Koala Monitoring Program

Yarrabilba Priority Development Area

Annual Report on Koala Health and Movements

2020

Picture of female 13558 “Gladys” being released after examination and tagging.

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Introduction

This report presents a summary of the findings from the 2020 *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 several 3-day fieldtrips that were spread throughout the year. In 2019, four fieldtrips were conducted but in 2020, this was reduced to three fieldtrips due to the impacts of the COVID-19 pandemic. On each three-day fieldtrip, 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 previous years. Recommendations are made on how the health of koalas infected with *Chlamydia* should be managed and monitored in 2021.

Methodology

Three *Koala Capture / Monitoring Events* were undertaken in 2020 during the following months: April, July, and 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. We attempted to examine collar fit approximately every 3-5 months, to ensure collars were neither too tight nor loose, and 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 University of Queensland Animal Ethics Certificate.

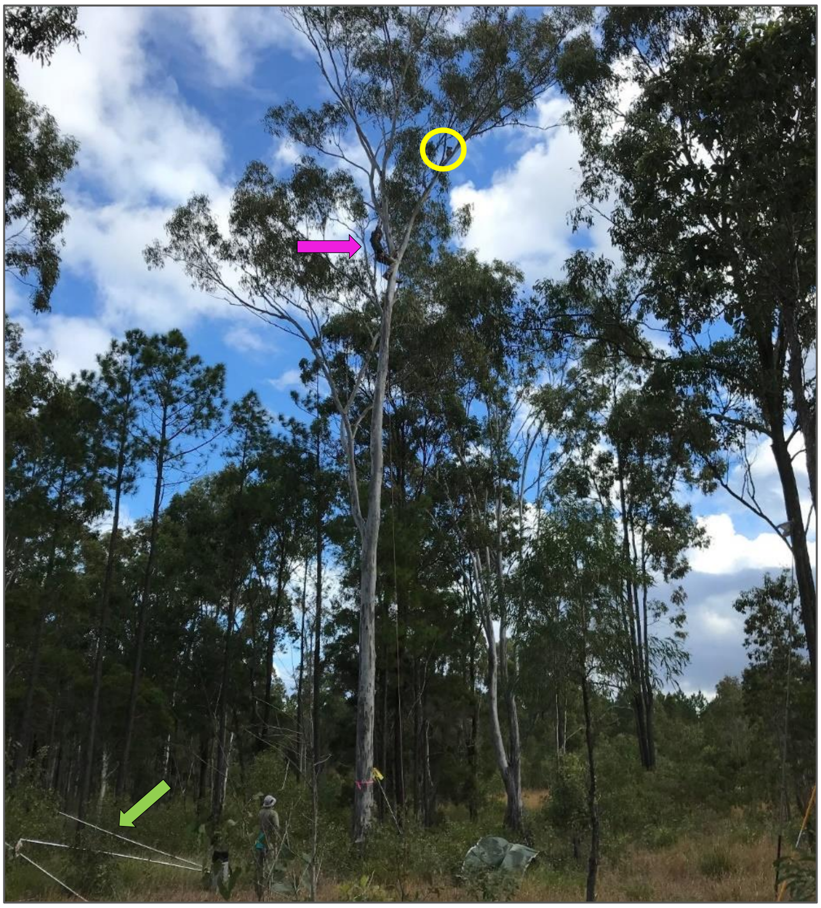

Figure 1. Image of the attempted capture of a koala (yellow circle) using the flagging method. The climber (pink arrow) used extendable poles (green arrow) to flag the koala down to a height that the ground team could take over and continue flagging it safely to the ground.

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 2020, a total of 14 tagged koalas were observed at the study site, comprising 12 independent koalas and two late-stage back young (i.e. still dependent upon their mothers to some extent)(Table 1). There was a relatively even sex ratio of five males and seven females among the tagged, independent koalas. Ten of the tagged koalas were caught and examined during 2020, including three that were new to the research program, having not been caught before. This brings the total number of koalas that have been examined at the site since 2017 to 23 individuals (Table 1).

In addition to the tagged koalas that were observed at the site, there were 19 records of untagged koalas (aka. 'cleanskins') throughout 2020 (plus one record of a cleanskin off site in the Birnam Range Reserve). Because these koalas had not been fitted with ear tags, it was not possible to distinguish between individuals. It is likely that some of these 19 records would have been the result of the same individual being observed on more than one occasion.

As in 2018 and 2019, there was a good demographic spread amongst the sampled population in 2020, including late-stage back young (Bilba, Kamala), young adults (Nyunga, Wooten), numerous mid-aged koalas (4-8yrs) and few older individuals (Bomber, Zara, Millie Mae). Approximately half of the mature females (4 of 7) were known to have reproduced in 2020.

Several of the observed koalas have been resident at the site for several years. The male koala named Bomber was the second koala tagged on the site, on 18th May 2017. He was recaptured and collared in April 2020, and tracked for the remainder of the year.

In contrast, some koalas have dispersed from the site. In 2019, the young male named Kevin dispersed in a westerly direction across Waterford-Tamborine Rd after which his VHF signal was lost. In November 2019, another young male (Wooten) was first captured as a back young. By April 2020, he had grown to 3.7kg and was independent, and by July 2020 he was 4.7kg (Figure 5). In late September, Wooten dispersed off site, crossing Waterford-Tamborine Rd to access the forests of the Birnam Range Reserve. His case highlights the large dispersal capability of young koalas, and the dangers they often face on these dispersal movements (e.g. crossing roads, passing through areas with domestic dogs) .

Figure 5. Image of Wooten after fitting with an LX collar (July 2020).

Table 1. List of the 23 koalas that have been tagged at the study site since May 2017. Koalas that were sighted in 2020 are shaded orange; koalas that were sighted, captured and examined in 2020 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	Found dead April 2020
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	

Summary of Koala Health

Overview

All 10 koalas caught in 2020 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 koalas that were examined in 2020. Swab test results were not available at the time of report preparation for the five koalas that were examined in November 2020. Where possible, Table 2 also also shows the equivalent health information and test results for the same koalas, from 2019.

Table 2. Details of health and swab test results for koalas examined in 2020 (blue highlight) and 2019 (grey highlight, where data available). Swab test results for koalas examined in November 2020 were not available at the time of report preparation (shown with dash).
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	21/7/2020	No clinical signs of disease; BCS 8 Carrying pouch young	not swabbed	not swabbed	not swabbed
Zara	30/4/2020	No clinical signs of disease; BCS 8 Carrying pouch young	negative	negative	no result
Zara	6/3/2019	No clinical signs of disease; BCS 8	negative	negative	negative
Bomber	29/4/2020	No clinical signs of disease; BCS 6	negative	negative	positive 175
Bomber	21/11/2019	No clinical signs of disease; BCS 5	negative	negative	negative
Bomber	31/7/2019	No clinical signs of disease; BCS 6	negative	negative	positive 666
Lucky	30/4/2020	No clinical signs of disease; BCS 9	negative	negative	negative
Lucky	27/5/2019	No clinical signs of disease; BCS 9	negative	positive 94	negative
Millie Mae	23/7/2020	No clinical signs of disease; BCS 7	negative	negative	positive 567,337
Millie Mae	21/11/2019	No clinical signs of disease; BCS 7	positive 595	positive 263	positive 950,244
Wooten	10/11/2020	No clinical signs of disease; BCS 8	not swabbed	not swabbed	not swabbed
Wooten	29/4/2020	No clinical signs of disease; BCS 9	positive 131	negative	no result

Cain	9/11/2020	Right eye inflamed, rump stained; BCS 5	-	-	-
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
Nyunga	10/11/2020	No clinical signs of disease; BCS 6 With young (Kamala)	-	-	-
Nyunga	28/5/2019	No clinical signs of disease; BCS 9	negative	negative	negative
Kamala	10/11/2020	No clinical signs of disease; BCS 9	-	-	-
Bilba	10/11/2020	No clinical signs of disease; BCS 8	-	-	-
Gladys	11/11/2020	No clinical signs of disease; BCS 7	-	-	-

*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.

The results show that in 2020, three of five koalas (Bomber, Wooten & Millie-Mae) for which data are available, returned positive test results from at least one swab site. None of these koalas displayed overt signs of disease.

The low positive test results for Bomber and Wooten (see IFU/mL values in Table 2 above) suggest low-grade infections. It is possible that Bomber has had a low-grade infection since at least mid-2019. His negative test results in November 2019 may have been due to an undetected low-level infection in his urethra, given the low positive results both before and after this time point (see Table 2). Low-level infections may go unnoticed if the swab fails to collect a detectable amount of chlamydial DNA. This highlights an issue with the current gold standard method of testing (quantitative PCR), which is that negative test results do not provide unequivocal evidence of the absence of *Chlamydia*. Where possible, repeat testing can be used to help overcome this short-coming, and we have attempted to do that as part of the management program.

This detectability issue may also relate to Lucky's test results in 2020. A swab sample collected from Lucky's right eye in May 2019 returned a weak positive result (94 IFU/mL), suggesting he had a low-level chlamydial infection at that time. The decision was made to monitor the condition of this eye to see if the infection resolved naturally. The negative test result from his right eye swab sample in April 2020 suggests that either there was no longer an infection at this site, or that it persisted but was not detected.

