Koala Monitoring Program

Yarrabilba Priority Development Area

Annual Report on Koala Health and Movements

2021

Images: A climber preparing to catch a koala from a large eucalypt (left)
and a koala being released with a new A5 LX tag (right).

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Introduction

This report presents a summary of the findings from the 2021 *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. 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.

Methodology

Three *Koala Capture / Monitoring Events* were undertaken in 2021 during the following months: April, August, 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 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, as well as eye and urogenital swabs for disease testing (Figure 3). 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 LX Koala Tracker system. The main advantage of the LX monitoring system is that it provides close to real-time data on the location and activity level of collared koalas (see http://trackkoalas.com.au/ for further information on this koala-specific tracking technology). The LX system was first implemented at the Yarrabilba site in 2018 and since that time the developers have refined the technology to provide improved functionality and reliability. The new LX system was released in early 2021 so in April, we upgraded the LX monitoring system at the site to take advantage of these improvements. This involved replacing the solar-powered base stations (mounted high up trees on site) and swapping out the LX tags on collared koalas (Figure 4).

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. When collared koalas were recaptured, we reassessed the fit of the collar to ensure it was neither too tight nor loose, and that it was still in good working order.

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

Figure 1. Images of the attempted capture of a koala (yellow circle) using the flagging method. The climber used extendable poles to flag the koala down to a height where 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. Image of a koala (female 'Bilba') being anaesthetised to facilitate a health examination.

Figure 4. Images showing the installation of a new solar-powered LX base station, high up a gum-topped box. The base station was fastened to the tree using heavy-duty ratchet straps and high tensile wire.

Results & Discussion

During 2021, a total of 13 tagged koalas were observed at the study site, comprising 12 independent koalas and one late-stage back young (i.e. still dependent upon its mothers to some extent) (Table 1). The sex ratio amongst the tagged, independent koalas was skewed towards females, consisting of 8F:4M. Ten of the tagged koalas were caught and examined during 2021, including four 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 27 individuals (Table 1).

In addition to the tagged koalas that were observed at the site, there were nine records of untagged koalas (aka. 'cleanskins') throughout 2021. 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 nine records would have been the result of the same individual being observed on more than one occasion.

As in previous years (2018 – 2020), there was a good demographic spread amongst the sampled population in 2021, including late-stage back young (Amelia plus two other untagged young), young adults (Banjo, Bilba, Gladys), numerous mid-aged koalas (4-8yrs) and few older individuals (Bomber, Zara, Millie Mae, Jana). More than half (5 of 7) of the mature females that were captured and examined were known to have reproduced in 2021.

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, in May 2017. He was recaptured in August this year to remove his collar, at which time he was estimated to be approximately 10 years old. The male named Cain was also first caught in 2017, when he was taken into captivity at Australia Zoo Wildlife Hospital (AZWH) for treatment of a chlamydial infection. He was returned to the site in December 2017 and has been part of the monitoring program ever since. In late 2019, he underwent further treatment in captivity at AZWH and was returned to the site earlier this year. Several of the females (Zara, Nyunga, Scarlet) have also been part of the monitoring program for several years.

In contrast, it is likely that some of the young koalas that were weaned in 2021 have dispersed from the site. In previous years we recorded the dispersal off site of two young males (Kevin and Wooten), both of which dispersed in a westerly direction across Waterford-Tamborine Rd. Young koalas are capable of dispersing large distances, at which time they are often exposed to heightened levels of risk (e.g. the risk of vehicle strike while crossing roads, and domestic dog attack while passing through residential areas).

Figure 5. Dr Ben Barth measuring the head size of female 13558 ‘Gladys’.

Table 1. List of the 27 koalas that have been tagged at the study site since May 2017. Koalas that were sighted in 2021 are shaded orange; koalas that were sighted, captured, and examined in 2021 are shaded grey.

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

13565	Banjo	M	2.54	1	Maroon A3	Metal UQ987	20/04/2021	-27.810577, 153.103908	
13316	Jana	F	5.28	5-10	Metal UQ114	Light Blue B16	21/04/2021	-27.815245, 153.110754	
13328	Amelia	F	0.74	<1	Metal UQ917	-	22/11/2021	-27.811498, 153.104591	Gladys' offspring

Summary of Koala Health

Overview

All 10 koalas caught in 2021 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 2021. Where possible, Table 2 also shows the equivalent health information and test results for the same koalas, from 2019/2020.

Table 2. Details of health and swab test results for koalas examined in 2021 (blue highlight) and 2019/20 (grey highlight, where data available).
UGT = urogenital tract; BCS = body condition score (1 = very poor condition, 10 = excellent condition).

Koala	Examination date	Visual signs of disease / condition notes	Left eye swab	Right eye swab	UGT / penile swab
Cain	2/1/2021	Released at site after treatment at AZWH; no overt disease; swabs collected after antibiotic treatment	negative	negative	negative
Cain	9/11/2020	Overt disease - right eye inflamed, rump stained (BCS 5)	negative	positive	positive
Cain	4/3/2019	No overt disease (BCS 6); inflamed eye and stained rump when sighted Nov'19	negative	negative	negative
Ella	19/4/2021	No overt disease (BCS 7)	negative	negative	negative
Bilba	19/4/2021	No overt disease (BCS 7)	negative	no result	no result
Bilba	10/11/2020	No overt disease (BCS 8); with mother (Zara), late-stage young	negative	negative	negative
Banjo	20/4/2021	No overt disease (BCS 8)	negative	negative	negative
Zara	20/4/2021	No overt disease (BCS 7)	negative	negative	negative
Zara	30/4/2020	No overt disease (BCS 8)	negative	negative	no result
Zara	6/3/2019	No overt disease (BCS 8)	negative	negative	negative
Gladys	22/11/2021	No overt disease (BCS 7)	negative	negative	negative
Gladys	20/4/2021	No overt disease (BCS 5)	negative	negative	negative
Gladys	11/11/2020	No overt disease (BCS 7)	negative	negative	negative

