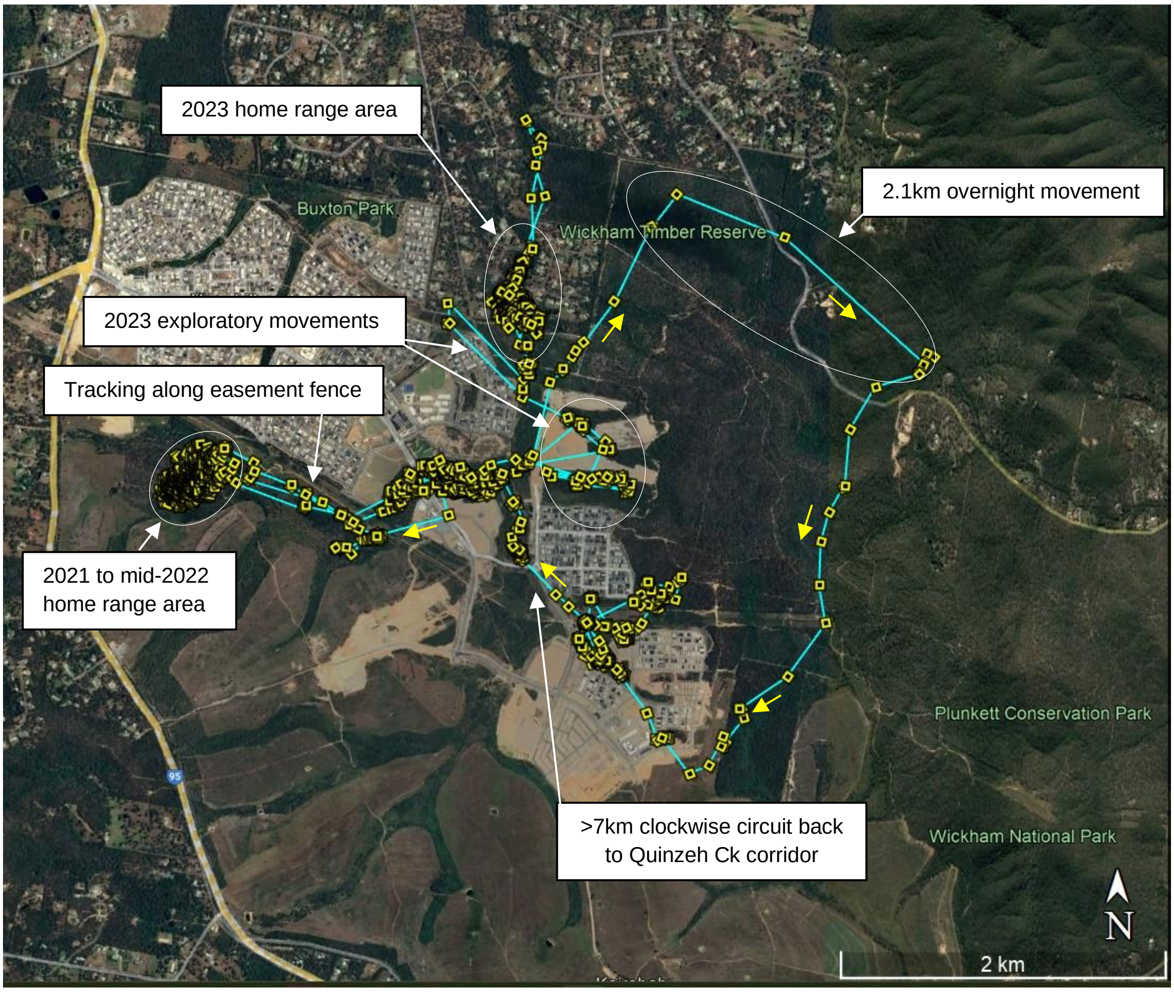

Figure 13. Plot of movements for Ella using her entire collar dataset (April 2021 – July 2023), with notes on features of interest. Direction of travel is shown by yellow arrows.