Mille Mae was the only koala that returned strong positive swab test results in 2020. The data suggests she had a major infection in her urogenital tract. It is possible that she also had low-level infections in each eye that went undetected, given the positive swab results from these sites in 2019 (see Table 2).

Details of examined koalas

This section provides greater detail on the health and physical condition of the ten koalas that were examined in 2020. As mentioned, several of these koalas were also examined in previous years, making it possible to assess changes in their health over this time period.

Two of the previously tagged females (Zara and Nyunga) bred in 2020, with their young being captured and tagged in November. These females have never returned positive swab samples, suggesting they are free from chlamydial infection (note: Nyunga's Nov'20 swab results are pending). When Nyunga was first captured in May 2019 her pouch appeared unused, so the young she reared in 2020 was likely her first offspring. Zara is known to have produced one other young (female 13496 "Squeak") since she was first captured in June 2018. Zara was in good condition (BCS 7) when examined in July 2020, and weighed 6.7kg. Nyunga was a younger koala (est. 2-4yrs), and when examined in November 2020 she weighed 4.9kg and was given a body condition score of 6.

Figure 6. Image of Zara being released up a small gum-topped box after her examination.

Zara's young in 2020 was a female named Bilba (# 13269). She was in good condition (body score 8/10) and had no signs of infection. She weighed 2.08kg and was fitted with unique ear tags (see Table 1). Bilba was a capable climber and will likely become independent in late 2020 or early 2021.

Figure 7. Picture of Bilba at first capture.

Nyunga's offspring in 2020 was a female named Kamala (# 13557). She was in very good condition (body score 9/10) and had no signs of infection. She weighed 2.47kg and was fitted with unique ear tags (see Table 1). Kamala was a capable climber and will likely become independent before the end of 2020.

Figure 8. Picture of Kamala being released by Dr Bill Ellis after her first health examination.

Wooten (M) was first captured as a back young in November 2019 with his mother Lilly. He was not swabbed at that time due to his small size (1.4kg), but Lilly tested positive for *Chlamydia* at all three swabbed sites (left eye, right eye, urogenital tract). Wooten was recaptured in April 2020 and swabs collected, with the left eye returning a weak positive result (131 IFU/mL, see Table 2). He appeared healthy and in good condition otherwise. It is possible that this infection was the result of vertical transmission from his infected mother Lilly. She was found deceased at the site in April 2020. We estimated that she died 1-2 months prior, based on the extent of decay. Unfortunately, the carcass was too decomposed to conduct a meaningful necropsy, but it is possible that her death was related to the chlamydial infection. When Wooten was recaptured in November 2020 he was still in good condition and did not have any overt signs of disease. At that time, he had moved several kilometres from the study site so his collar was removed as he was no longer part of the monitoring program.

Figure 9. Image of Wooten when he was recaptured to remove his collar (November 2020).

The large male named Bomber was first captured in mid-2017. He was examined on numerous occasions since that time, and has generally had a body condition score of 5 or 6 (i.e. despite his very large size, we have never recorded him as being in very good condition). He weighed 9.1kg at first capture, dropped approximately 1.2kg in 2019 and then regained that mass to weigh 9kg in April 2020. At first capture Bomber 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; 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 collected in November 2019 returned a negative result, but the same sample collected in April 2020 returned a weak positive result (175 IFU/mL, see Table 2). At all these time points both ocular swabs have returned negative results.

As mentioned, the results suggest that Bomber has had a low-level chlamydial infection in his reproductive tract since at least mid-2019, and that the swabs collected in November 2019 failed to capture chlamydial DNA, simply because the level of infection was very low. At the end of 2020, Bomber was still fitted with an LX tracking collar. His condition and infection status will be re-examined in early 2021 to determine if any intervention is required.

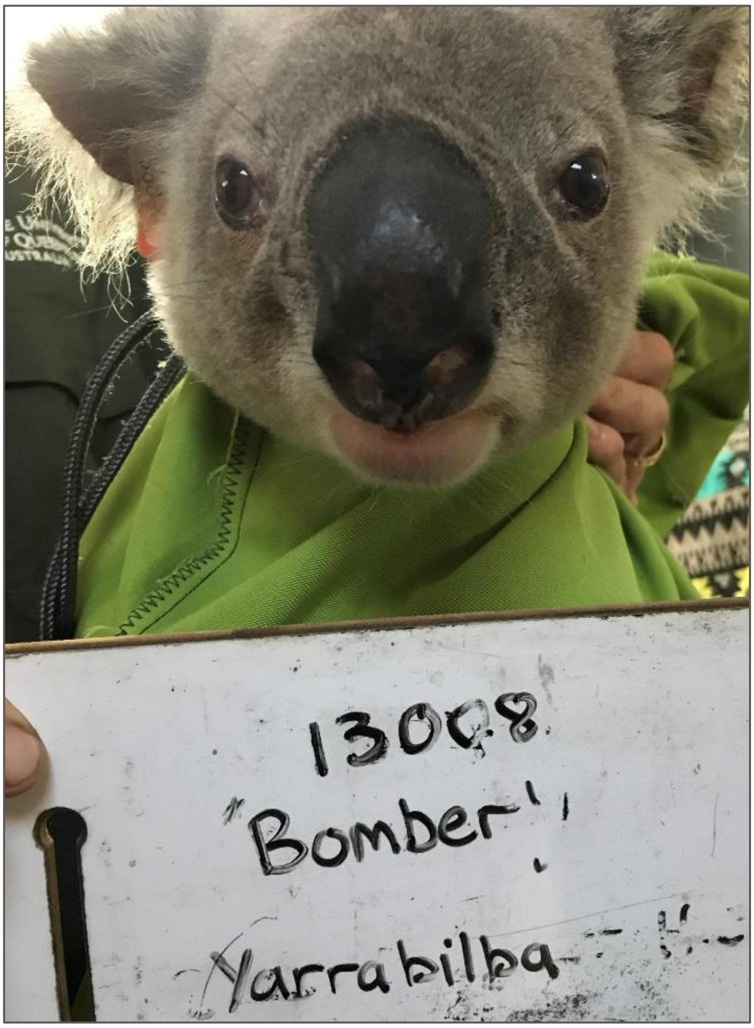

Figure 10. Image of Bomber showing that his eyes were clear and free of obvious infection.

When first captured in May 2019, Lucky was a young male in excellent physical condition (BCS 9) but his right eye swab returned a weak positive result (94 IFU/mL, see Table 2). When he was re-examined in April 2020 he still appeared in very good condition (BCS 9) and all swabs tested negative for *Chlamydia*. While it is possible that his infection had resolved, there is also the possibility that he still had a low-level infection that was not detected with the collected swabs. Between May 2019 and April 2020, Lucky went from 7.4kg to 8.5kg, making him one of the larger males at the site.

Figure 11. Image of male koala 13508 Lucky.

In November 2020, a new female (Gladys 13558) was captured and tagged. She was given a health assessment and was found to be in good condition (7/10 body score), weighed 4.93kg and was carrying a young in her pouch that was estimated at 6-7mths old. Her eyes and rump appeared clear and free of clinical signs of infection. The laboratory test results for collected swabs are still pending. The level of tooth wear suggested that Gladys was young (2-4 years of age).

Figure 12. Image of Gladys following her first health examination (November 2020).

Cain (M) was the only koala captured in 2020 that displayed overt signs of disease. He was first tagged at the site in 2017 (October) when his right eye appeared very inflammed and later tested positive for *Chlamydia*. He was taken into care (Australia Zoo Wildlife Hospital) and successfully treated with antibiotics, then returned to site in December 2017. 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 right eye. Unfortunately, he was unable to be captured, as he clearly required medical attention.

When Cain was recaptured in November 2020 his right eye was still inflammed and his rump was stained; his body score was 5/10. He was taken to Australia Zoo Wildlife Hospital for veterinary assessment and treatment, and was immediately put on a course of antibiotics. At the time of report preparation Cain was still undergoing treatment in captivity. If the treatment is successful then it is anticipated that Cain will be ready for release in January 2021.

Figure 13. Picture of Cain after several days of treatment at Australia Zoo Wildlife Hospital (November 2020). The inflammation of his right eye had already reduced considerably by this time. (Note: the water on his fur is from the sprinkler system, used to keep the koalas cool in their enclosures).

Lilly and Millie Mae were positive at all three swabbed sites (left eye, right eye, urogenital tract). Lilly's test results suggested a mild 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.

The female koala named Millie Mae was first captured in November 2019 when she weighed 7.3kg, was in good condition (BCS 7) and did not have a young. Although she did not present any overt signs of chlamydial infection, all collected swab samples tested positive for *Chlamydia.* These results were suggestive of a low-level infection in each eye and a very heavy infection in the urogenital tract (almost 1 mill. IFU/ml, see Table 2). Millie Mae was not able to be recaptured until July 2020. She again tested positive for *Chlamydia* on the urogential swabs, but negative on the occur swabs. Her weight and condition were the same as in November 2019, and she still had no overt signs of disease.

Figure 14. Millie Mae being anaesthetised prior to her health examination in July 2020.