Jana	21/4/2021	No overt disease (BCS 6)	negative	negative	negative
Bomber	17/8/2021	No overt disease (BCS 4)	negative	negative	positive 2,230
Bomber	29/4/2020	No overt disease (BCS 6)	negative	negative	positive 175
Bomber	21/11/2019	No overt disease (BCS 5)	negative	negative	negative
Bomber	31/7/2019	No overt disease (BCS 6)	negative	negative	positive 666
Amelia	23/11/2021	No overt disease (BCS 9); with mother (Gladys), 6-7mth old young	negative	negative	Swab not collected
Nyunga	23/11/2021	No overt disease (BCS 6)	negative	negative	negative
Nyunga	10/11/2020	No overt disease (BCS 6)	negative	negative	negative
Nyunga	28/5/2019	No overt disease (BCS 9)	negative	negative	negative

*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 of the ten koalas examined in 2021, only one individual (Bomber) returned a positive swab test result (Table 2). Eight of the other nine koalas returned negative test results at all three swab sites, indicating that chlamydial DNA was not detected. For one koala (Bilba), one swab was negative, while the other two returned 'no result'. This may have been due to the swabs being rubbed too lightly on the epithelial tissue during sampling.

None of the ten examined koalas (including Bomber) displayed overt signs of disease. Further, none of the nine cleanskins that were observed in 2021 had clear visual signs of disease when viewed through binoculars. However, it was not always possible to clearly view the rump and both eyes of the cleanskin koalas, so it is possible that some overt disease was missed.

Since mid-2019, Bomber has often returned low positive test results for his penile swabs (see IFU/mL values in Table 2 above). These results were suggestive of a low-grade infection. We decided not to take Bomber in for treatment but rather to monitor his condition to see if the infection resolved naturally, as is sometimes known to occur. Although Bomber returned a negative test result in November 2019, this 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. Bomber again returned a low-moderate positive test result (2,230 IFU/mL) in August this year, when he was recaptured so that his collar could be removed. If we are able to locate Bomber in 2022 (he no longer has a collar), then it would be worthwhile taking him in for treatment, as the recent test results suggest his infection has worsened.

The swab test results are encouraging as they suggest that in 2021 there was a relatively low level of chlamydial infection within the population. Further, several of the females that tested negative also reproduced in 2021, so it is highly likely that these young were not infected with *Chlamydia* via vertical transmission (i.e. from mother to offspring). This was certainly true for Amelia when she was swabbed as a late-stage young in November, and tested negative (see Table 2).

Although only one of the 10 examined koalas returned a positive test result, we are aware of at least one additional koala in the study area that is infected with Chlamydia. The female named Millie Mae was last swabbed in 2020 and returned a positive result for her urogenital sample. However, we were unable to catch this female during 2021 so it was not possible to take her into care for treatment. As with Bomber, she was not showing overt signs of disease.

The low level of detectable chlamydial infection amongst the study population in 2021 is likely due, in part, to management actions we have taken since commencing the koala monitoring program. Since 2017, several diseased koalas have been taken off site for detailed veterinary assessment and treatment at Australia Zoo Wildlife Hospital. Some koalas have been successfully treated and returned, while some had to be euthanised due to untreatable disease (e.g. Kobe euthanised 2018). As previously discussed, Cain has twice been taken to AZWH for treatment and was most recently returned to site in early 2021. While the loss of a small number of koalas with untreatable disease is somewhat disappointing, their removal from the population has likely helped to reduce chlamydial transmission and improve overall population health and viability (especially given that there has been a high level of reproduction amongst the healthy mature females, as discussed in more detail below).

Details and health profiles of examined koalas

This section provides greater detail on the health and physical condition of the ten koalas that were examined in 2021. 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.

Male 13488 'Cain'

Cain was first captured in October 2017 and was immediately taken to Australia Zoo Wildlife Hospital (AZWH) for treatment of an infected right eye. The eye was inflamed and closed over due to severe conjunctivitus. After successful antibiotioc treatment, Cain was released back at the site in December of that year.

In March 2019, Cain was recaptured and examined. He was in fair condition (body score 6/10) and had no clinical signs of chlamydial disease. Ocular and urogenital swabs were collected and later tested negative for *Chlamydia*. Later that same year Cain was sighted and with the aid of binoculars, we could see that his right eye was again inflamed and his rump appeared stained (suggestive of cystitis). Two attempts were made to recatch Cain (on consecutive days) but both were unsuccessful. 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.

Cain was next sighted in November 2020 and he was able to be recaptured. It was immediately apparent that his right eye had major inflammation. His rump also appeared to have minor staining and his body score was 5/10.

Given his obvious poor health, Cain was immediately taken to AZWH (Figure 6). The antibiotic treatment was again successful in resolving the infection of his right eye and rump. He was returned to the site in January 2021 after being fitted with an ear tag transmitter.

In April 2021, Cain was radio-tracked to an area close to his point of release in January. He was sitting in a small eucalypt which facilitated visual assessment of his health. There was no obvious signs of disease. We attempted to track Cain again in August 2021 but were unable to detect the transmitter signal. It is likely that the battery in the small transmitter had expired. Cain was not observed opportunistically during the final fieldtrip in November 2021, but there is no reason to suspect that he was not still resident at the site. He was estimated to be 6-8 yrs old in 2021.

Figure 6. Picture of Cain after several days of treatment at Australia Zoo Wildlife Hospital in late 2020. The inflammation of his right eye had already reduced considerably by this time. He was released back at site in January 2021.

Female 13564 'Ella'

This cleanskin female koala was first sighted up a gum-topped box (*Euclayptus moluccana*) in April 2021. She was with a large, semi-independent offspring, which was sitting in a separate part of the tree. The offspring was not caught.

Ella was estimated to be between 3-6 years old, and her physical examination suggested she was in good health (body score 7/10). She had no signs of chlamydial infection or disease and weighed 5.2kg. Ella was fitted with a coloured tag in the right ear (blue R10) and a small metal tag in the left ear (UQ934).

