Koala Monitoring Program

Yarrabilba Priority Development Area

Annual Report on Koala Health and Movements

2019

Picture of Nyunga ascending an ironbark.

Prepared by:
Koala Ecology Group
University of Queensland
St Lucia QLD 4072

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Introduction

This report presents a summary of the findings from the 2019 *Koala Capture / Monitoring Events* that were conducted at the Yarrabilba Priority Development Area, by the Koala Ecology Group (University of Queensland) 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 four 3-day fieldtrips that were spread throughout the year. The aims were 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 each fieldtrip (as outlined in Fieldtrip Summary Reports) and includes a detailed examination of movement and home ranges for collared koalas across the entire year. These analyses are based on movement data that was collected by 1. Monthly radio-tracking of collared koalas (*Koala Monitoring Events*) 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 throughout the year, and assessing how health has changed among those koalas that were part of the research program in 2017 or 2018. Recommendations are made on how the health of koalas infected with *Chlamydia* should be managed and monitored in 2020.

Methodology

Four *Koala Capture / Monitoring Events* were undertaken in 2019 during the following months: March, May, July/August, November. 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), with frequent assistance from two personnel from Austecology (Lindsay and Heath Agnew).

During each fieldtrip, collared koalas were radio-tracked and habitat searches were conducted to try to locate new/untagged koalas (“cleanskins”), to tag and fit with collars. The nominated target habitat area within EPBCA Offset Area 1 was prioritised for these searches. 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). Alternatively, we also used the “fence trap” technique where the situation allowed (e.g. isolated tree, flat ground; Figure 2).

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 (Figure 3), as well as eye and urogenital swabs for disease testing (Figure 4). 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). 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 Koala Tracker system (see http://trackkoalas.com.au/ for further information on this koala-specific tracking system).

All collars were manufactured with a 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. Collar fit was examined approximately every 3-4months to ensure it was neither too tight nor loose.

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 University of Queensland Animal Ethics Certificate.

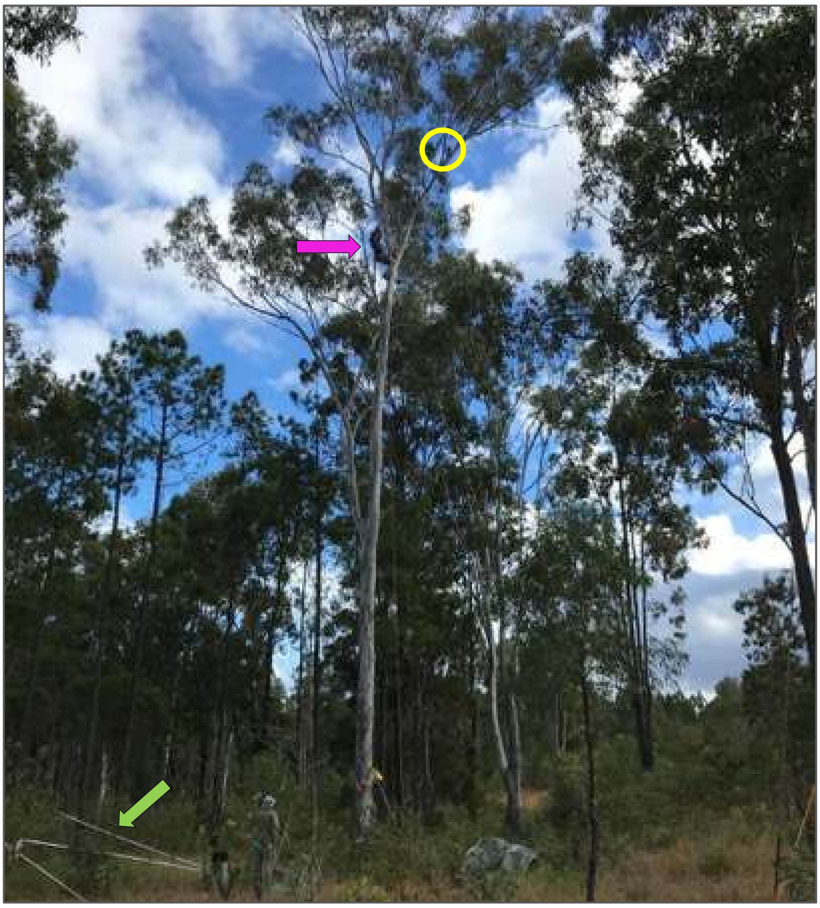

Figure 1. Image of the attempted capture of a koala (yellow circle) using the flagging method. The climber (pink arrow) used extendable poles (green arrow) to flag the koala down to a height that the ground team could take over and continue flagging it safely to the ground.

Figure 2. Image of a fence trap set up around an isolated tree to try and catch a koala; an SMS motion-sensor camera (bottom right) was used to send an immediate alert if the koala entered the trap.

Figure 3. Dr Ben Barth and Dr Bill Ellis measure head width of a koala; the anaesthetic machine is contained in the wooden box in the background.

Figure 4. Image showing how a swab sample is taken from the eye of an anaesthetised koala.

Results & Discussion

During 2019, a total of 13 independent koalas were captured and monitored, with a relatively even sex ratio of six males and seven females. In addition, two dependent young (i.e. juveniles still with their mothers) were examined (1M, 1F). This brings the total number of koalas that have been examined at the site since 2017 to 20 individuals (Table 1).

Of the 13 independent koalas examined in 2019, six were new to the research program while the remainder had been tagged prior to 2019 (see Capture Date, table 1). Interestingly, the male koala named Heath was the first koala tagged on the site (17th May 2017) but he was not seen again until May 2019, two years later. This highlights how cryptic koalas can be even within fragmented landscapes where their habitat is relatively limited, which aids search efforts.

As in 2018, there was a good demographic spread in the sampled population during 2019, including young adults (Kevin, Nyunga, Lucky), mid-aged koalas (3-6yrs) and few older individuals (Bomber, Sue-Bob, Jean). Approximately half of the mature females (3 of 7) were known to have reproduced in 2019.

The young female named Nyunga was first captured in May 2019 when she was 3.2kg and thought to be sexually immature (Figure 5). By the end of the year she had gained 1.2kg and was carrying her first pouch young, which is expected to be weaned in late 2020.

Figure 5. Image of Nyunga after fitting with white tag in the right ear; her eyes were clear.