Given the strong positive urogenital tract swab results, we had planned to recapture Millie Mae at the November fieldtrip and take her to Australia Zoo Wildlife Hospital for thorough veterinary assessment and treatment. The intention was two-fold; firstly, to improve Millie Mae's health by eliminating or at least greatly reducing her chlamydial infection, and secondly, remove Millie Mae from the population while she was carrying such a high chlamydial load, as she was likely a source of infection to males that mated with her. It is possible that her infection had already caused the formation of cysts in the reproductive tract, but this could only be confirmed by specialist ultrasound examination. Such cysts generally lead to infertility in female koalas. However, during the November fieldtrip Millie Mae evaded capture.

Conclusion

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. 20% of the population was infected with *Chlamydia*). In 2019, six of 12 examined koalas tested positive for *Chlamydia* (50% of population). In 2020, three of five koalas for which swab results were available, tested positive for *Chlamydia* (60% of population), though none displayed overt signs. Interestingly, large quantities of chlamydial DNA were detected in only one individual (Mille Mae's UGT sample). All other swabs were either negative or had a low number of detected units (i.e. <200 IFU/ml).

Although the 2020 sample size is small, if it is representative of the broader population then the results suggest that chlamydial infection is still common. As in 2019, it is impossible to be certain about the driver(s) that have led to an apparent increase in chlamydial infection in the population since 2018. We have previously suggested that plausible explanations may include 1. increased sexual interactions (due to a more concentrated/dense population following habitat reduction), and 2. Increased physiological stress (due to challenging environmental conditions). However, there is no way to test these theories.

The apparent increase in the proportion of koalas infected with *Chlamydia* at the site during 2019 and 2020 warrants further investigation and management action, where possible. We recommend that in 2021, PCR testing of all examined koalas be continued, with repeat testing undertaken where appropriate. We also recommend that koalas with swab test results that are suggestive of heavy infections (e.g. Millie Mae), be taken into captivity for veterinary assessment and treatment. Similarly, we recommend that koalas with overt disease (e.g. stained rumps or inflamed eyes) be taken in for assessment and treatment. These actions are not aimed at trying to eliminate *Chlamydia* from the population (a near impossible task), but rather at minimising the negative consequences/manifestations of infections within the population, and the potential for transmission between individuals. This is especially important given that the local koala population continues to experience dramatic landscape change during ongoing development of the site.

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 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 15 – 40).

All LX collars had 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. In 2019, the weak-link mechanism was made of fishing line with known breaking strains, but unfortunately this design was too sensitive and collars frequently fell off koalas within one month of attachment. This led to the use of o-ring weak-links in late 2019 and throughout 2020 (following breaking strain tests), which proved far more suitable. Collars with these refined weak-links were rarely dropped, and there were no instances of koalas being 'hung' by the collar or sustaining collar rub. The o-ring weak-link has clearly resulted in improved collar retention while still providing protection against koalas being snagged; it will be used as the weak-link fitting for all deployments in 2021.

In 2020, eight koalas were collared and monitored for varying durations. This resulted in detailed movement datasets for seven of the eight koalas (Table 3). The eighth koala (Gladys) was only collared for a short period prior to the end of 2020, and the acquired movement dataset (n=14 fixes) was too limited to enable home range analysis.

Table 3 lists the number of fixes that were obtained for collared koalas in 2020, using radio-tracking points and collar data. The table also presents estimates of home range size using two common techniques; the same techniques were used to examine koala home ranges in the 2018 and 2019 annual reports.

Several of the koalas collared in 2020 were collared in 2019, and two koalas (Bomber and Zara) were also collared in 2018. This enabled a comparison of their movement and home range metrics across years (see values in brackets, Table 3).

An obvious difference in 2020 was the larger dataset available for most koalas. This was directly due to an improved weak-link design and resultant collar retention. In 2020, the mean number of fixes per koala was 292 ± 68, and for five of the seven koalas, more than 200 geographical fixes were available for analyses after filtering of inaccurate points (see Table 3). In 2019, while more koalas were collared (n=13), the deployments were generally shorter and the mean number of fixes per koala was 116 ± 31; only two individuals had movement datasets exceeding 200 fixes. Ultimately, the more extensive the dataset, the greater the level of confidence in the calculated home range metrics.

Table 3. Details of movement datasets and home range estimations for koalas collared in 2020. Where data was available, numbers presented in round brackets are the equivalent metric from 2019, and in square brackets from 2018.

UQ #	Koala name	Sex	No. fixes*	Avg no. fixes/day	MCP 95% (ha)	KUD 50% (ha)	KUD 95% (ha)
13008	Bomber	M	451 (62) [105]	1.3 (0.2) [0.4]	11.5 (7.9) [33.3]	3.9 (2.9) [12.0]	17.0 (21.0) [64.7]
13307	Lilly	F	75 (53)	0.6 (1.3)	51.1 (19.4)	14.8 (11.2)	89.7 (45.8)
13508	Lucky	M	52 (54)	0.2 (0.3)	9.3 (10.4)	3.7 (6.8)	20.6 (38.8)
13533	Millie Mae	F	489 (59)	1.4 (1.5)	8.3 (3.3)	2.9 (2.7)	11.7 (10.3)
13509	Nyunga	F	435 (64)	1.3 (0.3)	19.6 (2.5)	3.1 (1.0)	22.5 (7.1)
13308	Wooten	M	308	1.4	396.3	91.0	687.8
13304	Zara	F	236 (77) [139]	0.8 (0.3) [0.8]	5.5 (4.9) [5.3]	2.0 (2.5) [2.4]	8.9 (9.4) [8.8]

* 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 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.

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

Examination of dispersal in the sub-adult Wooten

Wooten was initially fitted with a lightweight VHF collar in April 2020, because he was too small to fit with the heavier LX collar (min. 4kg koala). We were interested to see if this sub-adult male koala would disperse from his natal area. Wooten had not dispersed from the study area by July 2020, at which time he was large enough (4.7kg) to fit with an LX collar. He moved widely on the site and then in late September, he crossed Waterford-Tamborine Rd moving in a westerly direction (see Figures 16 & 23). The last upload that was received from his LX tag occurred on 30th September and indicated Wooten's location on the eastern spine of the Birnam Range, approximately 1.3km west of the study site.

Wooten was not sighted again until the November 2020 fieldtrip, when he was radio-tracked to an ironbark on a steep slope within the Birnam Range Reserve. He was recaptured so that his collar could be removed. Fortunately, although Wooten's collar had not been regularly uploading during his dispersal (due to the large distance from a base station), the collar was logging the scheduled fixes. These data points were obtained after the collar was retrieved. The data show that Wooten had settled and taken up a home range in the area where he was captured (see Figures 31 and 39; discussed in more detail below).

Koala habitat use and home ranges

Very detailed movement datasets were obtained for most collared koalas (>50 fixes ea., avg. 1.0 fix/day), permitting an examination of habitat use and home ranges. The smallest datasets were those for Lilly (n=75 fixes) and Lucky (n=52 fixes); it is possible that these koalas did not move throughout their entire home range areas during the period that they were collared. All other datasets consisted of more than 200 fixes per koala.

Movements plots (Figures 15 – 24) 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 included 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 Gladys and Zara (and by Cain, Kevin and Sue-Bob in 2019; see Figures 18 and 24).

The data also showed that the female koala named Lilly utilised isolated trees retained in cleared areas zoned for future development (Figure 19). In 2019, 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). In 2019 and 2020, the data suggest that Lilly used the retained trees as 'stepping stones', facilitating safe movement (Figure 19). Koalas moving through largely cleared areas such as these are at greater risk of attack from ground-based predators, especially wild dogs, due to the lack of trees that offer refuge.

Because collar deployments were longer in 2020, the home range estimates were generally larger than in previous years (for the same individuals; see Table 3). This was very likely due to the larger datasets available for mapping. The 95% MCP home range estimates for females averaged 21.1ha, and ranged from 5.5ha (Zara) to 51.1ha (Lilly); in 2019 the average was 10.9ha. However, Lilly's home range was inflated by her use of isolated trees; much of her range consisted of areas devoid of trees (see Figures 27 and 35). This highlights a major drawback of some home range estimator methods, which can incorporate 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 Lilly.

The 95% MCP home range estimates for the three collared males averaged 139ha; in 2019 the average was 28.3ha. Bomber had a range of 11.5ha, Lucky 9.3ha and Wooten 396.3ha. When Wooten was excluded, the average 95% MCP for males dropped to 10.4ha. Wooten's far larger range estimate was due to the fact that his dataset included his dispersal movement to the Birnam Range Reserve, on the western side of Waterford-Tamborine Rd (Figure 31). For consistency, all of Wooten's datapoints were included in the home range analyses, but this resulted in an MCP polygon with a length exceeding 4km (Figure 31). It makes greater ecological sense to separate Wooten's movement data into that period when he was considered to be dispersing, and that period when he appeared to settle and take up a home range. Examining the data more closely, Wooten's movements appeared to settle around October 3rd, after which his overnight movement distances were greatly reduced. Using the ~40 fixes that were obtained after that time, Wooten's new home range in the Birnam Range was estimated at approximately 15-20ha in size. It was located 2.65km west of his previous range at the Yarrabilba study site.