Ella was briefly anaesthetised so that swabs could be collected from each eye and her urogenital sinus. These swabs were sent for laboratory PCR analysis. All swabs later returned negative test results, indicating that no *Chlamydia* DNA was detected (Table 2).

Ella was fitted with one of the new LX tags (A5-549) and a VHF transmitter, to facilitate locating her by radio-tracking (Figure 7). She was also fitted with an ear tag transmitter as her ears were considered rigid enough to support this extra weight.

After her examination, Ella was allowed sufficient time to recover from anaesthesia before being released at the point of capture. She was monitored for the remainder of 2021 via routine radio-tracking and frequent uploads to the LX webpage.

Figure 7. Drs Ellis and FitzGibbon examining and collaring the new female koala 'Ella'.

Female 13304 'Zara'

Zara has been part of the research program for many years, following her initial capture in June 2018. She has been fitted with a collar for extended periods since that time, enabling us to acquire an excellent movement dataset and to monitor her health.

We have also been able to examine Zara's reproductive output over several years. In 2018, she produced a female offspring (13496 "Squeak") that was tagged as a back young. This young was still with Zara in early 2019. In late 2020/early 2021, she weaned another young (13269 "Bilba; details below). When Zara was recaptured in April 2021, she was carrying a new pouch young (unfurred) that was estimated to be 3-4 months old. The new pouch young was too small to assess its sex or to collect tissue.

Zara's collar was removed in April as her LX tag had been superseded by the new A5 model, and sufficient movement data had been obtained. She appeared healthy and displayed no signs of chlamydial infection (Figure 8). She was anaesthetised and given a standard health assessment, incuding the colection of swab samples. She was in good condition (body score 7/10) and weighed 6.7kg. The ocular and urogenital swabs tested negative for *Chlamydia* (Table 2).

After she had recovered from anaesthesia, Zara was returned to the ironbark tree she was found in.

Figure 8. Dr Bill Ellis with Zara after her examination and collar removal (left) and upon release (right).

Female 13269 'Bilba'

Bilba was first captured and tagged as a sub-adult in November 2020, when she was found with her collared mother, Zara. At that time Bilba was semi-independent, sitting in a separate part of the tree to her mother. She was estimated to be 11-12 months old, given that she was first seen as a 'pinkie' (i.e. unfurred young) in Zara's pouch on 30th April 2020.

During the April 2021 fieldtrip, Bilba was found in a medium-sized introduced pine tree. She was several hundred metres from her mother (Zara) so it was assumed that she was completely independent. She was captured using the flagging technique and then anaesthetised for examination and swab collection. Bilba weighed 3.74kg and was in good condition (body score 7/10).

Remarkably, despite her young age, Bilba was found to be carrying a pouch young that was estimated to be approximately two months old (i.e. born late Feb/early March). If Bilba was 12 months old in November 2020, then she must have conceived her young when she was only about 14 months old (gestation is 34-36 days). Female koalas are generally regarded to become sexually mature at two years of age, and many do not reproduce until three years. So it is quite surprising that Bilba was found with a pouch young at such a young age.

Ocular and urogenital swabs were collected from Bilba while she was anaesthetised and later examined in the laboratory. As mentioned above, one of the swabs (left eye) returned a negative test result, while there was insufficient koala DNA captured on the other two swabs (right eye and urogenital) to test for the presence of *Chlamydia*. This may have been due to the swabs being rubbed too lightly on the epithelial tissue during sampling.

Bilba was fitted with one of the new LX tags (A5-639) and a VHF transmitter for radio-tracking purposes. After her examination, she was allowed sufficient time to recover and was then released at the point of capture. She was monitored for the remainder of 2021 via routine radio-tracking and frequent uploads to the LX webpage.

Figure 9. Image of Bilba recovering after the anaesthetic and health examination.

Male 13565 'Banjo'

During April 2021, this cleanskin koala was sighted in an area of dense regrowth dominated by short gum-topped box. He was caught using the flagging technique and then placed in a cloth bag.

Banjo weighed 2.54kg and was in good condition (8/10 body score). He had no visual signs of poor health or disease, and his small size suggests he was only recently weaned. He was fitted with ear tags but was regarded as too small to be fitted with an LX collar. Ocular and urogenital swabs were collected, which later tested negative for *Chlamydia* (Table 2).

After the examination and recovery Banjo was released at the point of capture. He was observed in the same area during November 2021, when binoculars were used to read his ear tag details and confirm his identity. He appeared to be in good condition and had no overt signs of disease.

Figure 10. Image of Banjo, a new sub-adult male tagged during the April 2021 fieldtrip.

Female 13558 'Gladys'

Gladys was a cleanskin koala when she was first encountered during November 2020. At that time she was carrying a large back young estimated to be 6-7 months old. Gladys was recaptured in April 2021. Her young was not sighted but her right teat was still enlarged, suggesting the young was either still suckling or had been weaned very recently. Gladys had also dropped body condition from 7/10 in November 2020 to 5/10 in April 2021. This drop in condition is not uncommon among females enduring the physiological stresses of late-stage lactation.

When examined in April 2021, Gladys weighed 4.9kg and her eyes and rump appeared clear and free of clinical signs of infection. Gladys was fitted with one of the new LX tags (A5-617) and a VHF transmitter for radio-tracking purposes.

After her examination, Gladys was allowed sufficient time to recover and was then released at the point of capture. She was monitored via routine tracking and frequent uploads to the LX webpage.

In November 2021, the collar that Gladys was fitted with in April was found wedged up a small eucalypt. The rubber weak link had not torn so clearly Gladys had become snagged and the link stretched enough to enable her to pull her head free, through the collar loop. This is exactly how the weak link is designed to function, to ensure that snagged koalas cannot get hung by the collar loop.

After searching the general area around Gladys' fallen collar we located her in a small gum-topped box. She was recaptured using the standard flagging technique and again examined in the field. Gladys had no overt signs of disease and had a new young (female 13328 'Amelia'; details below), which she was carrying on her front (i.e. it was already out of the pouch). The young weighed 740g, which suggests that Gladys must have given birth very soon after her examination in April 2021. At her November examination, Gladys had regained body condition (7/10) and weighed 5.7kg (up from 4.9kg in April).