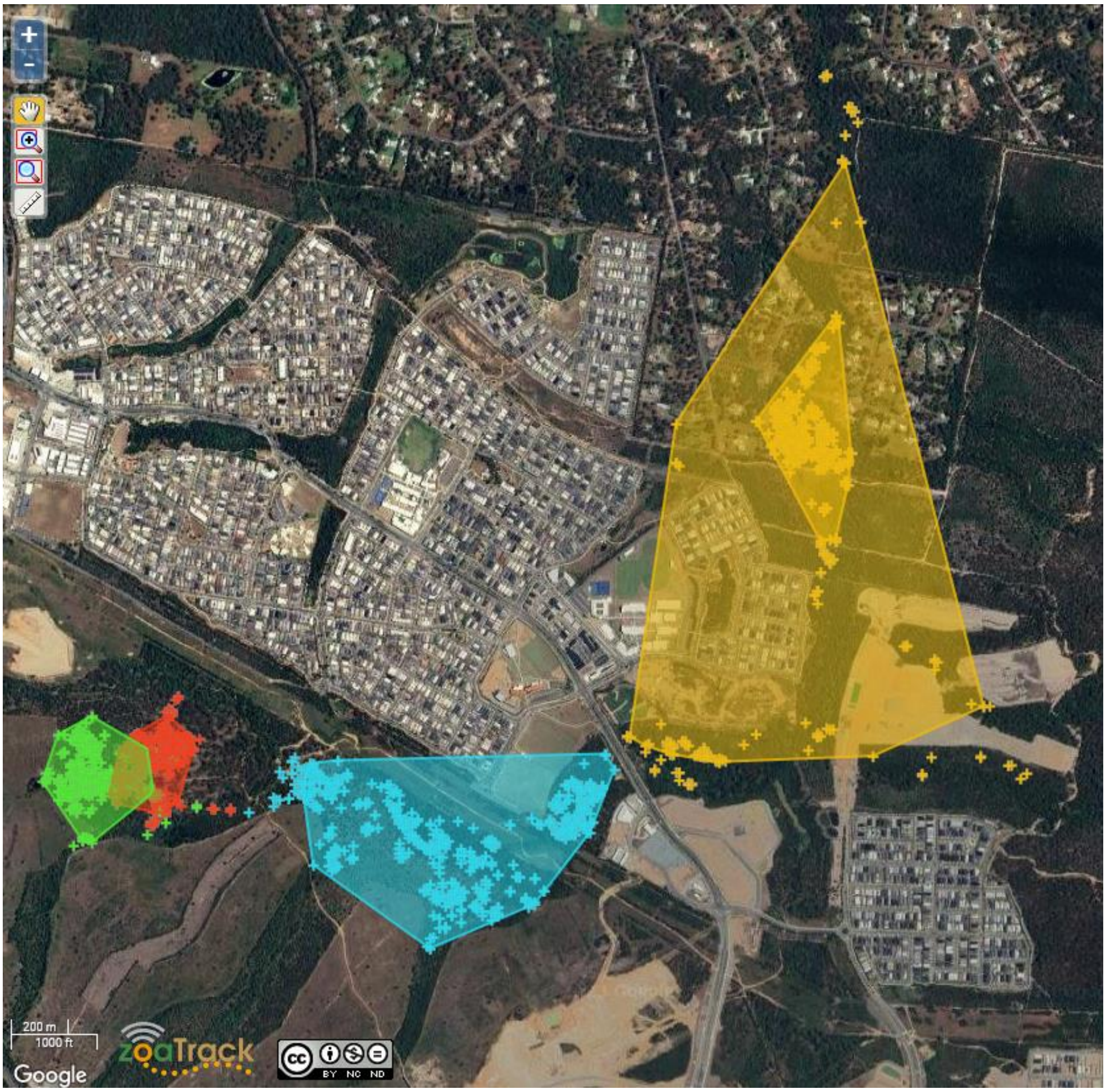

Figure 14. Plot of 95% Minimum Convex Polygon (MCP) home range estimates for 2023. Two estimates were calculated for Ella (orange polygons); the smaller polygon was based on a subset of recorded locations, which excluded all points recorded prior to 5th February 2023 (regarded as exploratory movements).

Colour key: Emily (green), Marlee (red), Douglas (blue), Ella (orange).

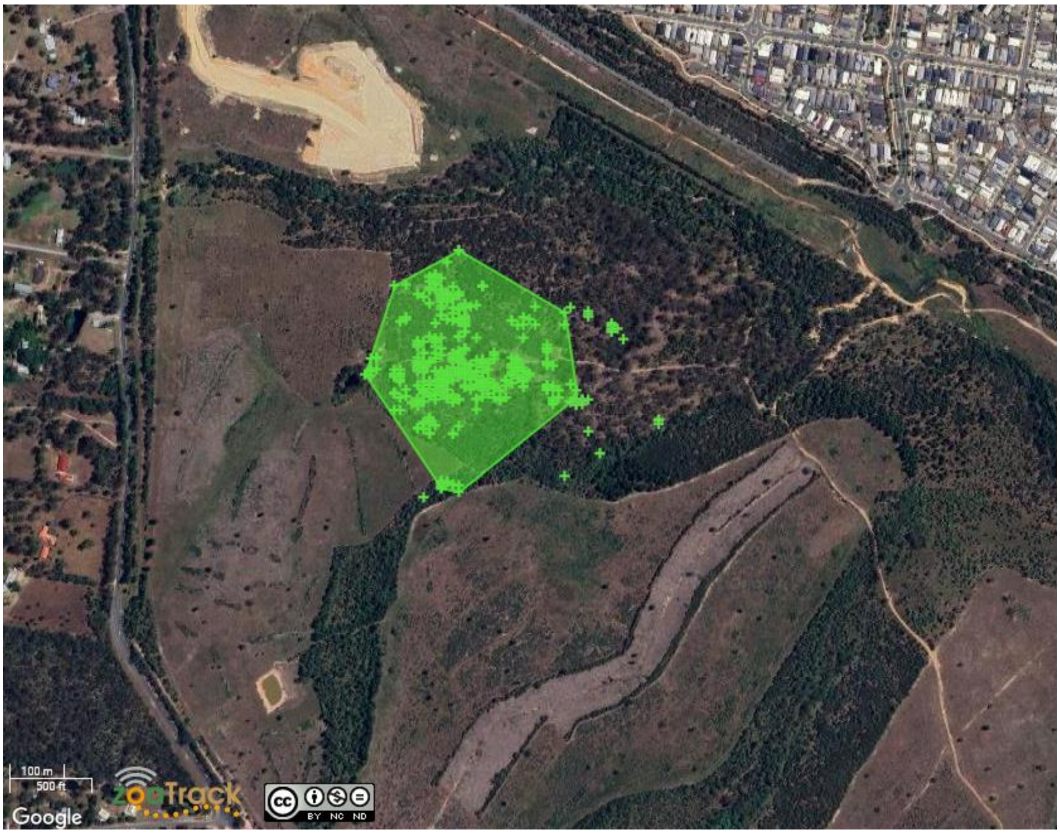

Figure 15. Plot of 95% MCP home range estimate for Emily.