Table 1. List of all koalas that have been examined and tagged at the study site since 2017; koalas examined in 2019 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	

The old female named Sue-Bob was first captured in October 2017. In 2018, she weaned a young male (Kevin) despite being in poor body condition throughout the lactation period. In 2019, it was possible that she was 10-12yrs old. Her collar was removed in March because she had lost body condition, had patches of thinned fur and was very skinny, suggesting she was nearing the end of life (Figure 6).

Figure 6. Image of Sue-Bob, showing the brown thinned fur on her face and ears.

The final fieldtrip for 2019 was conducted in November and during those three days, 16 individual koalas were observed at the study site. Eight of the observed koalas were already tagged (Kevin, Nyunga, Lucky, Bomber, Heath, Jean, Scarlet, Cain) while the other eight koalas were cleanskins. The detection of 16 koalas during the fieldtrip represents the highest number of koalas that we have seen during any single *Koala Capture / Monitoring Event* at the site.

It is probable that the progressive clearing of large vegetated areas (total 95ha) during late 2018 and early 2019, resulted in an increased concentration of koalas in the remaining habitats. Although the cleared areas were dominated by introduced plantation pines and acacias, they also contained scattered koala food trees (various eucalypts and other native species such as swamp box and paperbark). Our 2018 tracking data showed that koalas occasionally utilised these areas and even sheltered in introduced pines, so the loss of these areas would likely have affected the population even though they were not considered good quality habitat.

Summary of Koala Health

Overview

All 13 koalas caught in 2019 were given a basic physical health examination. This 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 13 koalas that were examined in 2019. Swab samples were not collected from Sue-Bob due to her very poor condition; Bomber was swabbed at two time points.

Table 2. Details of health and swab test results* for koalas examined in 2019. 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
Zara	6/3/2019	No clinical signs of disease; BCS 8	negative	negative	negative
Bomber	31/7/2019	No clinical signs of disease; BCS 6	negative	negative	positive 666
Bomber	21/11/2019	No clinical signs of disease; BCS 5	negative	negative	negative
Cain	4/3/2019	No clinical signs of disease when swabbed (BCS 6); inflamed eye and stained rump when sighted Nov'19	negative	negative	negative
Heath	29/5/2019	Mild inflammation left eye; BCS 7	positive 68,774	negative	positive 295
Jean	1/8/2019	No clinical signs of disease; BCS 7	negative	negative	negative
Lindsay	5/3/2019	No clinical signs of disease; BCS 7	negative	negative	negative
Kevin	4/3/2019	No clinical signs of disease; BCS 9	negative	negative	negative
Meghan	5/3/2019	Stained rump; BCS 4	negative	negative	positive 9,692
Lucky	27/5/2019	No clinical signs of disease; BCS 9	negative	positive 94	negative
Nyunga	28/5/2019	No clinical signs of disease; BCS 9	negative	negative	negative
Lilly	19/11/2019	No clinical signs of disease; BCS 6	positive 276	positive 297	positive 1,004
Millie Mae	21/11/2019	No clinical signs of disease; BCS 7	positive 595	positive 263	positive 950,244
Sue-Bob	6/3/2019	No clinical signs of disease; very poor condition (BCS 1)	-	-	-

*Note: the PCR testing method permits quantification of the copies of chlamydial DNA from each swab sample, expressed as the number of infectious units per millilitre (IFU/ml). This number is shown in red for swabs that returned a positive test result.

Details of examined koalas

As previously mentioned, several koalas examined in 2019 had also been examined in previous years, making to possible to determine if their health had changed over this time period.

Zara and Jean (breeding females) were both in good body condition during 2019 and tested negative for *Chlamydia*, as they did in 2018 (Table 2). Both females weaned a young during 2018/2019. Sue-Bob also weaned a young (Kevin) during this period but she was in poor condition throughout 2018 (BCS 3-4) and had declined further when examined in March 2019 (BCS 1); she tested negative for *Chlamydia* in 2018 and was not swabbed in 2019. It is unlikely that she would have survived into 2020.

Bomber was a large male that was first captured in mid-2017, at which time he tested negative for *Chlamydia* and had no physical signs of disease/illness He was not tested in 2018 but displayed no clinical signs of infection when physically examined in March and August that year. Swabs were next collected in July 2019 and the penile sample returned a weak positive result (i.e. <1,000 IFU/ml, see Table 2); he otherwise appeared physically healthy and showed no signs of disease. Because the test result was weakly positive, the decision was made to re-swab Bomber at the next opportunity to check the level of chlamydial infection. A penile swab sample was collected in November 2019 and returned a negative result, as did both ocular swabs. These results suggest that Bomber may have had a very mild chlamydial infection in his reproductive tract and that he was able to resolve this naturally. However, it is also possible that the follow-up swabs (collected in November) failed to capture chlamydial DNA, simply because the level of infection was very low. It should be noted that between July'19 (first swabbing) and November'19 (second swabbing), Bomber dropped approximately 1.2kg and went from BCS 6 to 5. It is possible that this decline in condition was unrelated to *Chlamydia* and may have been related to challenging environmental conditions, his older age (8-10+ yrs) or a combination of influences. Bomber's condition and infection status will be re-examined in early 2020 to determine if any intervention is required.

Cain was another large male that was first first captured in 2017 (October). He presented overt signs of disease (very inflammed right eye) and returned a positive result on the swab test of this eye. He was taken into care (Australia Zoo Wildlife Hospital) and successfully treated with antibiotics, then returned to site (Dec'17). In October 2018, Cain was recaptured and appeared healthy (BCS 7); the collected swabs tested negative. Similarly, in March 2019 he returned negative test results and appeared healthy (BCS 6). Cain was not captured again in 2019 despite two attempts being made (on consecutive days) during the November fieldtrip. During the second attempt, the tree climber was able to closely observe Cain while near him in the tree; he observed that his right eye was almost completely closed due to inflammation and his rump was mildly stained brown. These clinical signs suggest that Cain had a chlamydial infection in the urogenital tract and eye. Unfortunately, he was unable to be captured, as he clearly required medical attention. If possible, he will be recaptured and taken into veterinary care in 2020.

Heath was first examined in May 2017 when he was a subadult male (3.7kg). No swabs were collected. He was recaptured in May'19 when his left eye appeared mildly inflamed (Figure 7), but he was otherwise in good physical condition (BCS 7, wt. 7kg). The decision was made to collar Heath so that he could be monitored while the laboratry swab tests were completed. The test results confirmed that the serious infection in his left eye was indeed chlamydial (69,000 IFU/ml, see Table 2).