Ocular and urogenital swabs collected in April and November 2021 were sent for laboratory analysis and tested negative for *Chlamydia* (Table 2).

Figure 11. The female koala named 'Gladys' prior to being fitted with one of the new A5 LX collars.

Female 13328 'Amelia'

This female was the offspring of Gladys, and was tagged in November 2021 when she was being carried as a front young. Amelia weighed 740g and was in excellent condition (9/10 body condition score). She was estimated to be 6-7 months old.

Amelia was large enough to be fitted with a small metal ear tag (UQ 947). Her ears were still too thin and floppy for her to be fitted with a coloured ear tag. Amelia was briefly anaesthetised so that swabs could be collected from her eyes (she was too small to collect a urogenital swab). These swabs were sent for laboratory PCR analysis and returned negative test results, indicating that no chlamydial DNA was detected (Table 2).

After her examination, Amelia was allowed sufficient time to recover and was then placed back on her mother before they were released at the point of capture with her young.

Figure 12. Image of female 13328 Amelia, that was caught with her mother 13558 Gladys.

Male 13008 'Bomber'

This male koala was first tagged in May 2017 when he weighed 9.1kg. He was been collared several times over the intervening years. In 2021, he was estimated to be at least 11 years old.

Despite his considerable size and weight, all our examinations of Bomber (over a 5yr period) have found him to be quite bony and lacking in muscle mass, resulting in body scores usually around 5-6 out of 10. During his most recent examination (August 2021), Bomber's condition was rated only 4/10. But given that Bomber is relatively old (estimated 11yrs, but may be several years older), it is likely that his inclusion in our monitoring program occurred after his physical peak.

Bomber was recaptured in August 2021 and his superseded A4 collar tag was removed. He was briefly anaesthetised and examined. Although he did not present any obvious signs of disease, laboratory testing of his urogenital swab returned a positive result (Table 2). Bomber was not seen during the November 2021 fieldtrip so it was not possible to take him into care for treatment of his infection.

Figure 13. Image of Bomber being released after removal of his collar.

Female 13316 'Jana'

In April 2021, this cleanskin female koala was sighted up a large blue gum (*Eucalyptus tereticornis*) with her semi-independent offspring, which was sitting higher up in a separate part of the tree. The offspring was not caught.

Jana weighed 5.28kg and was estimated to be between 5-10 years old. The physical examination suggested she was in good health (body score 7/10). Her eyes and rump were clear and had no signs of chlamydial infection or disease. Jana was fitted with a coloured tag in the right ear (light blue B16) and a small metal tag in the left ear (UQ114).

We briefly anaesthetised Jana so that swabs could be collected from the urogenital sinus and each eye. These swabs were sent for laboratory PCR analysis and all returned negative test results, indicating that no chlamydial DNA was detected (Table 2).

Jana was fitted with one of the new LX tags (A5-578) and a VHF transmitter (Figure 14). After her examination she was allowed sufficient time to recover before being returned to the same tree, where her young was still located high in the canopy. She was monitored for the remainder of 2021 via routine radio-tracking and frequent uploads to the LX webpage.

Figure 14. Image of Jana being released back up the tree from which she was caught, fitted with a new A5 LX tag.

Female 13509 'Nyunga'

Nyunga was first captured and tagged in May 2019, when she was estimated to be between 1-3 years old. In late 2020, she was fitted with an A4 model LX tag, which was superseded by the A5 model in 2021.

During fieldtrips in April and August 2021, Nyunga evaded attempts to recatch her. She was regularly sitting in tall pine trees, which were unsuitable for catching due to difficulties with our team climbing these trees.

Nyunga was able to be recaptured in November 2021 when she was tracked and found sitting in a medium-sized bloodwood. Her collared was removed and she was examined in the usual manner. She weighed 5.7kg, was in fair condition (body score 6/10) and was not carrying a young. At her previous examination (November 2020) Nyunga weighed 4.8kg, so she had grown considerably over the past 12 months.

Nyunga's eyes and rump appeared clear and free of infection, and swabs collected from her eyes and urogenital sinus tested negative for *Chlamydia* (Table 2).

After her examination, Nyunga was allowed sufficient time to recover before being released at the point of capture.

Figure 15. Image of female 13509 Nyunga.

Conclusion

In 2021, only one koala (male 'Bomber') of the ten that were examined, tested positive for *Chlamydia*. That is, 10% of the studied population had a detectable chlamydial infection. Of the nine that tested negative, one was the male 'Cain' who had a chlamydial infection in 2020, was successfully treated at Australia Zoo Wildlife Hospital, and then returned to site in early 2021.

Our research at the site in 2019 and 2020 revealed that approximately half of the population was infected with Chlamydia; in 2019 six of 12 koalas tested positive (50%), while in 2020, three of five were positive (60%). Although the 2020 sample size was small, when viewed in combination with the 2019 statistic it caused concern that a significant proportion of the population was infected with *Chlamydia*.

The treatment of one infected koala from the 2020 sample, and the inclusion of several new healthy (i.e. uninfected) young koalas in the 2021 sample population, has painted a far more encouraging picture about current population health and viability. Further, and as previously mentioned, several of the females that tested negative also reproduced in 2021, so it is highly likely that their young were not infected with *Chlamydia* via vertical transmission (i.e. from mother to offspring).

Although only one of the 10 examined koalas returned a positive test result, we are aware of at least one additional koala (female 'Millie Mae') in the study area that is infected with *Chlamydia*. She returned a very strong positive swab test result in 2020 but we were unable to catch her for treatment in 2021. If this koala was included in the sample population then the level of detectable chlamydial infection jumps up to nearly 20% (2/11 koalas). However, this is still a significant improvement on the situation from 2019 and 2020.