Male and female home ranges were also examined using the alternative KUD estimator. The 95% KUD home range estimates for females averaged 33.2ha, and ranged from 8.9ha (Zara) to 89.7ha (Lilly). The 95% KUD estimates for males averaged 241.8ha (Bomber 17.0ha, Lucky 20.6ha, Wooten 687.8ha). When Wooten was excluded the average dropped to 18.8ha. Surprisingly, the average female home range size was larger than the average male (when Wooten was excluded), but Lilly's estimates inflated the female average for each technique (MCP and KUD). The averages were heavily impacted by atypical ranges as the overall sample size was quite small (3M,4F).

Home range estimates calculated using the 95% MCP were consistently smaller than those derived using the 95% KUD estimator (Table 3). Core home range areas were examined using the 50% KUD polygons, which were generally focused on riparian areas (Figures 33 – 40).

During 2020, the female koala named Millie Mae was regularly recorded crossing Waterford-Tamborine Rd, at the western edge of the site (Figure 21). Her core home range was centred on the riparian vegetation along Quinzeh Creek, either side of Waterford-Tamborine Rd (Figure 37). Millie Mae was also recorded crossing at this section of the road on numerous occasions in 2019. However, it is not clear if this koala uses the large drainage culvert to cross beneath the road, or if she walks across the road. Obviously, the latter option places Millie Mae at great danger of being hit by a vehicle.

Conclusion

In 2020, location data was collected for eight 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 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 Millie Mae, they can cross roads and large stretches of bare ground, and can make frequent use of isolated paddock trees and young regrowth eucalypts. Wooten also demonstrated the large dispersal capability of koalas, taking up a new home range (off site), approximately 2.65km from his natal range. Such dispersal movements are extremely important as they underpin gene flow and reduce the potential for inbreeding.

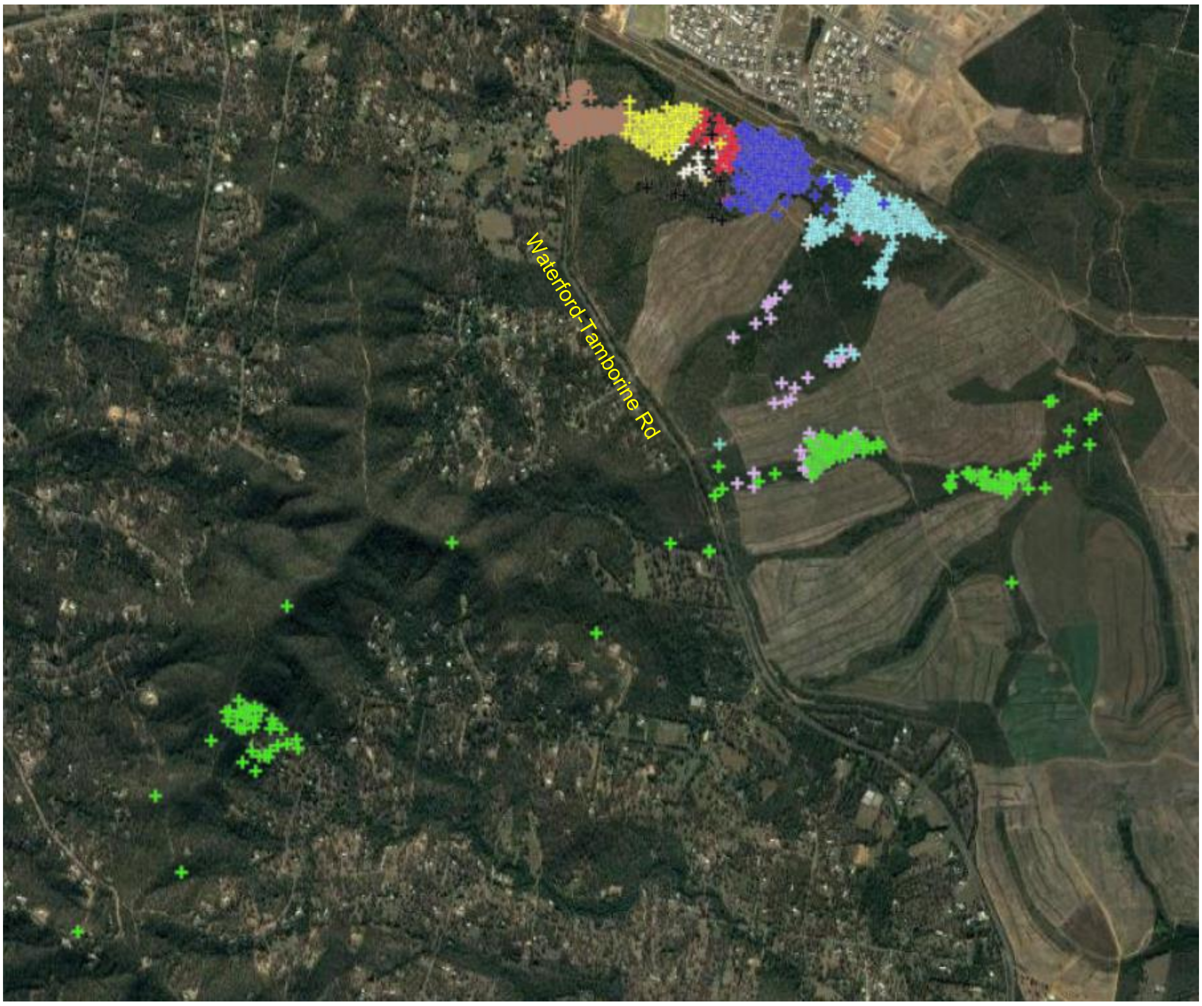

Figure 15. Plot of recorded locations for the 12 tagged adult koalas that were observed at the Yarrabilba study site in 2020, and 19 records of cleanskin koalas. The plot includes locations of collared and uncollared koalas.

Colour key: Bomber (dark blue), Cain (light green), Gladys (white), Jean (grey), Lilly (light purple), Lindsay (maroon), Lucky (red), Millie Mae (brown), Nyunga (light blue), Scarlet (mustard), Wooten (bright green), Zara (yellow), cleanskins (black).

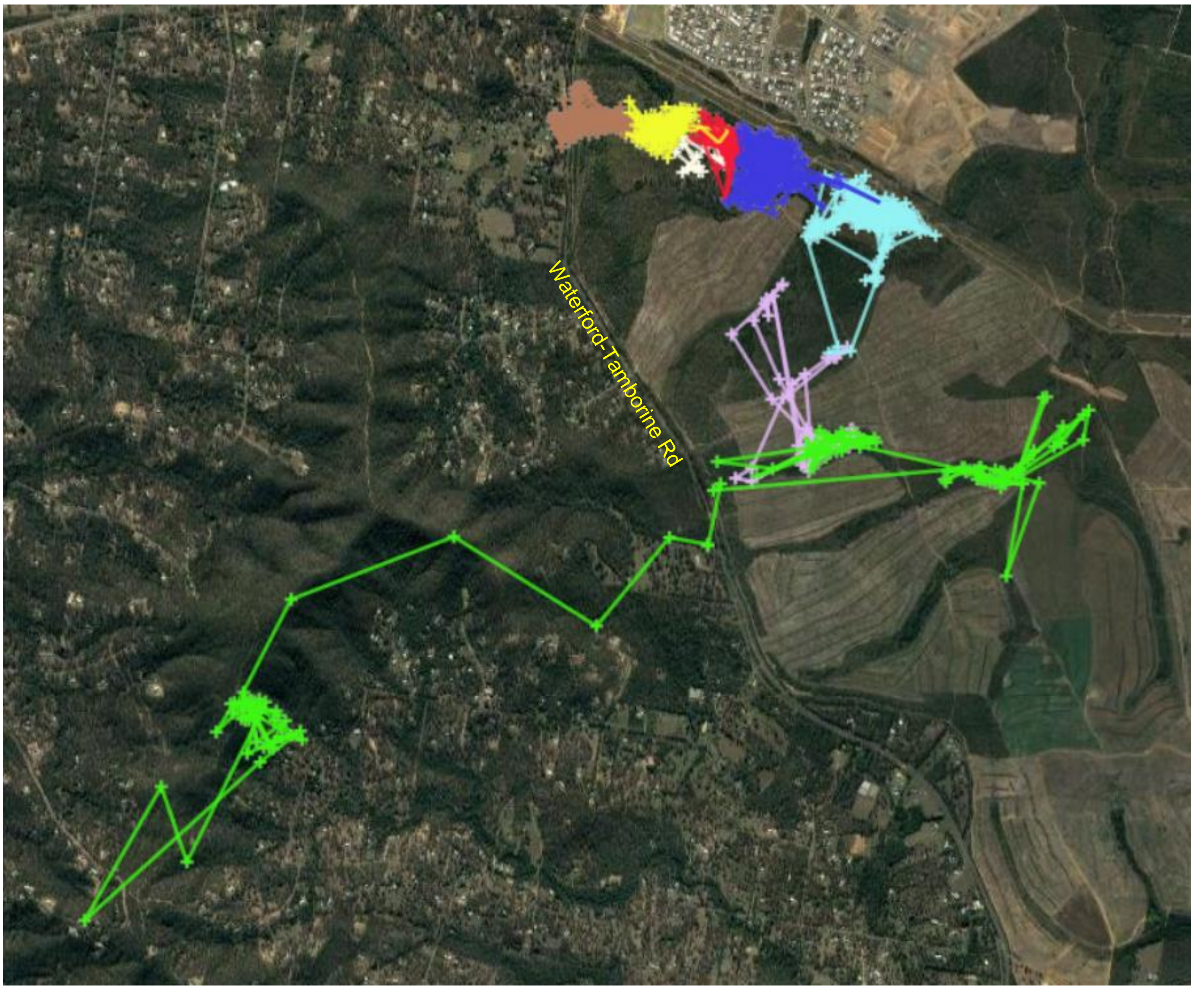

Figure 16. Plot of locations and movement trajectories for the eight koalas for which there were at least 10 data points. Consecutive fixes are joined by trajectory lines. Note, these lines do not necessarily indicate the exact movement pathways of the koalas, as they are only a straight line between consecutive points (most fixes were separated by 12 to 24 hours).