Figure 16. Plot of 95% MCP home range estimate for Marlee.

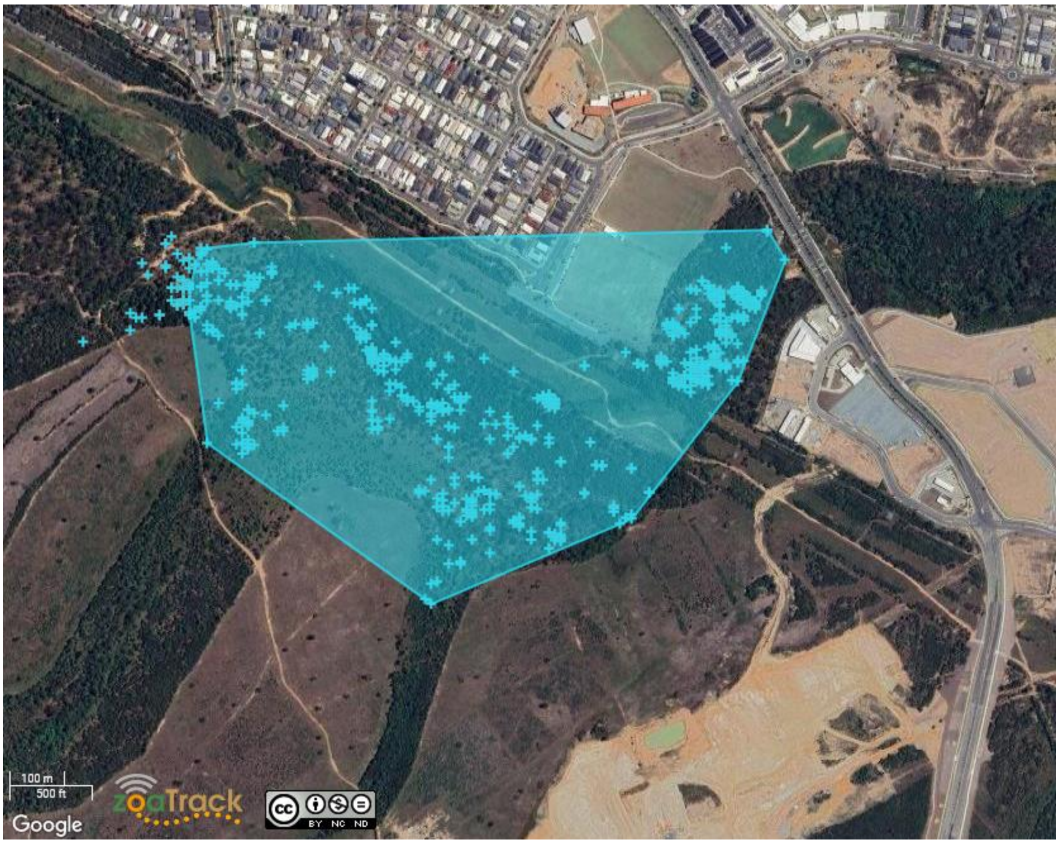

Figure 17. Plot of 95% MCP home range estimate for Douglas.