As mentioned, the low level of detectable chlamydial infection amongst the study population in 2021 is likely due, in part, to management actions we have taken since commencing the koala monitoring program in 2017. This includes the successful treatment of some diseased koalas that have been returned to site, as well as the euthanasia of some koalas with untreatable disease. These actions have likely reduced chlamydial transmission and improved population viability, especially given that there has been a high level of reproduction amongst the healthy mature females.

We recommend that in 2022, PCR laboratory 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 moderate to heavy infections 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.

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).

Two collar models were used in 2021. The LX A4 model was superseded by the A5 model, so the use of A4 tags was phased out during the year. The new A5 model had improved functionality, reliability and battery effeciency. For these reasons, the data recording schedules differed for the two models, as follows; A4 model tags were programmed to record location and activity data every 12 hours, at approximately 10:00 and 22:00 daily; A5 model tags were programmed to record location and activity data every four hours, at approximately 24:00, 04:00, 08:00, 12:00, 16:00 and 20:00.

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 16 – 41).

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 2020/21 (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.

In 2021, eight koalas were collared and monitored for varying durations. Datasets were obtained for four koalas using the now superseded A4 model tags, while a further four datasets were recorded for koalas fitted with A5 model tags (Table 3). These collar deployments resulted in detailed movement datasets for seven of the eight koalas (Table 3). Only a small dataset (16 points) was obtained for the eighth collared koala (Zara), due to collar malfunction. Zara's dataset was too limited to enable home range analyses.

Table 3 lists the number of fixes that were obtained for collared koalas in 2021. The table also presents estimates of home range size using the two common techniques (further detail provided below). The same techniques were used to examine koala home ranges in all previous annual reports for the study site.

Several of the koalas collared in 2021 were collared in 2020. This enabled a comparison of their movement and home range metrics across the two years (see values in brackets, Table 3).

An obvious difference in 2021 was the larger dataset available for the four koalas fitted with the new A5 model of LX tag. This was due to the fact that these tags were programmed to record location data every four hours, as opposed to every 12 hours (A4 model).

In 2021, the mean number of fixes per koala was 706 ± 202, and for six of the eight collared koalas, more than 300 geographical fixes were available for analyses after filtering of inaccurate points (see Table 3). These statistics represent a substantial improvement in the quantity of data collected when compared to 2020. In 2020, the mean number of fixes per koala was 292 ± 68.

Table 3. Details of movement datasets and home range estimations for koalas collared in 2021. Note, there were too few data points (16) to calculate home range estimates for Zara. Where available, numbers presented in square brackets are the equivalent metric from 2020.

LX tag model	Koala name	Sex	No. fixes*	Avg no. fixes/day	MCP 95% (ha)	KUD 50% (ha)	KUD 95% (ha)
A4	Bomber; 13008	M	334 [451]	1.8 [1.3]	13.9 [11.5]	3.1 [3.9]	17.3 [17.0]
A4	Zara; 13304	F	16 [236]	0.1 [0.8]	N.A. [5.5]	N.A. [2.0]	N.A. [8.9]
A4	Millie Mae; 13533	F	406 [489]	1.8 [1.4]	6.1 [8.3]	1.0 [2.9]	6.4 [11.7]
A4	Nyunga; 13509	F	174 [435]	1.7 [1.3]	22.5 [19.6]	4.1 [3.1]	24.3 [22.5]
A5	Ella; 13564	F	1356	5.3	4.7	1.3	5.5
A5	Jana; 13316	F	907	4.1	16.3	5.1	21.2
A5	Gladys; 13558	F	1273	5.0	4.5	1.2	5.4
A5	Bilba; 13269	F	1180	5.1	4.4	0.6	3.7

* 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/).

Koala habitat use and home ranges

Very detailed movement datasets were obtained for seven of eight collared koalas (>150 fixes ea.), permitting an examination of habitat use and home ranges. The smallest datasets were those for Zara (n=16 fixes) and Nyunga (n=174 fixes), while more than 300 fixes were obtained for the remaining six individuals. It is very likely that Zara did not move throughout her entire home range area during the short period that her data poinst were collected. All other datasets consisted of a sufficient number of fixes to examine home ranges.

Movements plots (Figures 16 – 25) show that the collared individuals made extensive use of the site. As in previous years, most movements were concentrated along the creeklines and associated riparian vegetation. But some koalas also utilised habitat away from the creeklines. 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 Bilba in 2021 (and by Cain, Kevin and Sue-Bob in 2019, and Gladys and Zara in 2020; see figures in previous annual reports).

In 2021, 95% MCP home range estimates were calculated for one male koala (Bomber) and six females (see Figures 26 – 33). The MCP estimate for Bomber was 13.9ha, which was very similar to his equivalent metric in 2020 (11.5ha; see Table 3). Further, the geographical extent of his home range was similar across the two years.

The 95% MCP estimates for the six examined females averaged 9.75ha, and ranged from 4.4ha (Bilba) to 22.5ha (Nyunga). In 2020, the average was 21ha but it was inflated by the large home range estimate of one individual (Lilly; 51ha) that made use of isolated trees in areas that were largely cleared. This highlights a major drawback of some home range estimation techniques, which can incorporate large areas of non-utilised space, especially in fragmented landscapes. For two females (Millie Mae and Nyunga), home range estimates were calculated in 2020 and 2021. The 95% MCP estimates were similar for both koalas across the two years (see Table 3). Further, the geographical extent of Nyunga and Millie Mae's ranges were similar across the two years. In 2021, Millie Mae had reduced use of habitat on the western side of Waterford-Tamborine Rd, which she was recorded crossing only twice (Figure 20).

Home ranges were also examined using the alternative KUD estimator. The 95% KUD home range estimates for females averaged 11.1ha, and ranged from 3.7ha (Bilba) to 24.3ha (Nyunga). The 95% KUD estimate for the one collared male (Bomber) was 17.3ha, which was remarkably similar to his estimate of 17.0ha in 2020 (see Table 3).