Colour key: Bomber (dark blue), Gladys (white), Lilly (light purple), Lucky (red), Millie Mae (brown), Nyunga (light blue), Wooten (bright green), Zara (yellow).

Figure 17. Plot of movements for Bomber.

Figure 18. Plot of movements for Gladys.

Figure 19. Plot of movements for Lilly.

Figure 20. Plot of movements for Lucky.

Figure 21. Plot of movements for Millie Mae.

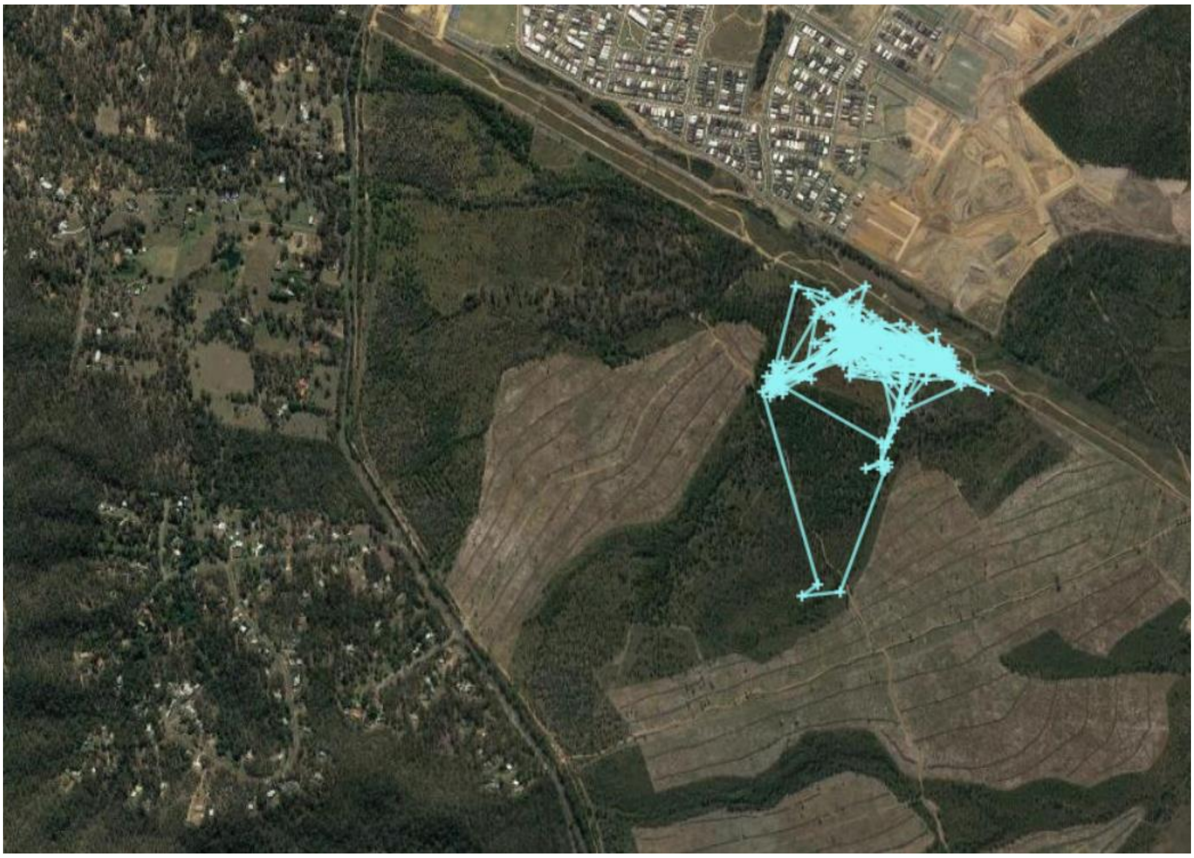

Figure 22. Plot of movements for Nyunga.

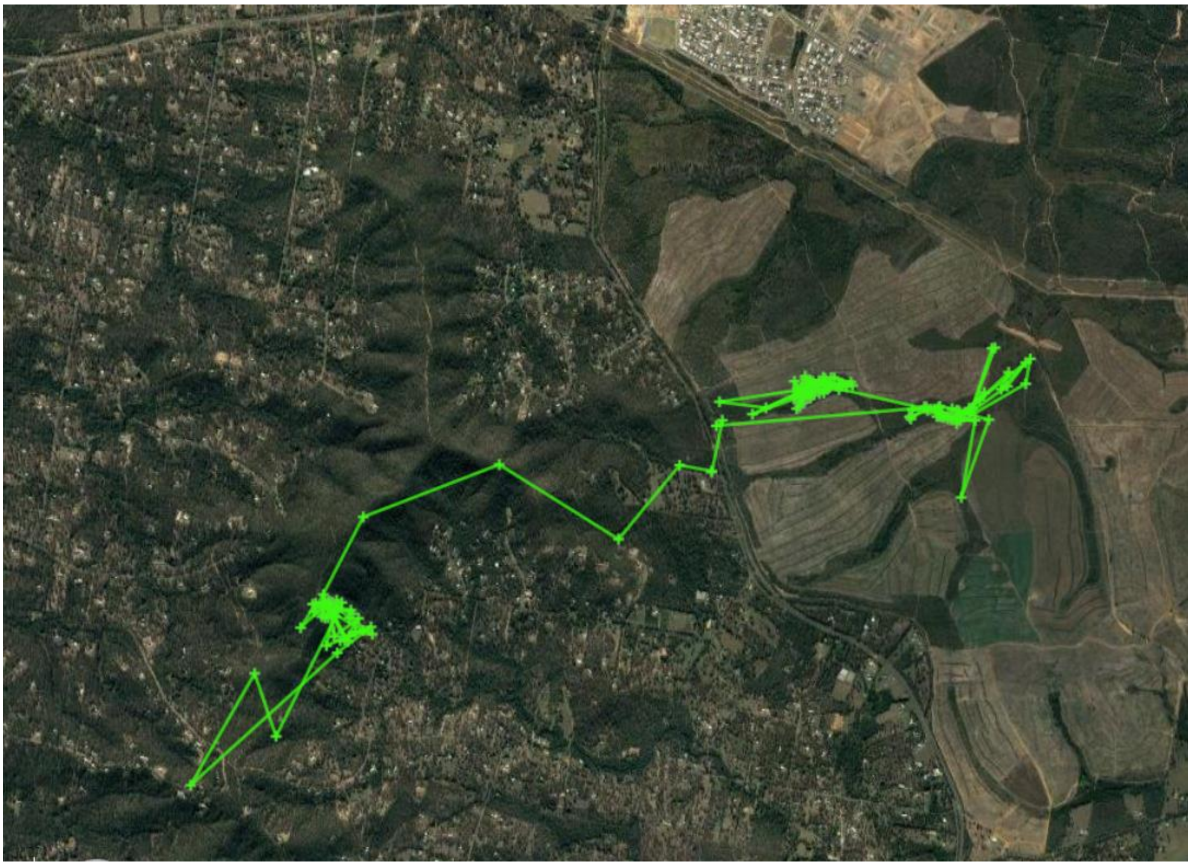

Figure 23. Plot of movements for Wooten.

Figure 24. Plot of movements for Zara.