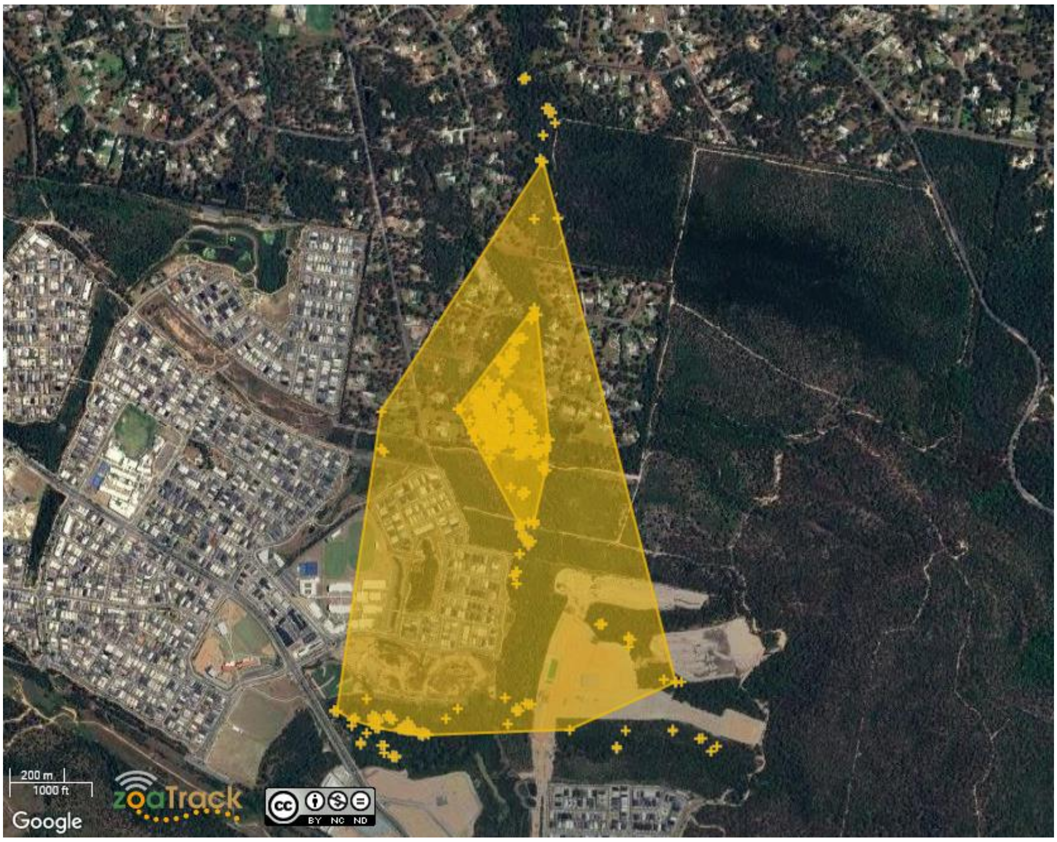

Figure 18. Plot of two 95% MCP home range estimates for Ella; the smaller polygon was based on a subset of recorded locations, which excluded exploratory movements (all points pre 5th February 2023).

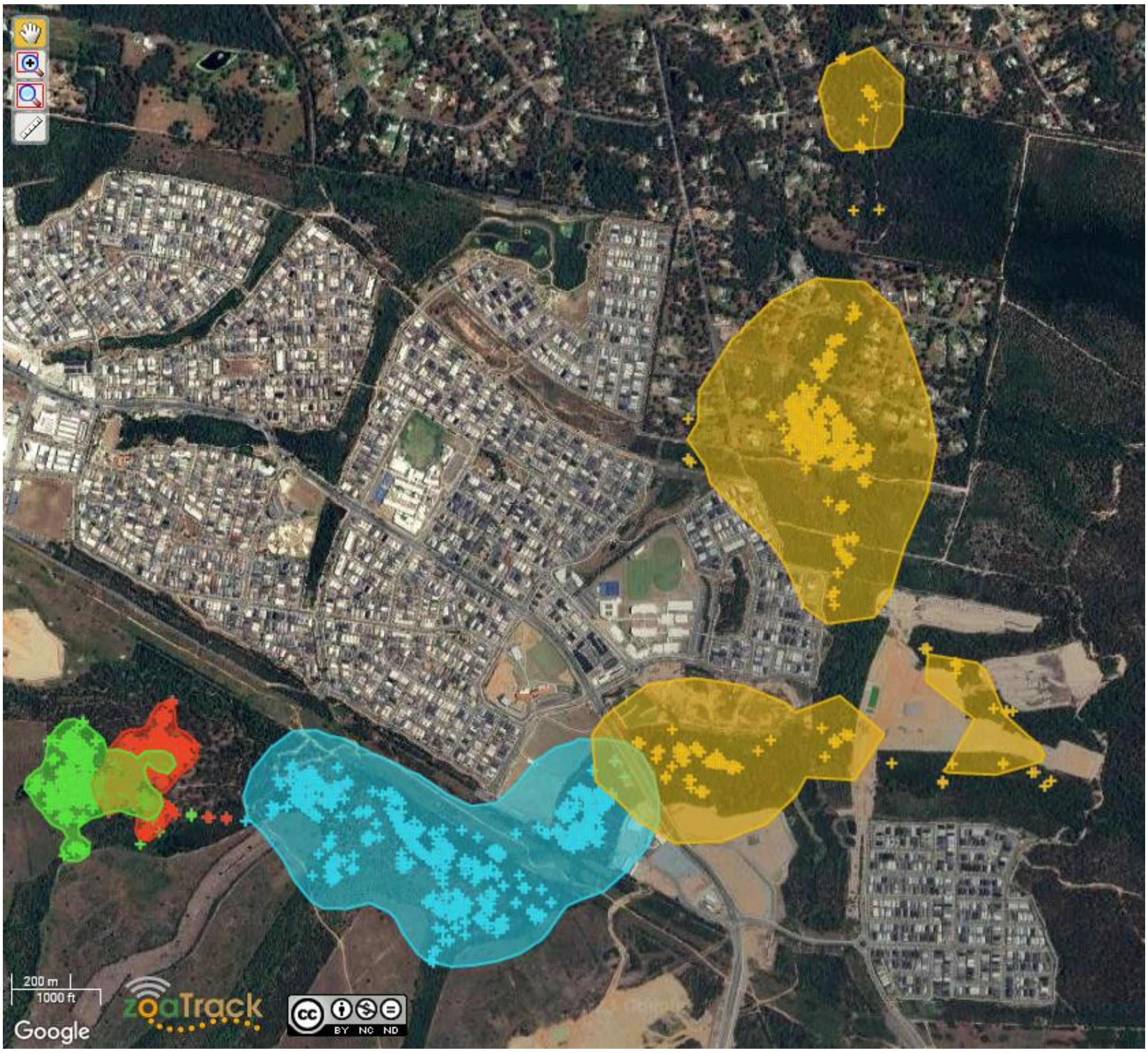

Figure 19. Plot of 95% KUD home range estimates for four koalas at the site in 2023.
Colour key: Emily (green), Marlee (red), Douglas (blue), Ella (orange, four polygons)
(Note: based on Ella's full dataset)