In 2020, home range estimates calculated using the 95% MCP were consistently smaller than those derived using the 95% KUD estimator. However, this was not the case in 2021, with the estimates being similar for most koalas (Table 3). Core home range areas were examined using the 50% KUD polygons, and the generated maps show they were generally focused on riparian areas with high habitat quality (Figures 34 – 41).

Conclusion

In 2021, 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. Core home ranges were focused on riparian areas along Quinzeh Creek. However, koalas are highly mobile and can traverse virtually any type of urban landscape element, including roads, residential housing estates, and large stretches of bare ground. This is especially true of dispersing individuals. Further, they can make frequent use of isolated paddock trees and young regrowth eucalypts, as data from our koala monitoring program has demonstrated over several years.

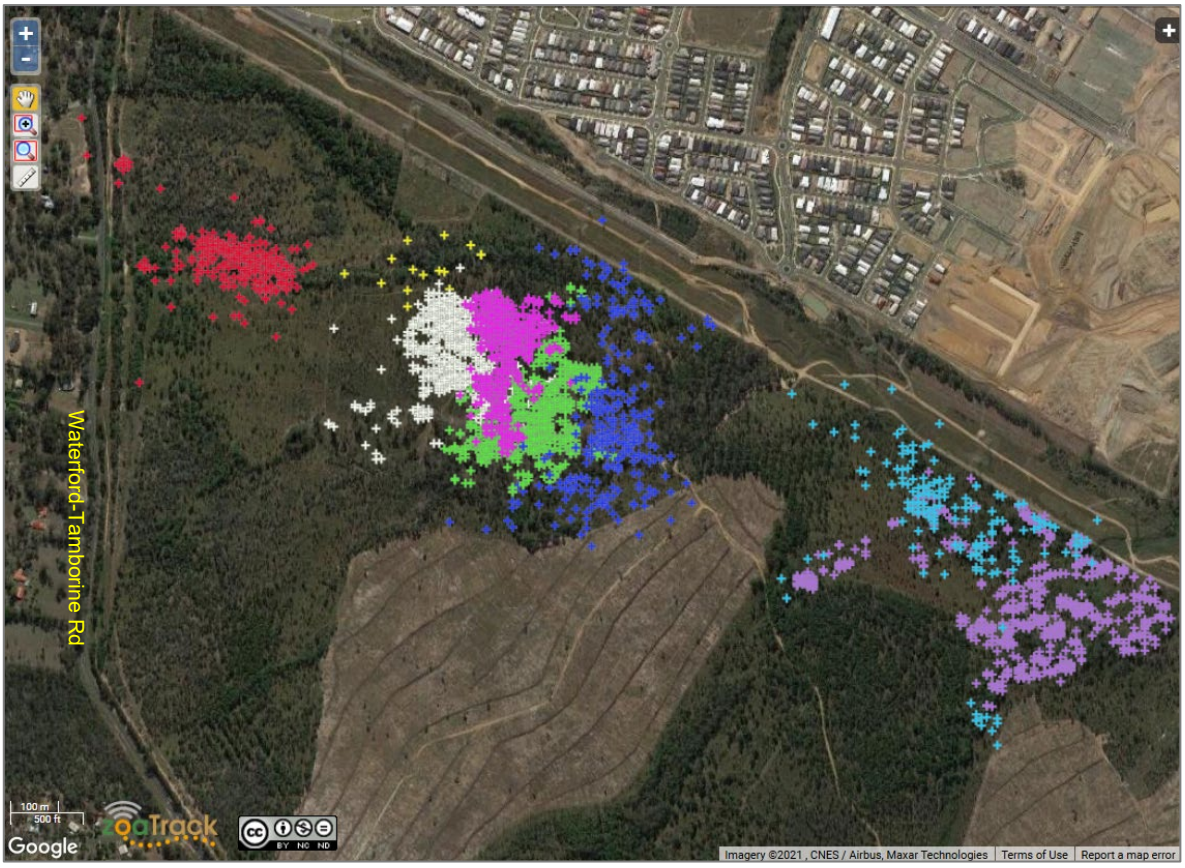


Figure 16. Plot of recorded locations for the eight koalas collared at the Yarrabilba study site in 2021.

Colour key: Bomber (dark blue), Zara (yellow), Millie Mae (red), Nyunga (light blue), Ella (green), Jana (purple), Gladys (white), Bilba (pink).