Heath was recaptured in November and taken to Australia Zoo Wildlife Hospital for veterinary assessment and treatment. Unfortunately, after several weeks of antibiotic treatment for his chlamydial infection, it became evident that Heath had further serious health issues, including a condition named oxalate nephrosis. This causes the deposition of calcium oxalate crystals in the kidneys, which seriously compromises their ability to function. The veterinarians were unable to successfully treat Heath and consequently he was euthanised. He is the second koala from the Yarrabilba study site that has had to be euthanised due to poor health; the other was Kobe (F) in 2018, that was also admitted to AZWH with chlamydial infection.

Figure 7. Image of Heath showing the inflammation of his left eye conjunctiva (orange arrow).

Lindsay was a young male first captured in October'18 and then recaptured in March'19. On both occasions he was in good condition, free of clinical signs of disease, and returned negative PCR test results. He had gained 1.2kg during the intervening period.

The remaining six koalas examined in 2019 were new to the research program, so no historical health data was available. Of these, Kevin (M) and Nyunga (F) appeared healthy and returned negative swab test results. These two koalas were regarded as subadults at the start of 2019 but Nyunga gave birth to a young later in the year. Three other cleanskins (Lucky, Lilly, Millie Mae) all appeared healthy at first capture but returned positive chlamydial test results.

Lucky was a young male in excellent physical condition (BCS 9) but the test results suggest he had a chlamydial infection in his reproductive tract. We will aim to re-test Lucky in 2020 to see if his infection resolves naturally, or if it becomes worse and requires treatment.

Lilly and Millie Mae were positive at all three swabbed sites (left eye, right eye, urogenital tract). Lilly's test results suggested infection at each site, whereas Millie Mae had a very high chlamydial load in her urogenital tract (almost 1 mill. IFU/ml, see Table 2). Interestingly, Lilly was carrying a back young (Wooten, Figure 8) and Millie Mae did not have a young. It is possible that Wooten was also infected with *Chlamydia* as a result of his mother's infection (i.e. vertical transmission). Wooten was not swabbed due to his small size (1.4kg). Given that Millie Mae and Lilly tested positive at all three swab sites, we recommend they be taken into care for treatment in 2020.

Meghan was a new female captured in March 2019. Her rump appeared stained and her PCR test results confirmed she was infected with *Chlamydia*. Unfortunately, she dropped her collar soon after her initial capture and despite targetted search efforts, she was not sighted again in 2019. Further search effort will be invested in Meghan's area in 2020 to locate her and take her into care.

Figure 8. Image of Lilly's back young, Wooten, which may be infected with *Chlamydia* via vertical transmission.

Conclusions

In 2018, nine of 10 examined koalas appeared healthy and without overt signs of disease; eight of these returned negative PCR test results for chlamydial infection (i.e. at least 20% of the population was infected with *Chlamydia* based on these results). In 2019, six of 12 examined koalas tested positive for *Chlamydia* (50% of population); this figure increases to 58% if Cain is regarded as infected, which he almost certainly is, based on having an inflammed eye and stained rump when observed in November. Two of the males (Bomber, Lucky) returned weak positive results (i.e. <1,000 IFU/ml) while most other koalas that returned positive PCR results were carrying heavy chlamydial loads (Table 2).

Assuming that the examined koalas are representative of the broader population, the test results represent a significant increase in the level of detected chlamydial infection in the population, over a short period. It is impossible to be certain about the driver(s) that led to this increase, but asuming a consistent probablility of detection using PCR, it may reflect the result of increased transmission between individual koalas. Alteratively, if detection probability reflects indivdual koala response to infection (e.g. immunocompromised koalas having higher chlamydial load and hence greater likelihood of infection being detected) then physiological stress, as a result of challenging environmental conditions in 2019 (e.g. very dry year, heat waves, and clearance of pine-dominated habitat) may be a factor.

With regards to the latter possibility, it has been argued by some researchers that increased physiological stress leads to suppression of the immune system, which may then lead to a reduced resilience to chlamydial infection in koalas. Conversely, this may lead to greater expression of chlamydial disease amongst infected koalas. However, there is little empirical evidence in support of this assertion, and it is clear that more detailed research is required to better understand the key mechanisms that regulate chlamydial infection and disease progression.

In 2019, relatively few infected koalas displayed overt signs of disease (excl. Meghan - stained rump, and Heath - eye inflammation). Treatment of such koalas generally has the best prognosis as it may halt progression of the infection to debilitating disease. However, it is also plausible that some concealed/non-visible disease went undetected as we were not able to conduct detailed veterinary examinations (e.g. reproductive tract cysts, which may have been present in Millie Mae given her very high PCR load). Regardless, the apparent increase in the number of koalas detected as infected with *Chlamydia* is cause for concern. In light of this evidence, we strongly recommend that an approach to managing diseased koalas that aims to reduce the overall incidence of *Chlamydia* in the population becomes part of the study. This strategy may need to include administration of antibiotics, which are commonly used in the treatment of koalas infected with *Chlamydia* (Osawa & Carrick 1990; McCallum *et al*. 2018).

The PCR test results highlight that despite being infected with *Chlamydia*, koalas can often appear to be healthy and in good condition, displaying no signs of inflammation or illness. This was the case with Kobe in 2018, and was exemplified by Lilly and Millie Mae in 2019. Clearly, it is not possible to rely solely on visual assessments to accurately determine a koala's health status, as many previous studies have also reported (Jackson *et al*. 1999; Griffith *et al*. 2013; McCallum *et al*. 2018).

In 2020, we strongly recommend the continuation of laboratory assessments of the chlamydial infection status of captured koalas, and whether this changes during the year. Testing requires the collection of eye and urogenital swabs while the koala is anaesthetised. Where possible, we recommend at least two tests per koala during the year, ideally at least six months apart. This will provide a clearer and more up-to-date picture of the health of koalas at the site, especially as urban development progresses. This is important for three reasons:

1. *Chlamydia* is a sexually-transmitted bacteria, so it can spread quickly through a population (especially where there are many individuals in a relatively small area);

2. There is some evidence to suggest that koalas living in stressful environments are more susceptible to disease expression if they are infected with *Chlamydia*; and

3. The likelihood that treatment efforts will be successful is greatly increased if infections are detected early (i.e. before there are serious pathological consequences such as reproductive cysts and bladder wall thickening).

Accordingly, our recommended approach for 2020 includes two chlamydial tests for each of the five collared koalas, as well as a further six tests for any other individuals that are captured.

Summary of Koala Movement

Overview

A select number of koalas were fitted with LX collars to enable them to be routinely radio-tracked, as well as monitored using the online Koala Tracker system (see http://trackkoalas.com.au/ for more).