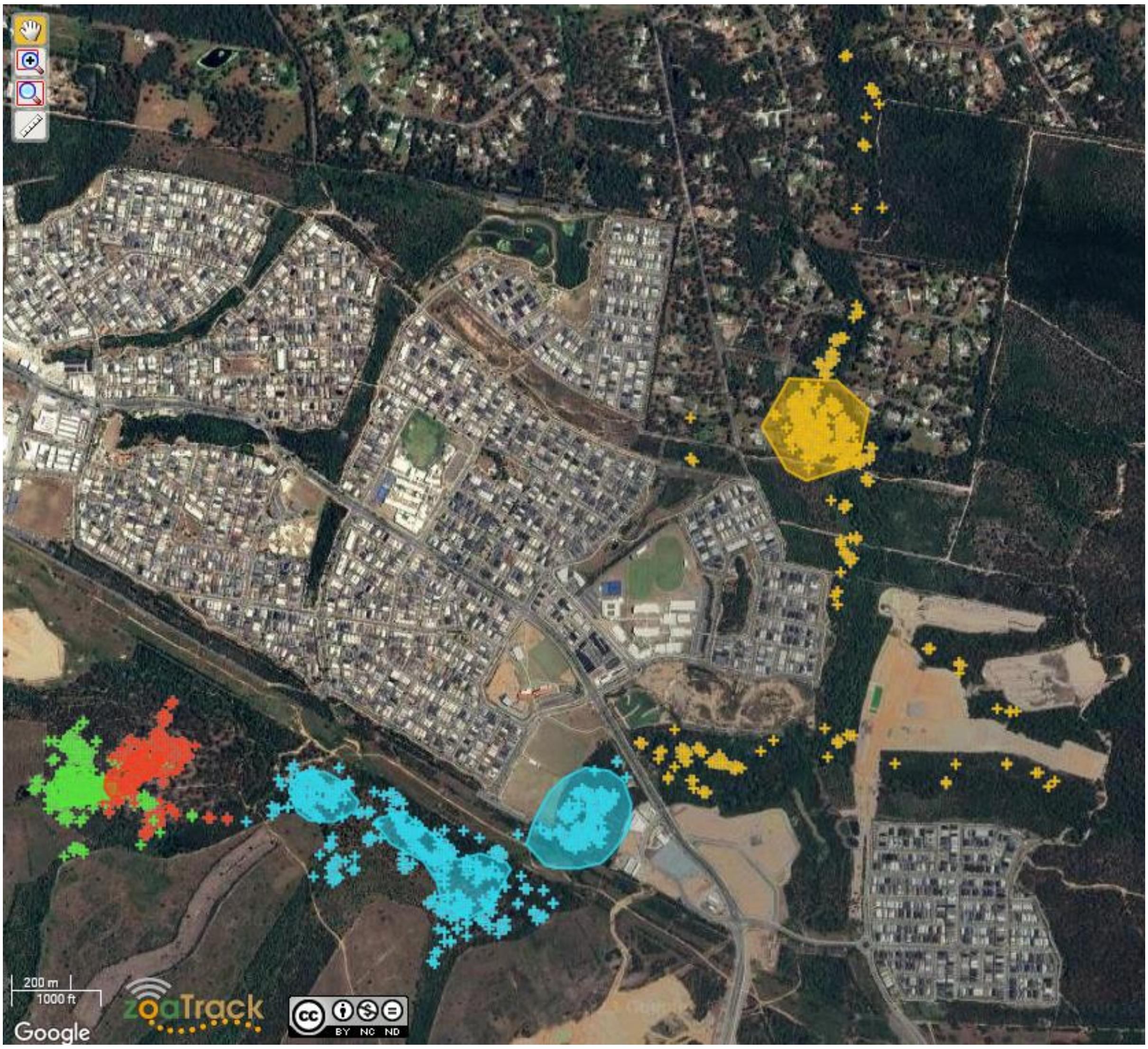

Figure 20. Plot of 50% KUD home range estimates for four koalas at the site in 2023.
Colour key: Emily (green), Marlee (red), Douglas (blue, three polygons), Ella (orange).
(Note: based on Ella's full dataset).