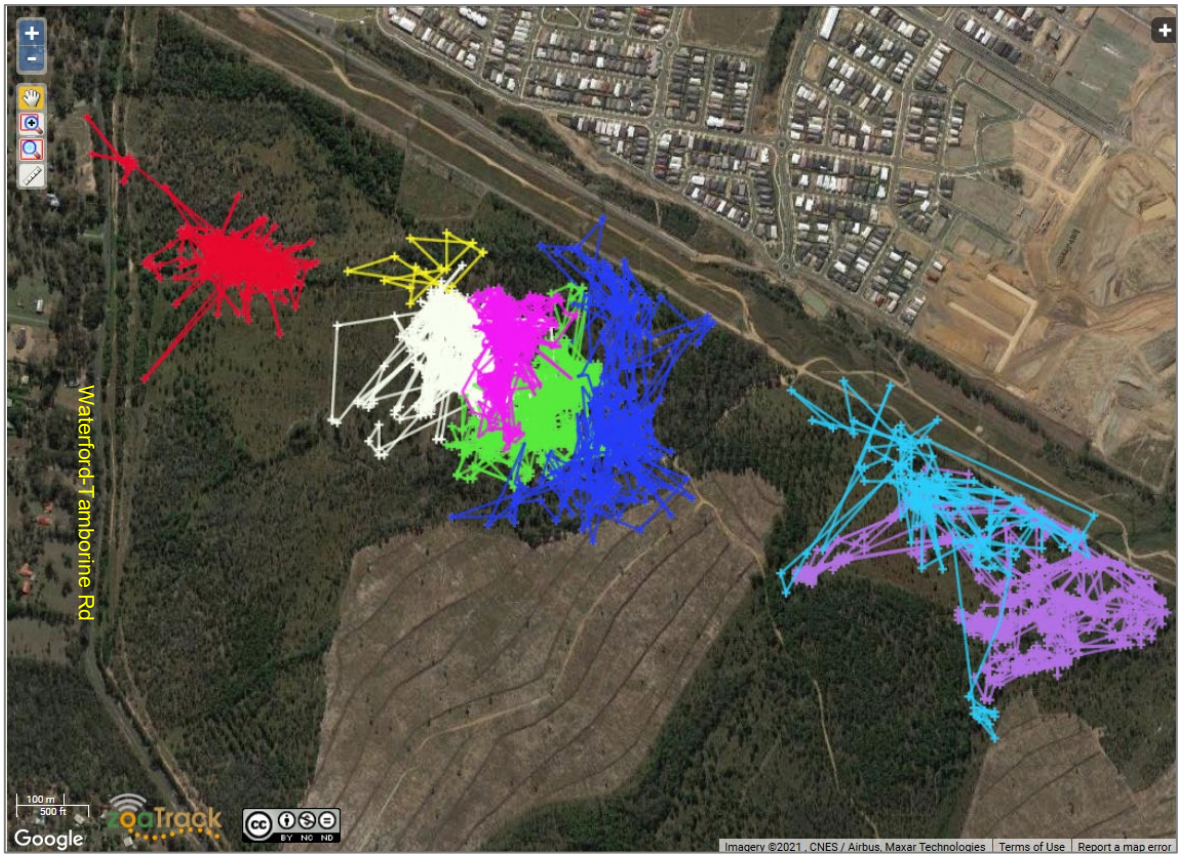
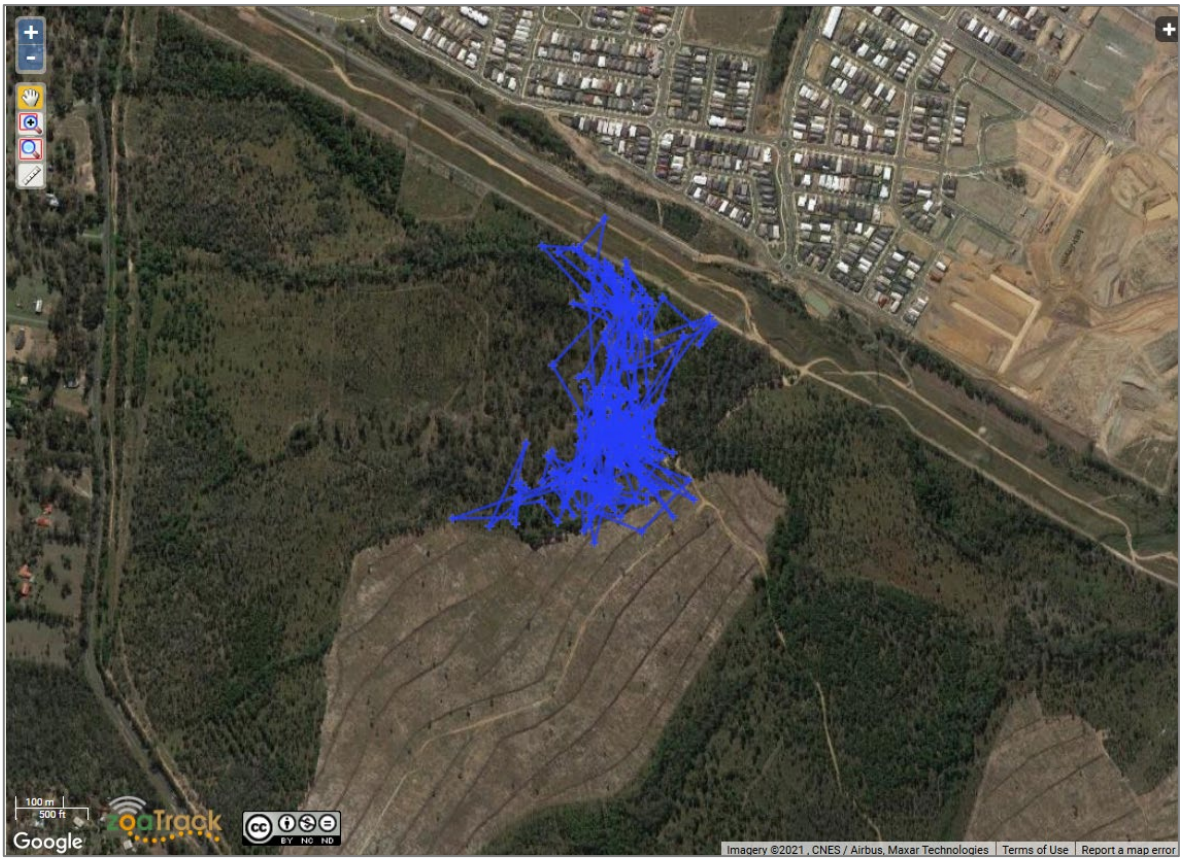


Figure 17. Plot of locations and movement trajectories for the eight koalas collared at the Yarrabilba study site in 2021. Consecutive fixes are joined by trajectory lines. Note, these lines do not necessarily indicate the exact movement pathways of the koalas, as they are simply a straight line between consecutive points.