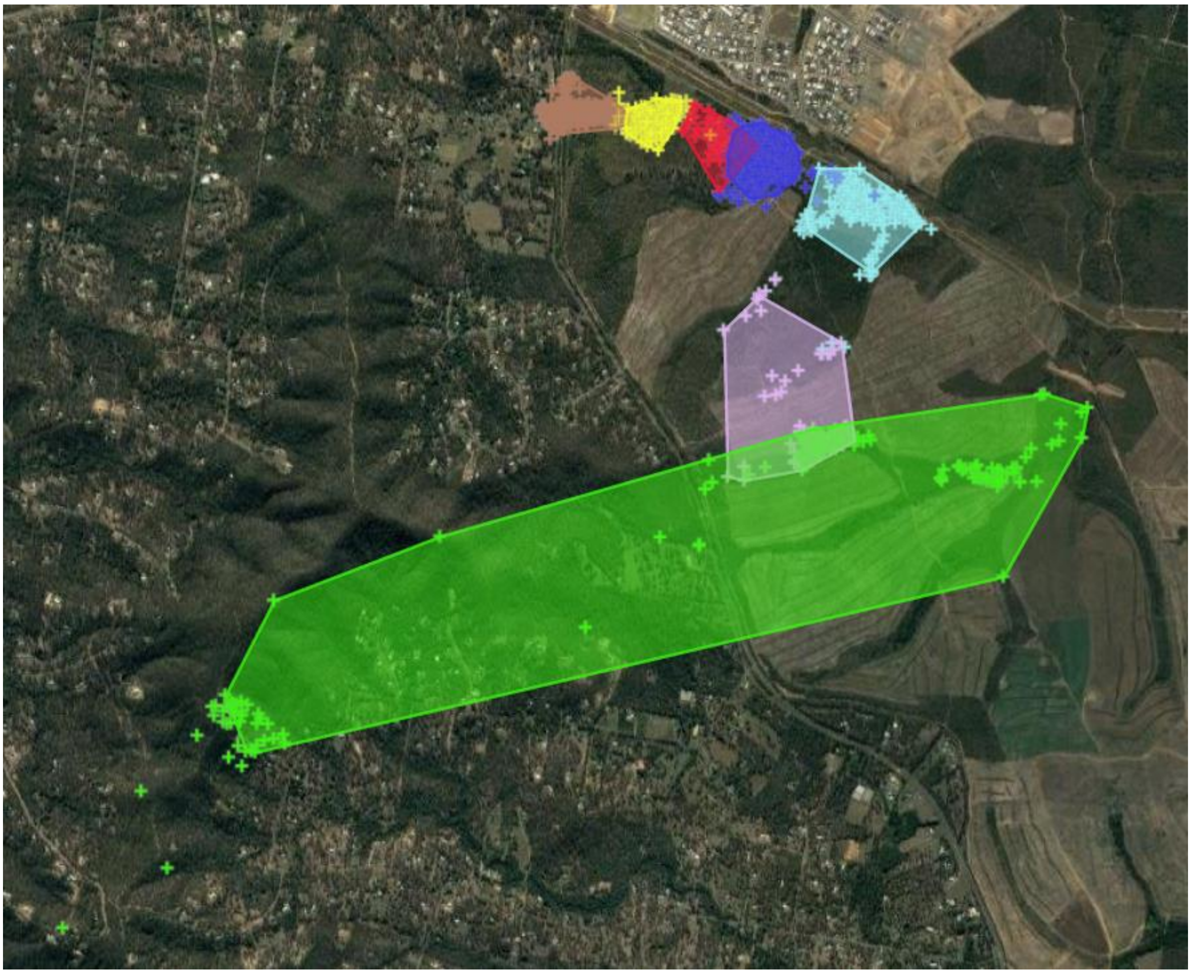

Figure 25. Plot of 95% Minimum Convex Polygon (MCP) home range estimates for seven koalas at the site in 2020.

Colour key: Bomber (dark blue), Lilly (light purple), Lucky (red), Millie Mae (brown), Nyunga (light blue), Wooten (bright green), Zara (yellow).

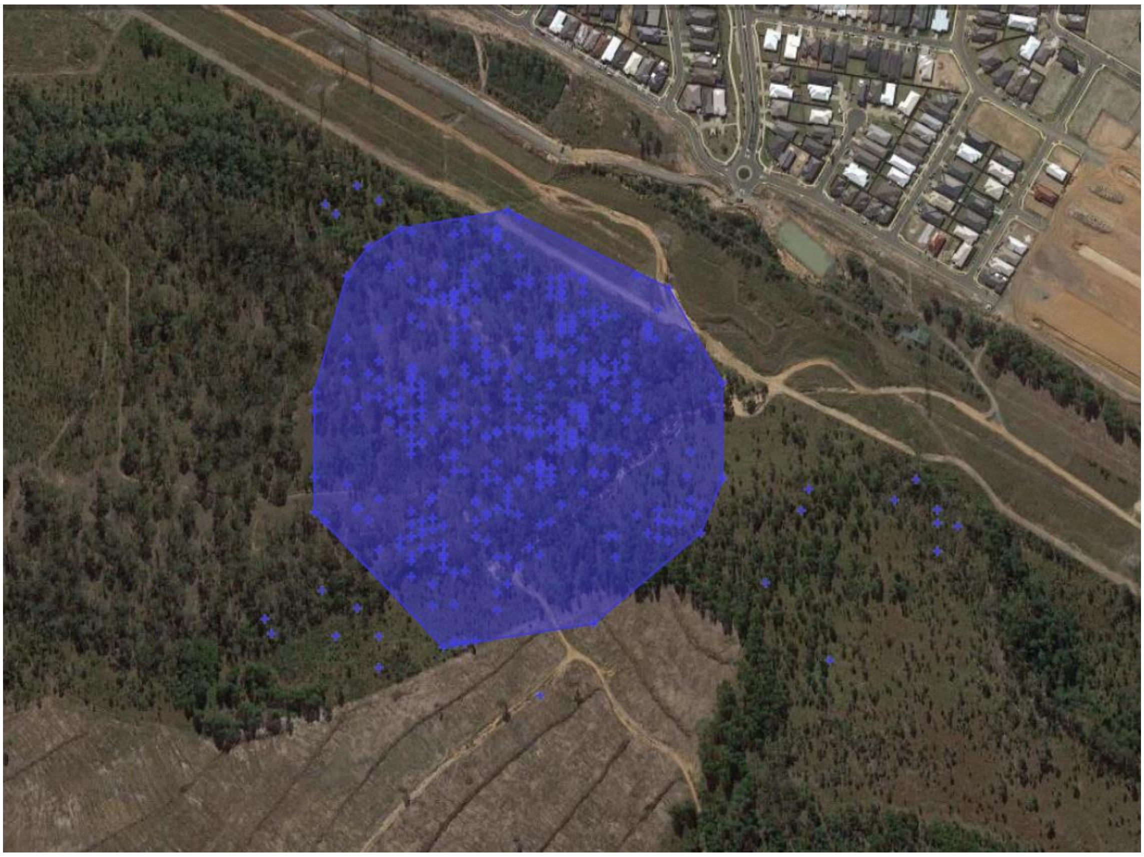

Figure 26. Plot of 95% MCP home range estimate for Bomber.

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

Figure 28. Plot of 95% MCP home range estimate for Lucky.

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

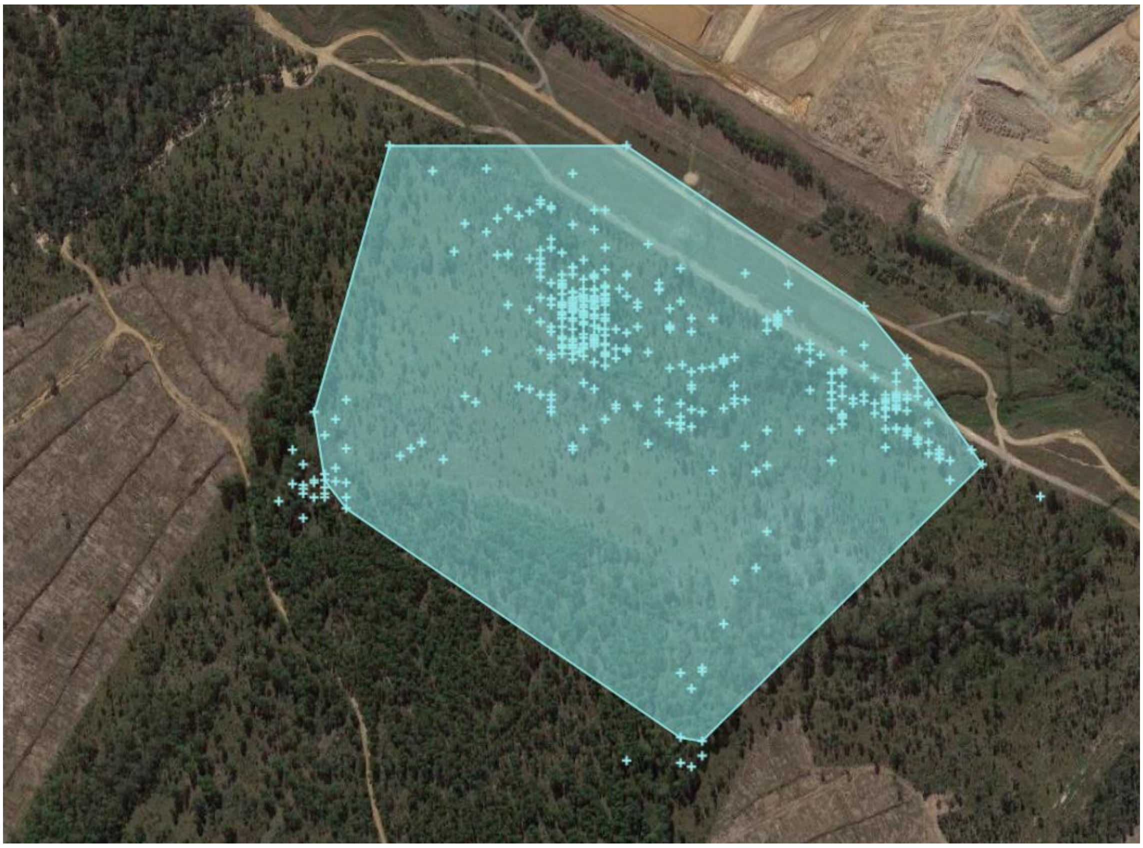
Figure 30. Plot of 95% MCP home range estimate for Nyunga.