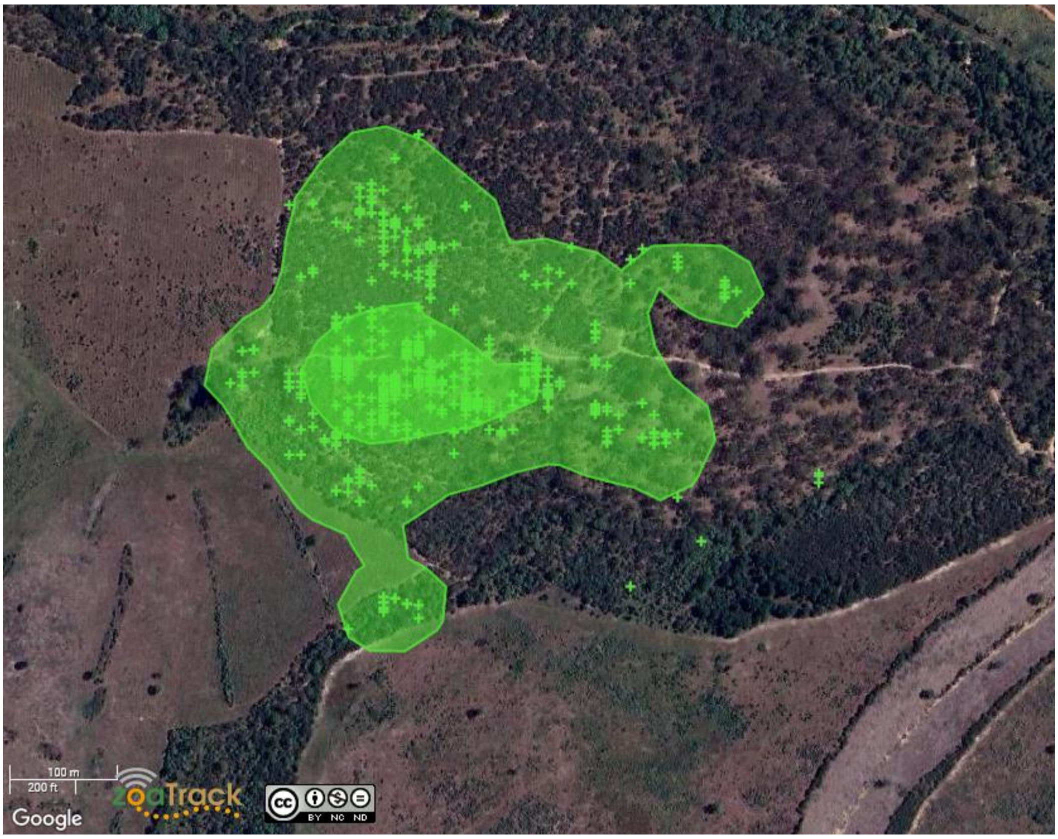

Figure 21. Plot of 50% and 95% KUD home range estimates for Emily. The 50% KUD is the smaller polygon within the larger 95% KUD polygon.

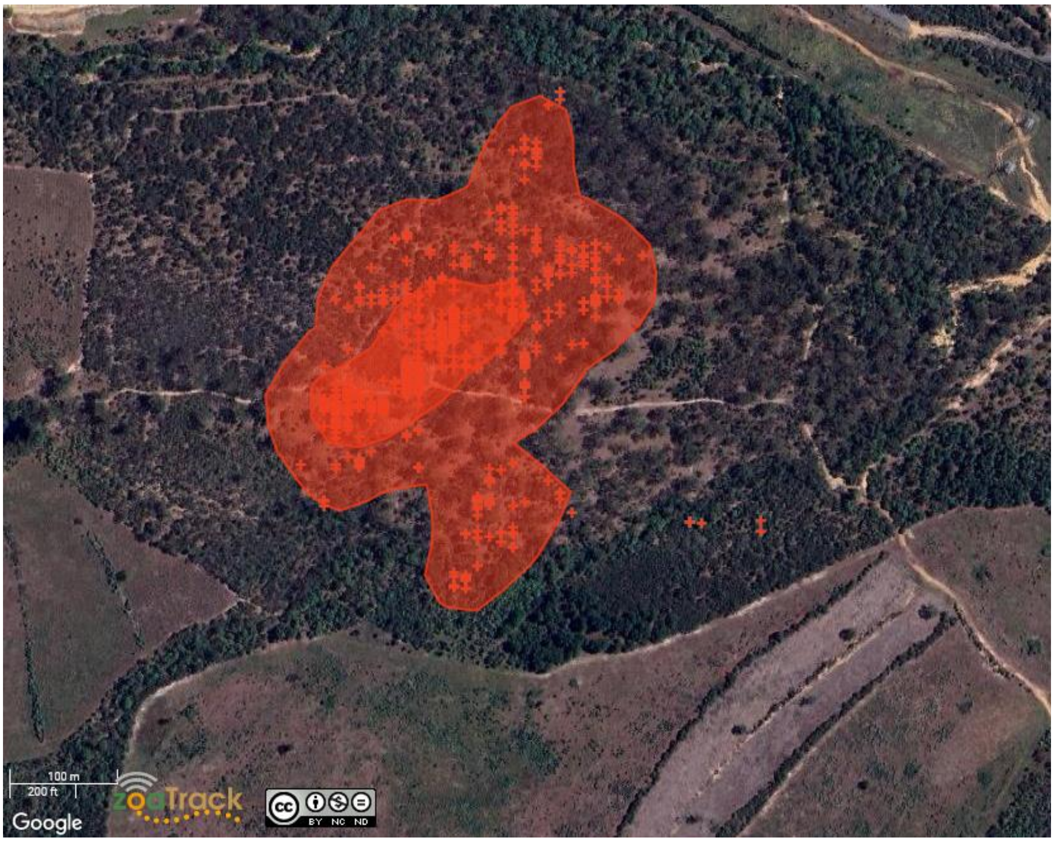

Figure 22. Plot of 50% and 95% KUD home range estimates for Marlee. The 50% KUD is the smaller polygon within the larger 95% KUD polygon.