LX collars were programmed to record location twice daily (at approximately 10:00am and 10:00pm AEST). 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 used in subsequent analyses, due to unacceptably high location error for some fixes (determined from 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 9 – 49).

All LX collars had a weak-link made from fishing line with breaking strain ratings appropriate to the size of the koala. The weak-link was designed to break should the koala become snagged by the collar, enabling the koala to free itself. Disappointingly, this weak-link mechanism was too sensitive and collars frequently fell off koalas within one month of attachment. This high level of drop-off far exceeded what typically occurred at our other research sites in SEQ, where we used collars with different weak-link mechanisms (rubber-based). During 2019, we were regularly frustrated by rapid collar drop-offs and the negative effect it had on our ability to monitor the well-being and movement of koalas at the study site. For this reason, we changed to a rubber-based weak-link late in 2019, after conducting breaking strain tests. This provided an immediate improvement in collar retention while still providing protection against koalas being snagged; it will be used as the weak-link fitting for all deployments in 2020.

In 2019, 13 koalas were collared and monitored for varying durations (Table 3). This was a considerably larger number of koalas than were collared in 2018 (7), due partly to the collar drop-off issue (leading to higher rotation of collars), but also to the fact that we used VHF-only collars on two sub-adult koalas (Kevin, Nyunga). This enabled us to have seven collars simultaneously deployed during periods of 2019. The drawback of VHF-only collars is that movement data was not automatically logged (as it was with LX collars), so location data was only obtained by physically radio-tracking koalas until they were sighted and then recording their positions with a handheld GPS.

Because collar deployments were generally of reduced duration in 2019, the resultant movement datasets were generally smaller than in 2018, but they were still sufficient to estimate home range size and location for all but one koala; only 16 data points were obtained for Kevin, too few for home range estimation.

Table 3 lists the number of fixes that were obtained for collared koalas in 2019, using radio-tracking points and LX collar data. The table also presents estimates of home range size using two common techniques. For the five individuals that were also collared in 2018, the equivalent statistics from that year are provided for comparison to the 2019 data.

Table 3. Details of movement datasets and home range estimations for koalas collared in 2019. Numbers presented in square brackets are the equivalent metric from 2018 (only available for five koalas).

UQ #	Koala name	Sex	No. fixes*	Avg no. fixes/day	MCP 95% (ha)	KUD 50% (ha)	KUD 95% (ha)
13008	Bomber	M	62 [105]	0.2 [0.4]	7.9 [33.3]	2.9 [12.0]	21.0 [64.7]
13488	Cain	M	322 [180]	1.1 [0.4]	23.8 [36.7]	9.7 [16.4}	35.1 [63.3]
13486	Jean	F	369 [562]	1.1 [1.2]	34.7 [47.5]	9.1 [18.0]	47.6 [77.2]
13490	Sue-Bob	F	99 [524]	0.6 [1.1]	3.2 [8.1]	1.4 [2.2]	6.3 [11.0]
13304	Zara	F	77 [139]	0.3 [0.8]	4.9 [5.3]	2.5 [2.4]	9.4 [8.8]
13007	Heath	M	129	0.7	78.7	28.5	146.9
12341	Kevin	M	16	-	-	-	-
13307	Lilly	F	53	1.3	19.4	11.2	45.8
13497	Lindsay	M	176	0.9	20.9	5.2	33.7
13508	Lucky	M	54	0.3	10.4	6.8	38.8
12342	Meghan	F	28	0.9	8.1	6.7	27.9
13533	Millie Mae	F	59	1.5	3.3	2.7	10.3
13509	Nyunga	F	64	0.3	2.5	1.0	7.1

* After filtering of inaccurate locations
MCP = minimum convex polygon home range estimator
KUD = kernal utilisation distribution home range estimator

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 most 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.

All movement plots and home range analyses were conducted in the ZoaTrack software package (https://zoatrack.org/).

Examination of dispersal in the sub-adults Kevin and Nyunga

Kevin and Nyunga were fitted with VHF-only collars at first capture because both were too small to fit with LX collars (min. 4kg koala) and we were interested to see if these sub-adult koalas dispersed from their capture locations. Nyunga (F) was collared in May and she did not disperse during 2019. Rather, she ranged within a small area close to her original capture location, for the remainder of the year (Figure 23).

Kevin (M) was collared in March, and he remained close to his natal area (Sue-Bob's home range) for most of the year. He then dispersed off site in October/November (Figure 17). Radio-tracking revealed that he dispersed approximately 3.6km from his last known location on the study site (near base station 2); Kevin crossed Waterford-Tamborine Road and moved onto private property. Home range estimates were not calculated for Kevin because too few data points were available, and his dispersal off site clearly showed that he had not established a stable home range.

Koala habitat use and home ranges

Excellent movement datasets were obtained for most collared koalas (>50 fixes, avg. 0.8 fixes/day), permitting an examination of habitat use and home ranges. Only one koala for which home ranges were estimated, had less than 50 fixes (Meghan, n = 28 fixes); it is possible that this koala did not move throughout her entire home range area during the short period that she was collared, so her estimated ranges should be treated cautiously.

Movements plots (Figures 9 – 23) show that the collared individuals made extensive use of the site. Most movements were concentrated along the creeklines and associated riparian vegetation. But many koalas also utilised habitat away from the creeks. This was especially true of the area between the two branches of Quinzeh Creek in the north of the site, which is dominated by acacias and eucalypt regrowth; it was well utilised by Cain, Sue-Bob, Zara and Kevin (see Figures 9 & 10 and relevant home range plots).

The data also showed that some koalas (Lilly, Meghan) utilised isolated paddock trees retained in cleared areas zoned for future development. Lilly was first captured out of such a tree; she and her offspring (Wooten) were captured in an area that had been largely cleared immediately north of the central haul road, but still contained scattered trees (~50-100m apart). The retained trees acted as 'stepping stones', facilitating safe movement. Koalas moving through these areas are at greater risk of attack from ground-based predators, especially wild dogs, due to the lack of trees, which offer refuge.

The 95% MCP home range estimates for females averaged 10.9ha, and ranged from 2.5ha (Nyunga) to 34.7ha (Jean). The 95% MCP home range estimates for males averaged 28.3ha, and ranged from 7.9ha (Bomber) to 78.7ha (Heath). These statistics show that in general, males had much larger home ranges than females (see Table 3), as has often been reported in studies of koalas elsewhere.

When male and female home ranges were compared using the alternative (KUD) estimator, the general conclusion was the same; males had much larger home ranges. The 95% KUD home range estimates for females averaged 22.1ha, and ranged from 6.3ha (Sue-Bob) to 47.6ha (Jean). The 95% KUD estimates for males averaged 55.1ha, and ranged from 21.0ha (Bomber) to 146.9ha (Heath).