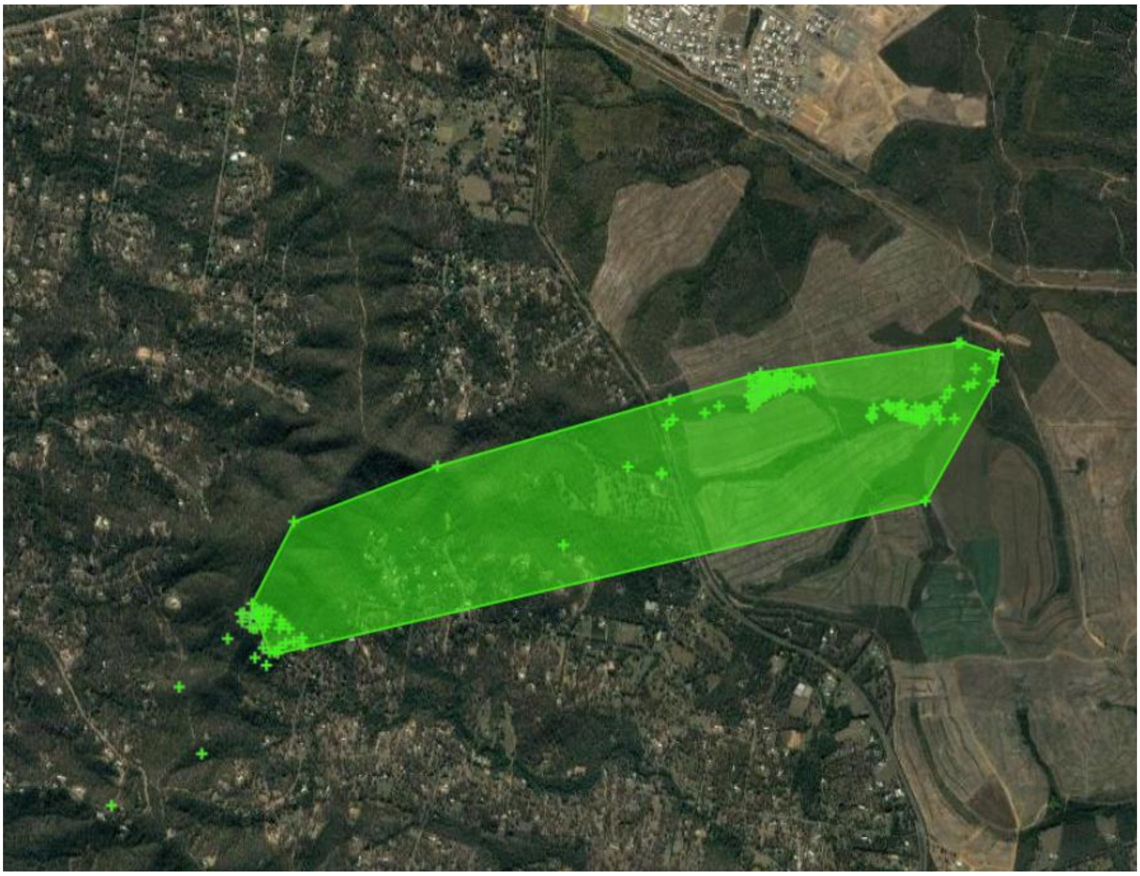
Figure 31. Plot of 95% MCP home range estimate for Wooten.

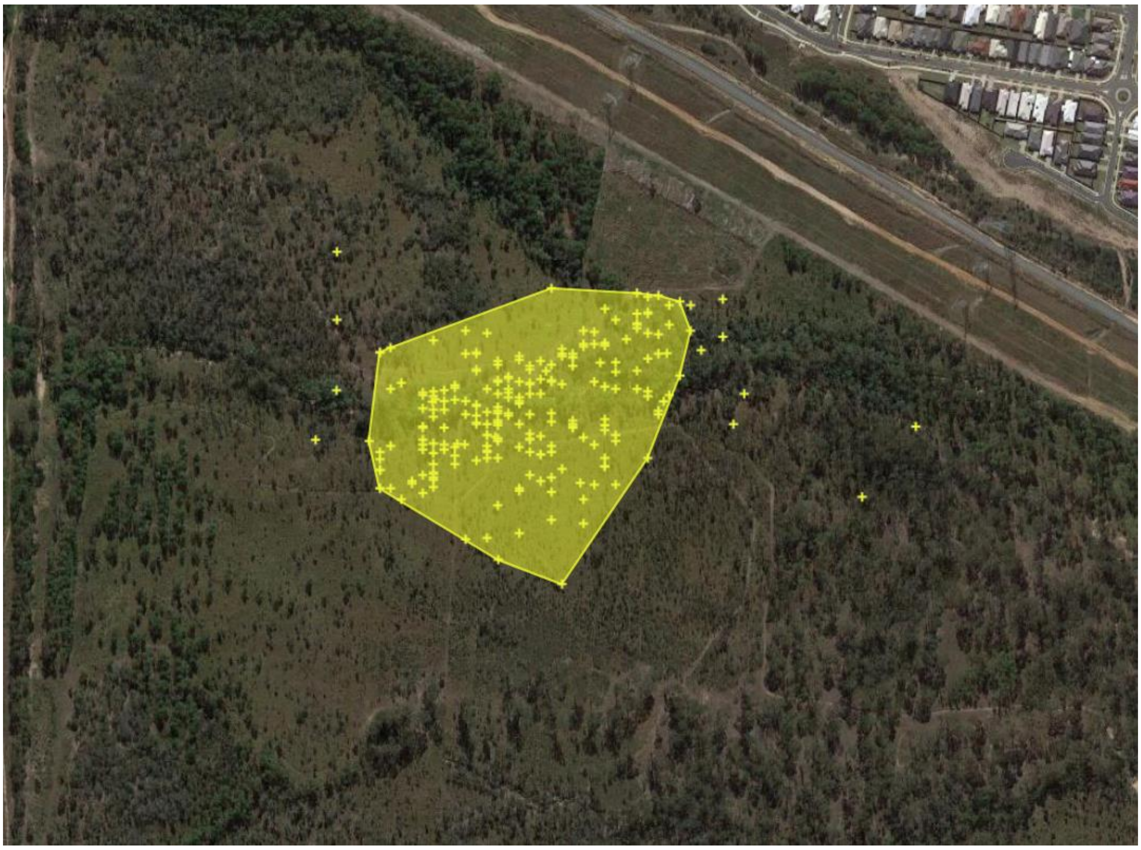

Figure 32. Plot of 95% MCP home range estimate for Zara.

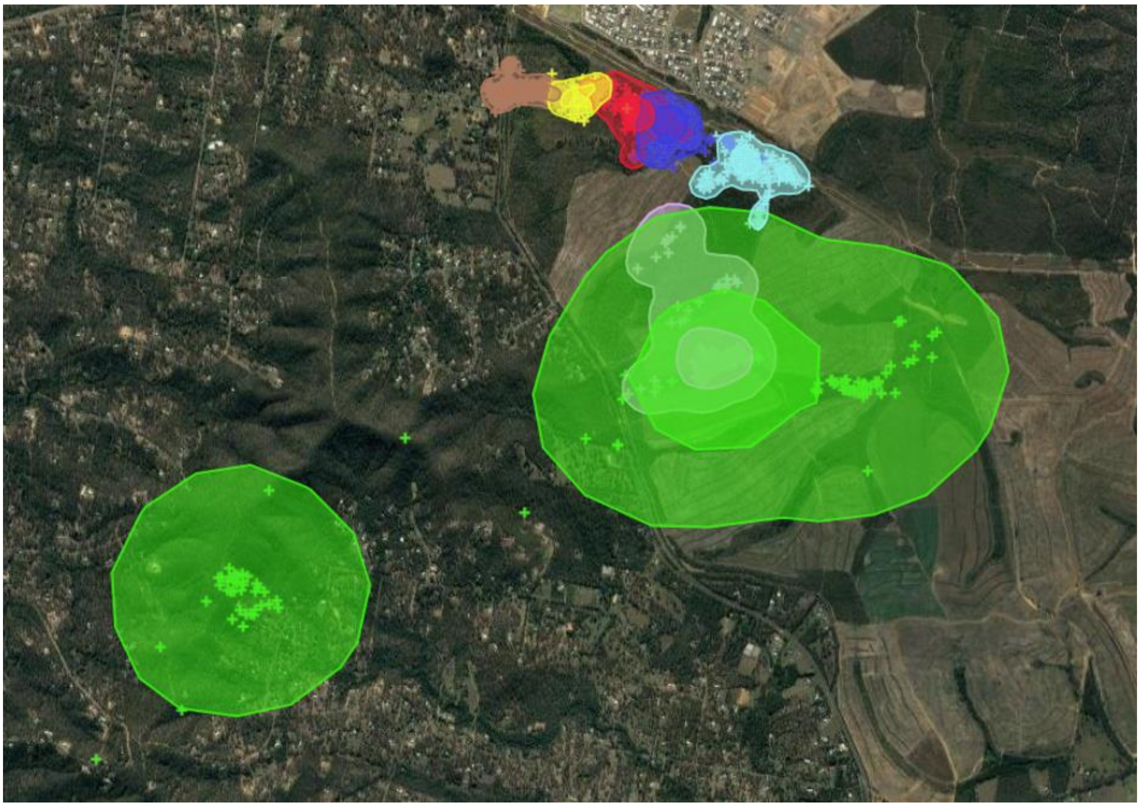

Figure 33. Plot of 50% & 95% KUD home range estimates for seven koalas at the site in 2020.