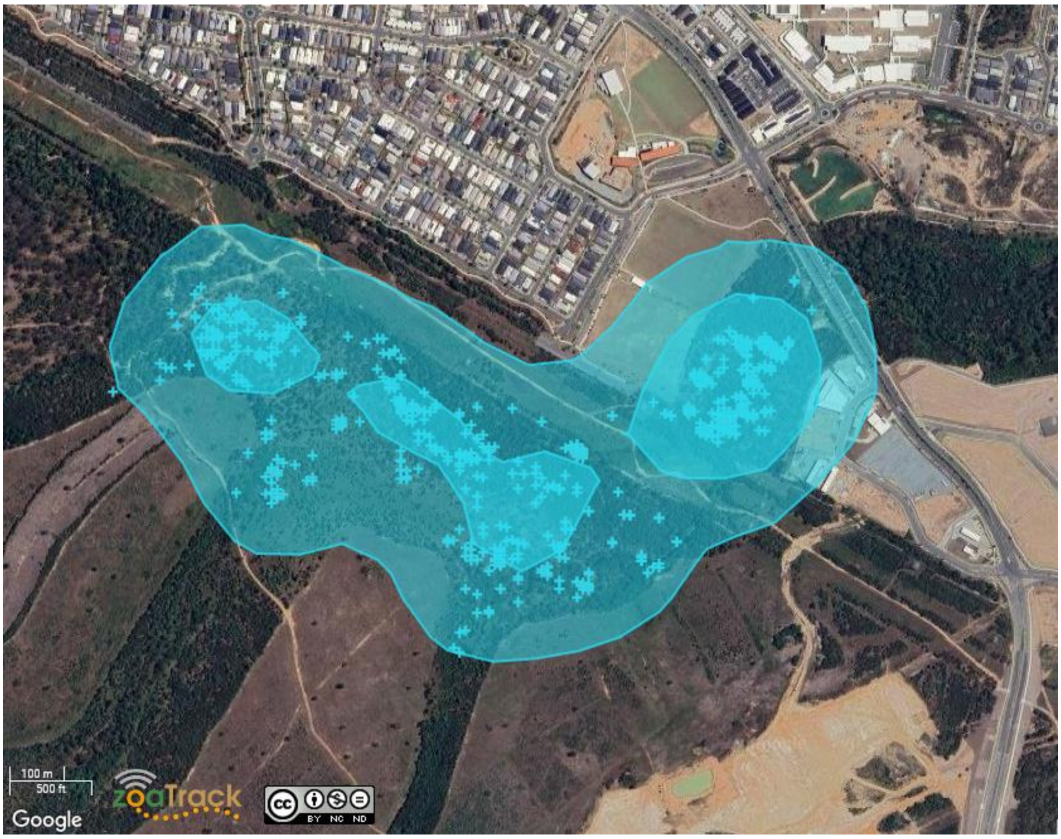

Figure 23. Plot of 50% and 95% KUD home range estimates for Douglas. The 50% KUD is comprised of the three smaller polygons within the larger 95% KUD polygon.