A major drawback of these home range estimator methods is that they often include large areas of non-utilised space in the calculated ranges, especially in fragmented landscapes. This fact was very evident in the home range estimates for Heath (Figure 16 & 30), which were much larger than all other koalas; the data strongly suggest that he did not utilise the large area of cleared land near the centre of his home range. This area was included simply because he utilised habitat fragments/corridors on either side of the cleared land. It is highly likely that the range estimates for Heath overstate the actual area of land that he utilised.

Home range estimates calculated using the 95% MCP were consideraby smaller than those derived using the 95% KUD estimator (Table 3). Core home range areas were examined using the 50% KUD estimator (Figures 37 – 49).

Five koalas were collared in both 2018 and 2019, permitting a comparison of their movements and home range areas. These koalas were Bomber, Cain, Jean, Sue-Bob and Zara. In the first four of these, the 95% MCP and 95% KUD estimates were markedly smaller in 2019 when compared to 2018 (see Table 3). It must be noted that the sample sizes (i.e. number of fixes) were also smaller in 2019, but they were large enough to permit a meaningful examination of home range size. The reduced home range sizes recorded in 2019 may be a consequence of a higher density of koalas, due to the loss of some vegetated areas (95ha). As koalas become more concentrated, it is plausible that intraspecific aggression and territoriality may lead to koalas tightening up their home ranges.

One koala (Millie Mae) was recorded making semi-regular crossings of the busy road that borders the western edge of the site. Millie Mae was fitted with an LX collar in November 2019, during the last fieldtrip for the year. She was captured along the northern branch of Quinzeh Ck, 240m directly east of Waterford-Tamborine Road. Within two days after capture, Millie Mae had crossed Waterford-Tamborine Road (see Figure 22). She remained on the western side of the road for many days before she crossed back east onto the study site. By the end of the year, she had crossed Waterford-Tamborine Road on numerous occasions. Both home range estimation techniques showed her home range spans the road. This obviously presents a serious threat to Millie Mae, as it is presumed she crosses via the road (as opposed to moving through the canopy of connected trees), which places her at great danger of being hit by a vehicle.

Conclusion

In 2019, location data was collected for 13 koalas using LX collars and by radio-tracking. These data showed that the examined koalas made extensive use of the fauna corridors as well as vegetated areas adjacent to them. The home range analyses showed that males tended to roam more widely than females, although some females (Jean, Lilly) had ranges that were larger than some males.

Interestingly, the analyses suggested that both male and female ranges were considerably smaller in 2019 than 2018. This may be the result of a more dense population, in the wake of some vegetation clearing, but it is not possible to be sure. This trend held true for 4 of the 5 koalas that were collared in both years (the fifth, Zara, had similarly sized ranges across both years).

The movement and home range plots revealed that there are very few habitat areas in the vicinity of the collared koalas that they do not utilise. Koalas are highly mobile and as demonstrated by Lilly and Meghan, they can cross large stretches of bare ground and can make frequent use of isolated paddock trees.

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Figure 9. Plot of locations that were retained for data analyses, for the 13 koalas collared in 2019. Two locations were recorded for Kevin after he dispersed off site (white arrows).

Colour key: Bomber (dark blue), Cain (green), Jean (white), Sue-Bob (aqua), Zara (mustard), Heath (orange), Kevin (yellow), Lilly (purple), Lindsay (red), Lucky (grey), Meghan (pink), Millie Mae (brown), Nyunga (light blue).