Colour key: Bomber (dark blue), Lilly (light purple), Lucky (red), Millie Mae (brown), Nyunga (light blue), Wooten (bright green), Zara (yellow).

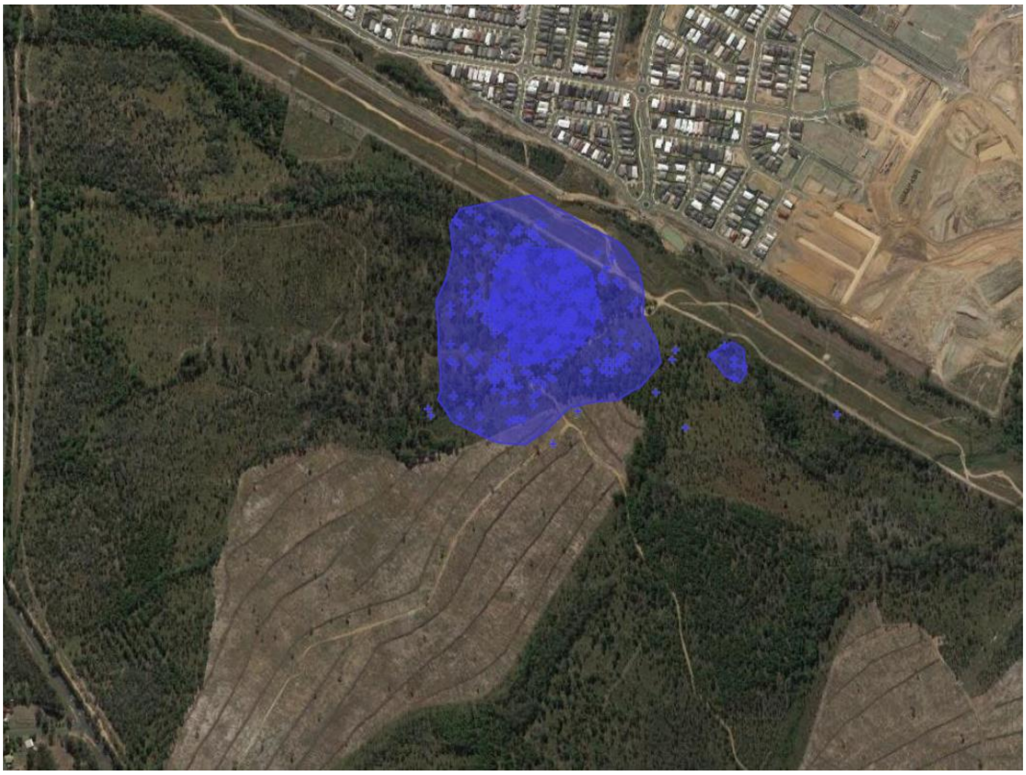

Figure 34. Plot of 50% and 95% KUD home range estimates for Bomber. The 50% KUD is the smaller polygon within the larger 95% KUD polygon.

Figure 35. 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 36. Plot of 50% and 95% KUD home range estimates for Lucky. The 50% KUD is the smaller polygon within the larger 95% KUD polygon.

Figure 37. Plot of 50% and 95% KUD home range estimates for Millie Mae. The 50% KUD is the smaller polygon within the larger 95% KUD polygon.

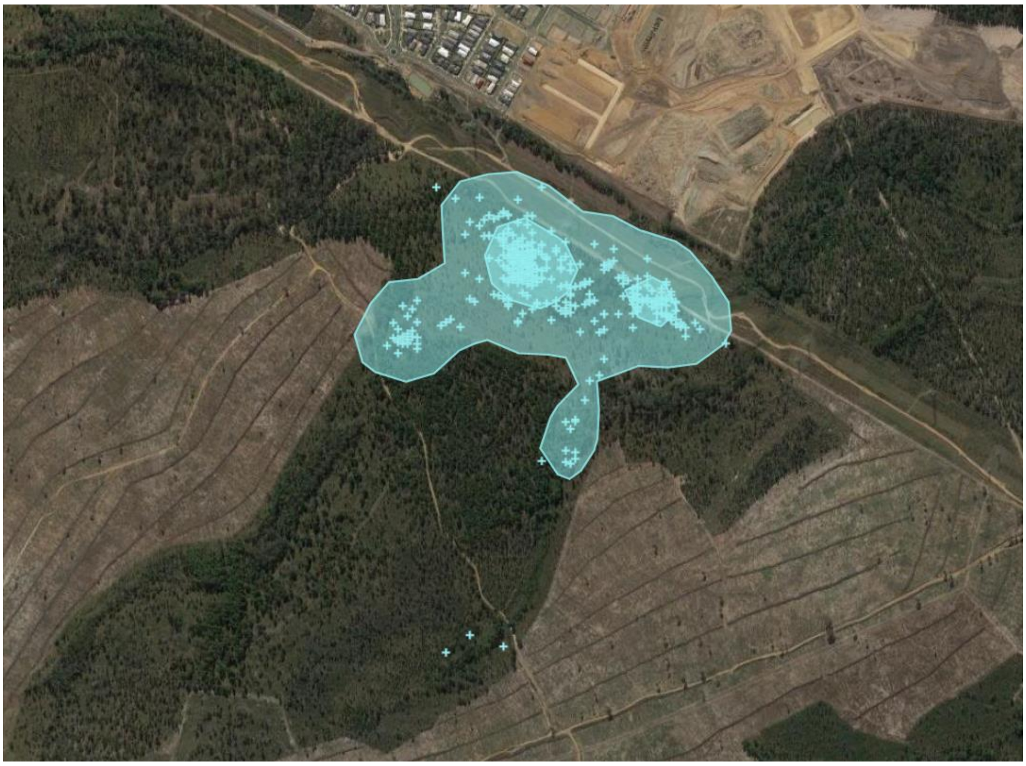

Figure 38. Plot of 50% and 95% KUD home range estimates for Nyunga. The 50% KUD are the two smaller polygons within the larger 95% KUD polygon.

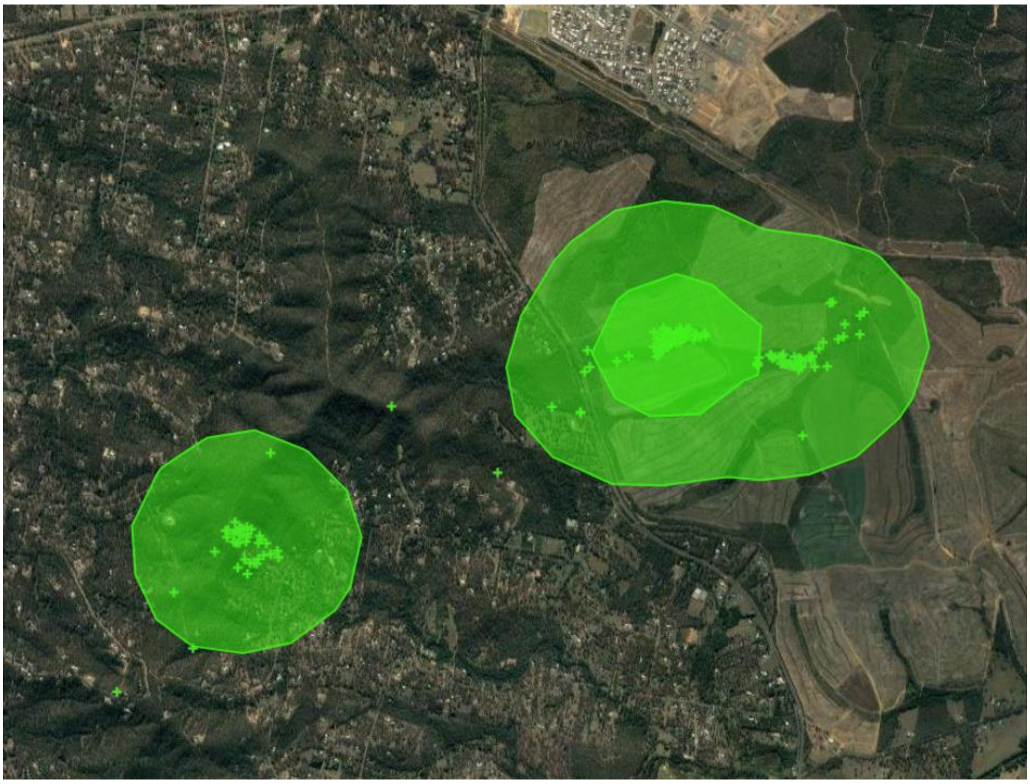

Figure 39. Plot of 50% and 95% KUD home range estimates for Wooten. The 50% KUD is the smaller polygon within the larger polygon at right. The 95% KUD includes the two larger polygons.

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