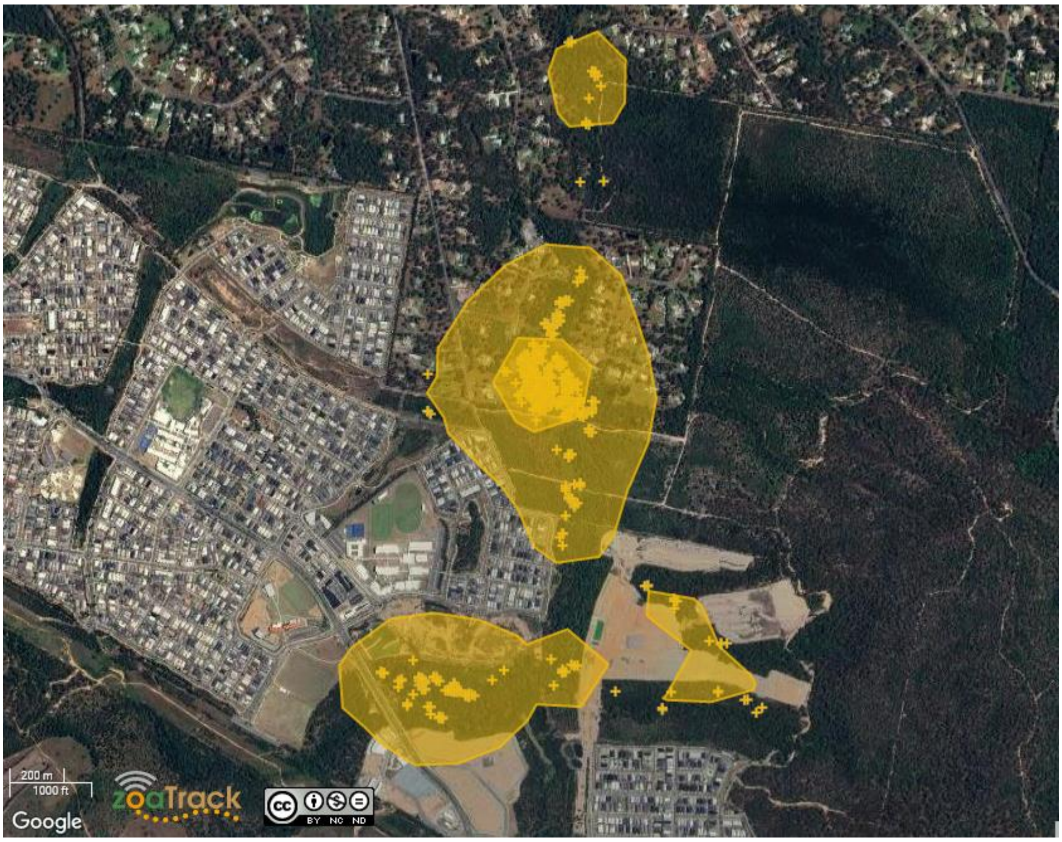

Figure 24. Plot of 50% and 95% KUD home range estimates for Ella. The 50% KUD is comprised of a single small polygon within one of the larger 95% KUD polygons. (Note: based on full dataset)

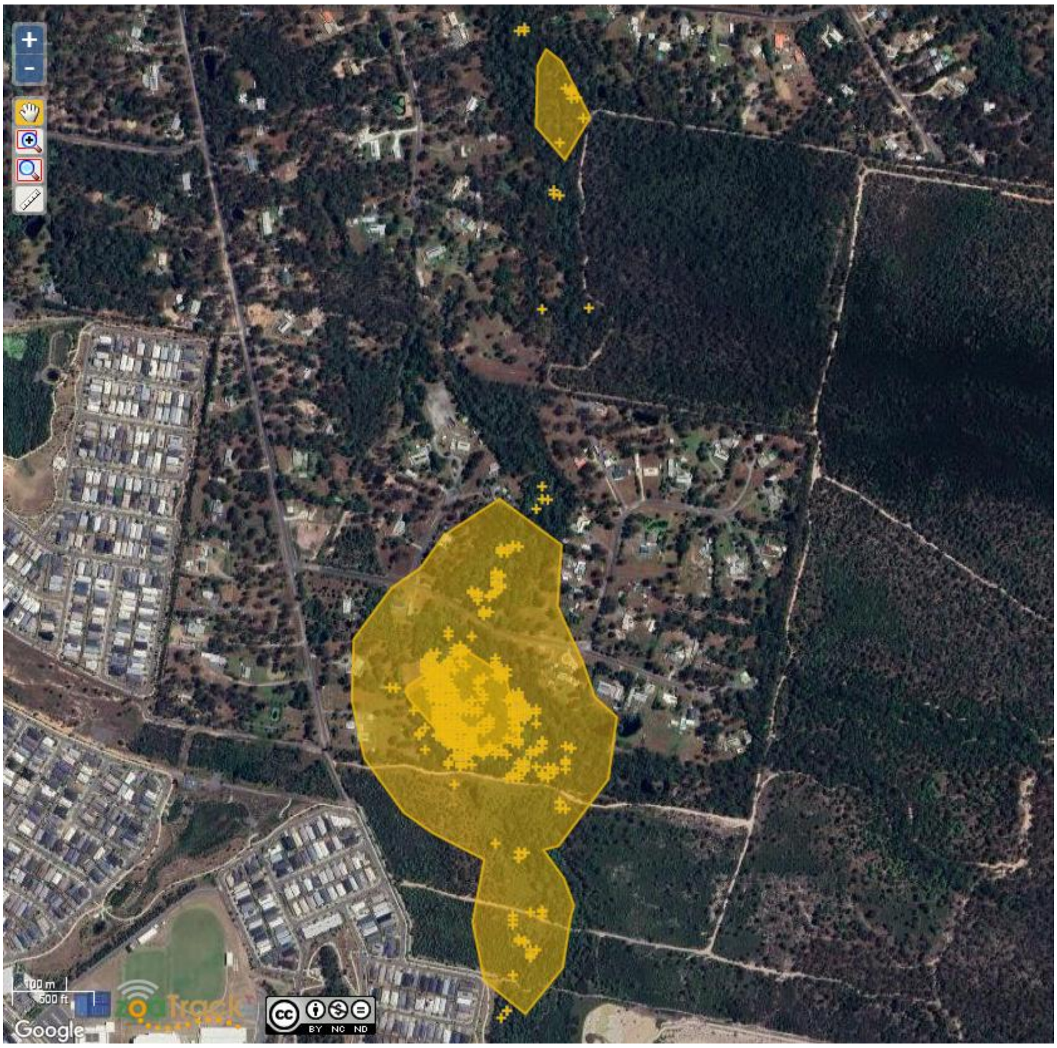

Figure 25. Plot of 50% and 95% KUD home range estimates for Ella, based on the subset of data points (excluding exploratory movements). The 50% KUD is the single small polygon within the larger 95% KUD polygon.