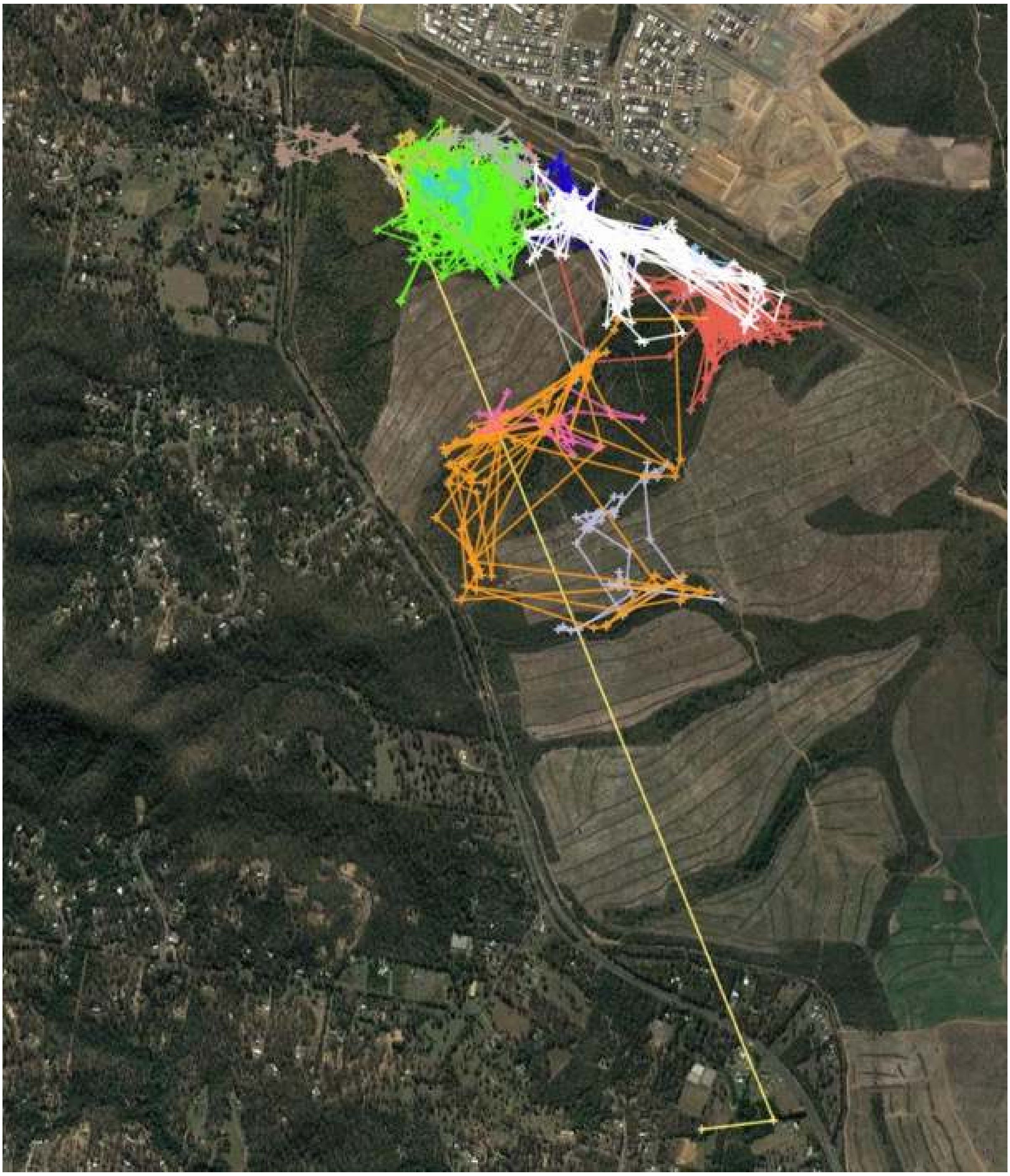

Figure 10. Plot of locations that were retained for data analyses, for the 13 koalas collared in 2019. Consecutive fixes are joined by trajectory lines. Note, these lines do not necessary indicate the exact movement pathways of the koalas, especially as most fixes were separated by 12 to 24 hours.

Colour key: Bomber (dark blue), Cain (green), Jean (white), Sue-Bob (aqua), Zara (mustard), Heath (orange), Kevin (yellow), Lilly (purple), Lindsay (red), Lucky (grey), Meghan (pink), Millie Mae (brown), Nyunga (light blue).


Figure 11. Plot of movements for Bomber.

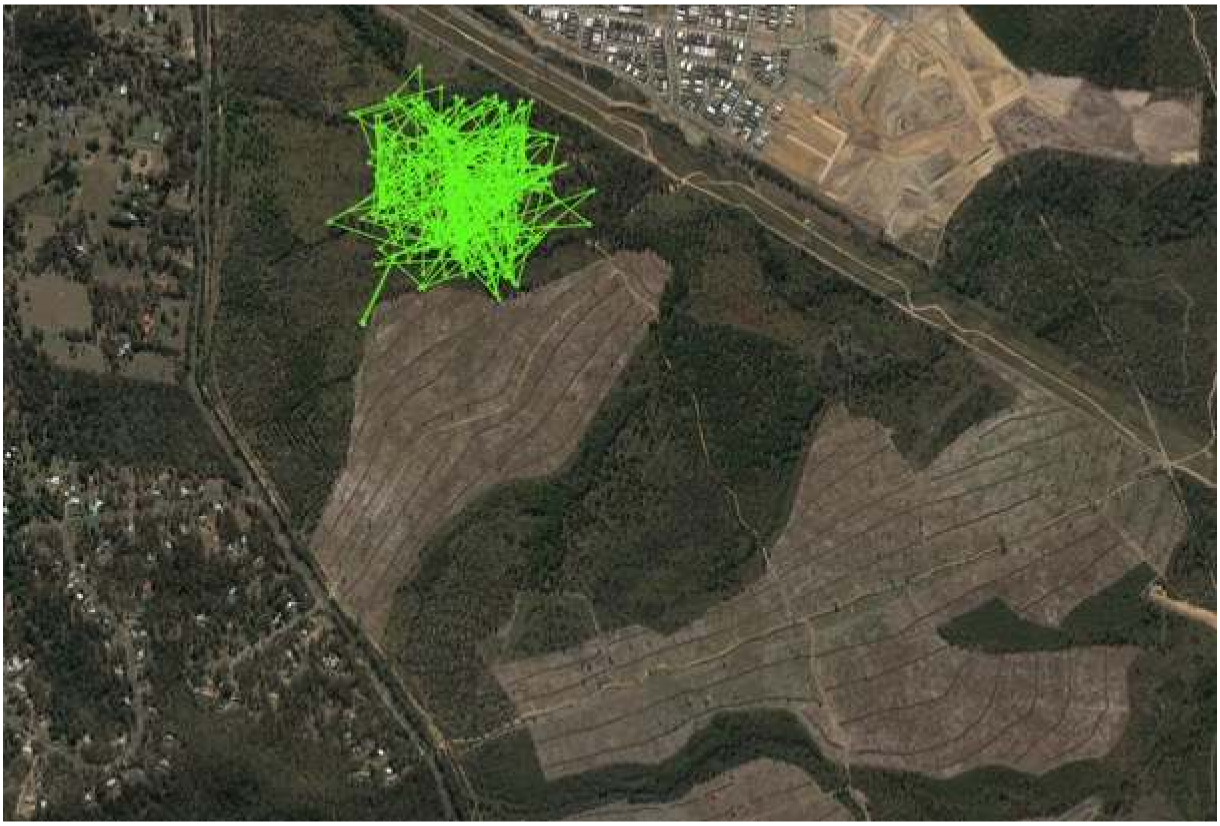
Figure 12. Plot of movements for Cain.

Figure 13. Plot of movements for Jean.

Figure 14. Plot of movements for Sue-Bob.

Figure 15. Plot of movements for Zara.

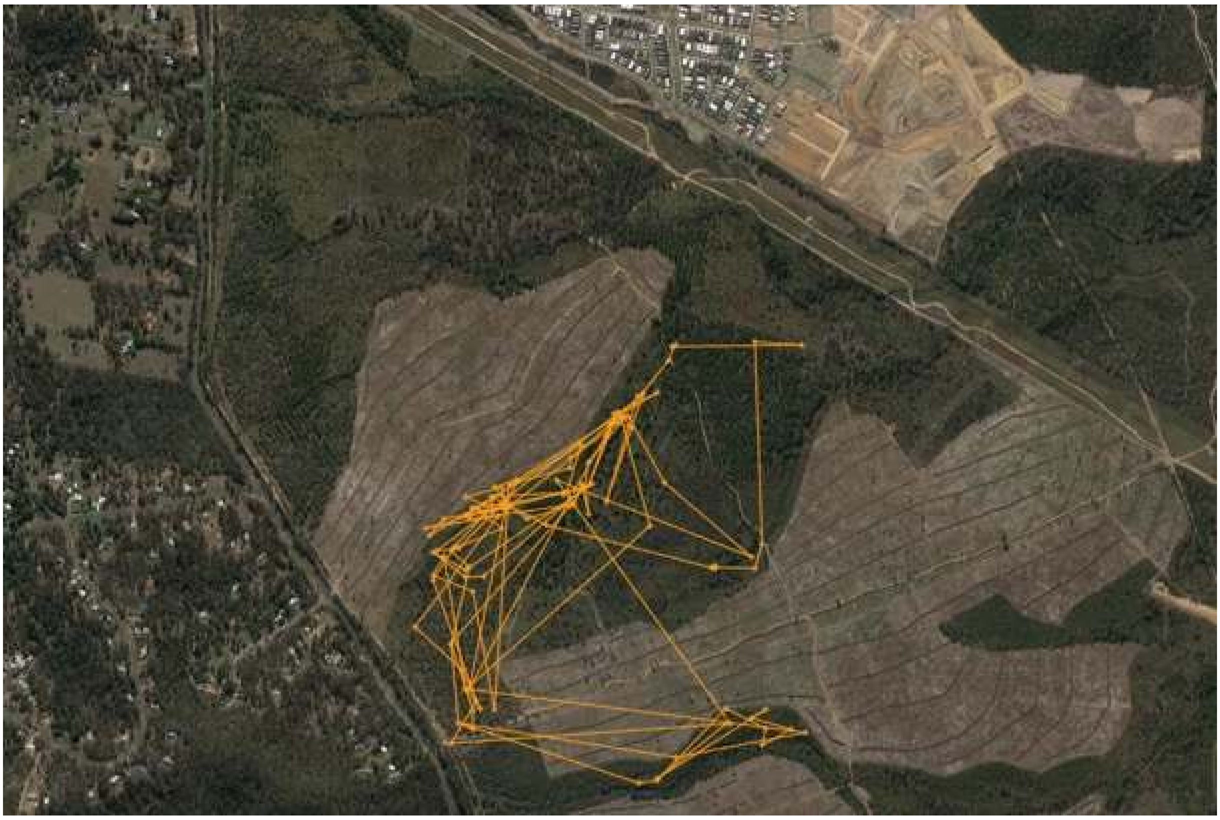

Figure 16. Plot of movements for Heath.

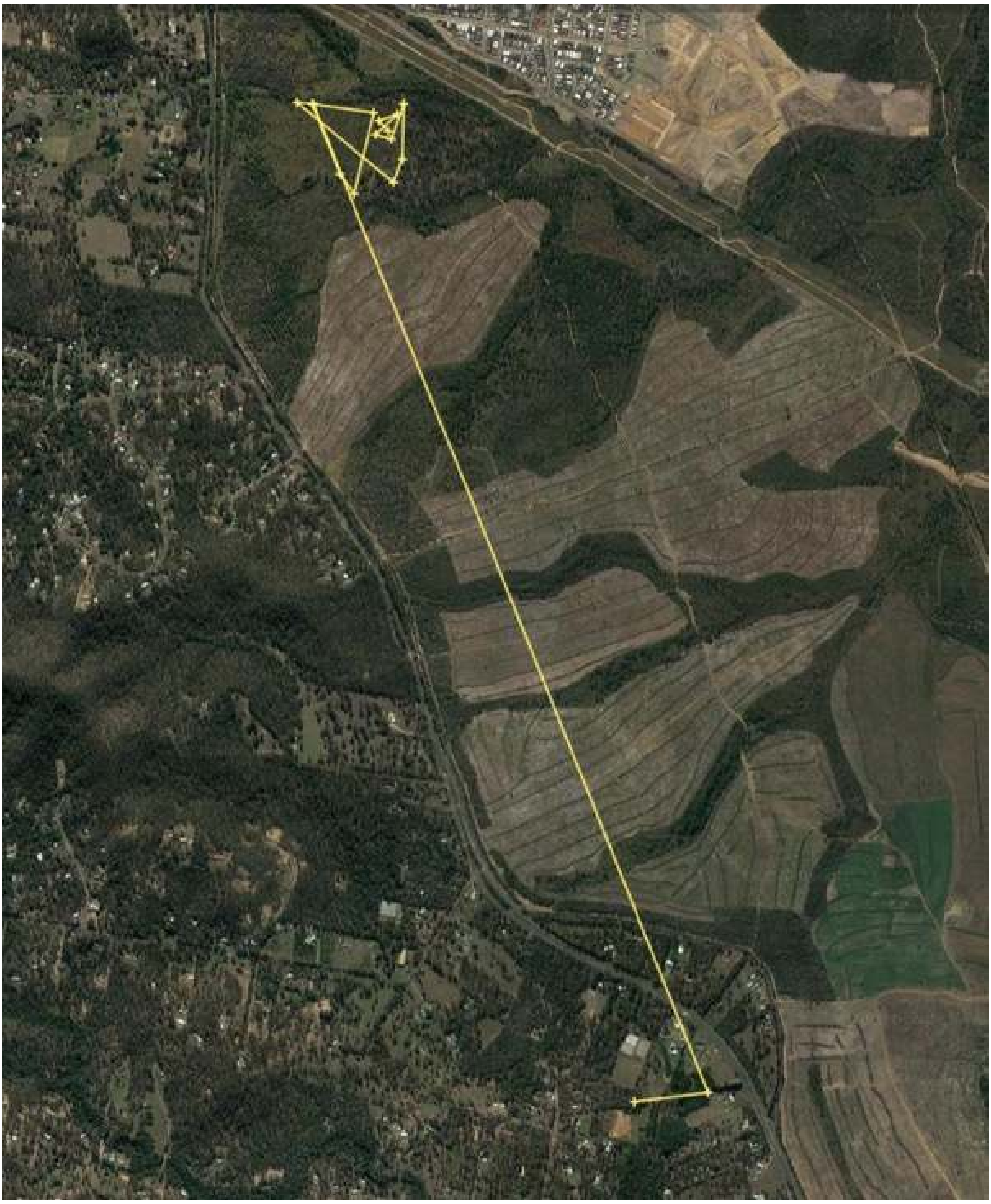

Figure 17. Plot of movements for Kevin.

Figure 18. Plot of movements for Lilly.

Figure 19. Plot of movements for Lindsay.

Figure 20. Plot of movements for Lucky.

Figure 21. Plot of movements for Meghan.

Figure 22. Plot of movements for Millie Mae.

Figure 23. Plot of movements for Nyunga.

Figure 24. Plot of 95% MCP home range estimates for12 koalas at the site in 2019.

Colour key: Bomber (dark blue), Cain (green), Jean (white), Sue-Bob (aqua), Zara (mustard), Heath (orange), Lilly (purple), Lindsay (red), Lucky (grey), Meghan (pink), Millie Mae (brown), Nyunga (light blue).

Figure 25. Plot of 95% MCP home range estimate for Bomber.

Figure 26. Plot of 95% MCP home range estimate for Cain.

Figure 27. Plot of 95% MCP home range estimate for Jean.

Figure 28. Plot of 95% MCP home range estimate for Sue-Bob.

Figure 29. Plot of 95% MCP home range estimate for Zara.

Figure 30. Plot of 95% MCP home range estimate for Heath.

Figure 31. Plot of 95% MCP home range estimate for Lilly.

Figure 32. Plot of 95% MCP home range estimate for Lindsay.

Figure 33. Plot of 95% MCP home range estimate for Lucky.

Figure 34. Plot of 95% MCP home range estimate for Meghan.

Figure 35. Plot of 95% MCP home range estimate for Millie Mae.

Figure 36. Plot of 95% MCP home range estimate for Nyunga.

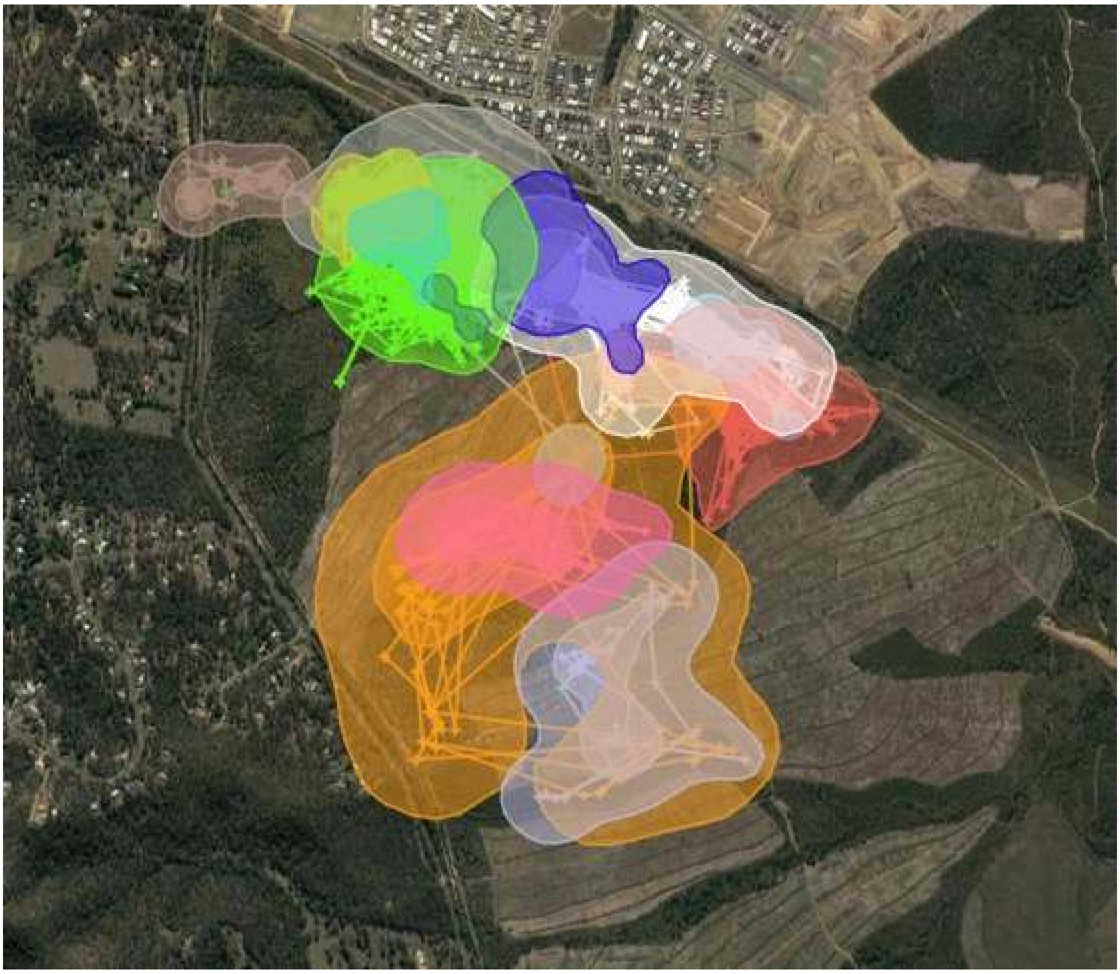

Figure 37. Plot of 50% & 95% KUD home range estimates for12 koalas at the site in 2019.

Colour key: Bomber (dark blue), Cain (green), Jean (white), Sue-Bob (aqua), Zara (mustard), Heath (orange), Lilly (purple), Lindsay (red), Lucky (grey), Meghan (pink), Millie Mae (brown), Nyunga (light blue).

Figure 38. Plot of 50% and 95% KUD home range estimates for Bomber. The 50% KUD is the smaller polygon within the larger 95% KUD polygon.

Figure 39. Plot of 50% and 95% KUD home range estimates for Cain. The 50% KUD are the two smaller polygons within the larger 95% KUD polygon.

Figure 40. Plot of 50% and 95% KUD home range estimates for Jean. The 50% KUD are the smaller polygons within the larger 95% KUD polygon.

Figure 41. Plot of 50% and 95% KUD home range estimates for Sue-Bob. The 50% KUD are the smaller polygons within the larger 95% KUD polygon.

Figure 42. Plot of 50% and 95% KUD home range estimates for Zara. The 50% KUD is the smaller polygon within the larger 95% KUD polygon.

Figure 43. Plot of 50% and 95% KUD home range estimates for Heath. The 50% KUD is the smaller polygon within the larger 95% KUD polygon.

Figure 44. Plot of 50% and 95% KUD home range estimates for Lilly. The 50% KUD is the smaller polygon within the larger 95% KUD polygon.

Figure 45. Plot of 50% and 95% KUD home range estimates for Lindsay. The 50% KUD is the smaller polygon within the largest 95% KUD polygon. The two small isolated polygons are part of the 95% KUD.

Figure 46. Plot of 50% and 95% KUD home range estimates for Lucky. The 50% KUD is the smaller polygon within the largest 95% KUD polygon. The small isolated polygon is part of the 95% KUD.

Figure 47. Plot of 50% and 95% KUD home range estimates for Meghan. The 50% KUD is the smaller polygon within the larger 95% KUD polygon.

Figure 48. Plot of 50% and 95% KUD home range estimates for Millie Mae. The 50% KUD includes both the smaller polygons within the larger 95% KUD polygon.

Figure 49. Plot of 50% and 95% KUD home range estimates for Nyunga. The 50% KUD is the smaller polygon within the largest 95% KUD polygon. The two small isolated polygons are part of the 95% KUD.