Colour key: Bomber (dark blue), Zara (yellow), Millie Mae (red), Nyunga (light blue), Ella (green), Jana (purple), Gladys (white), Bilba (pink).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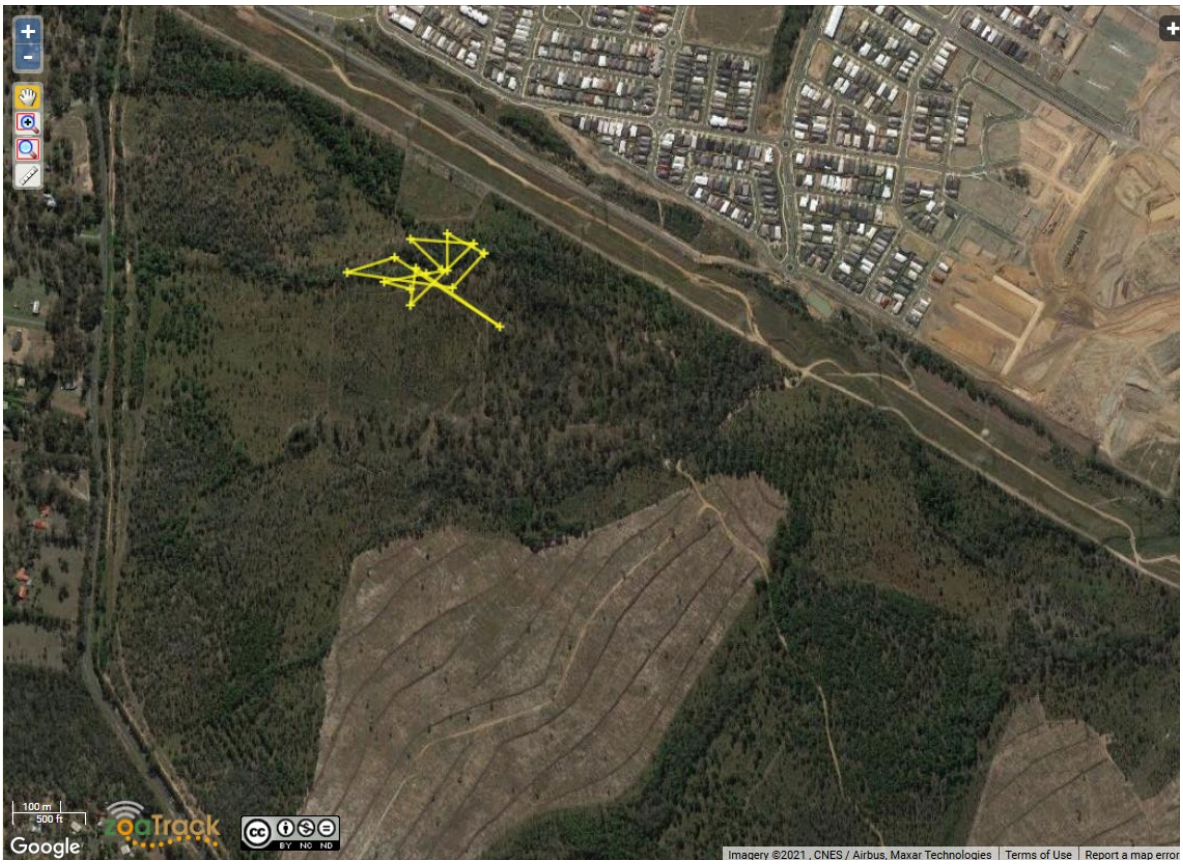
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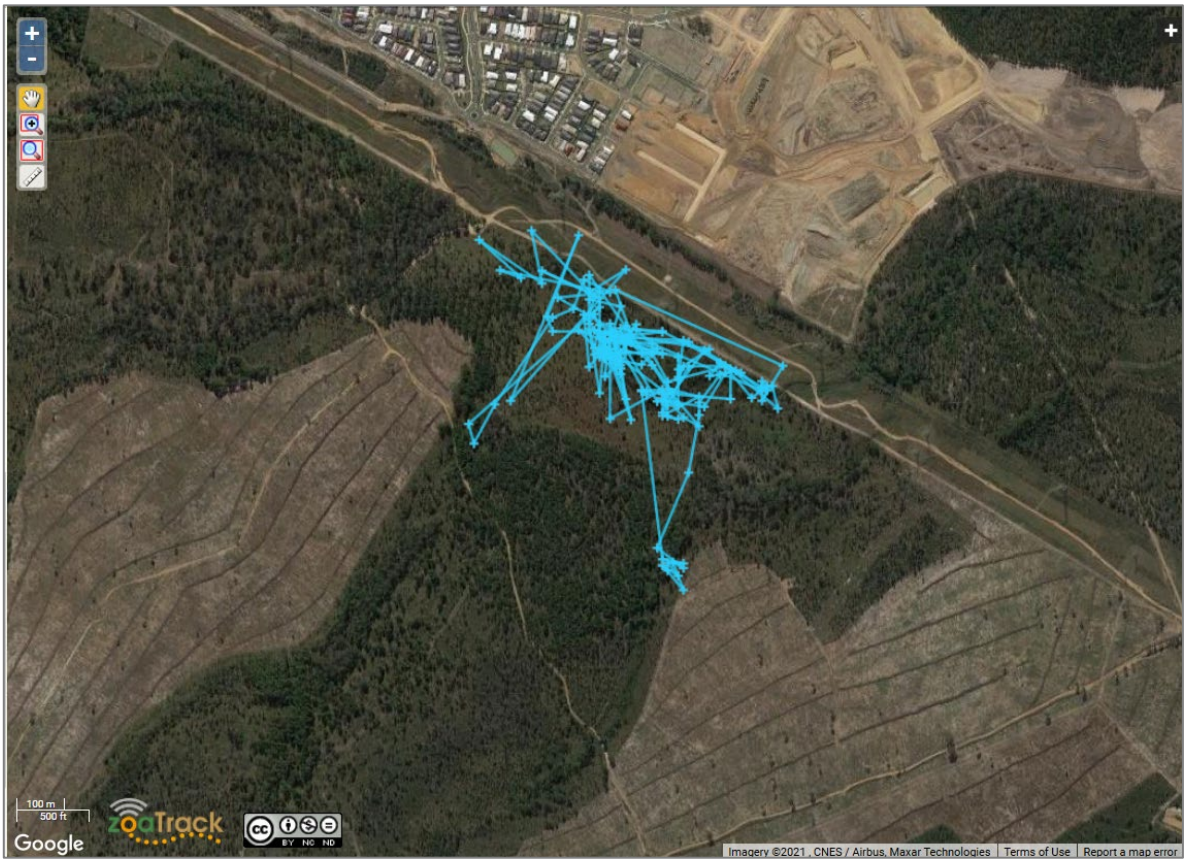
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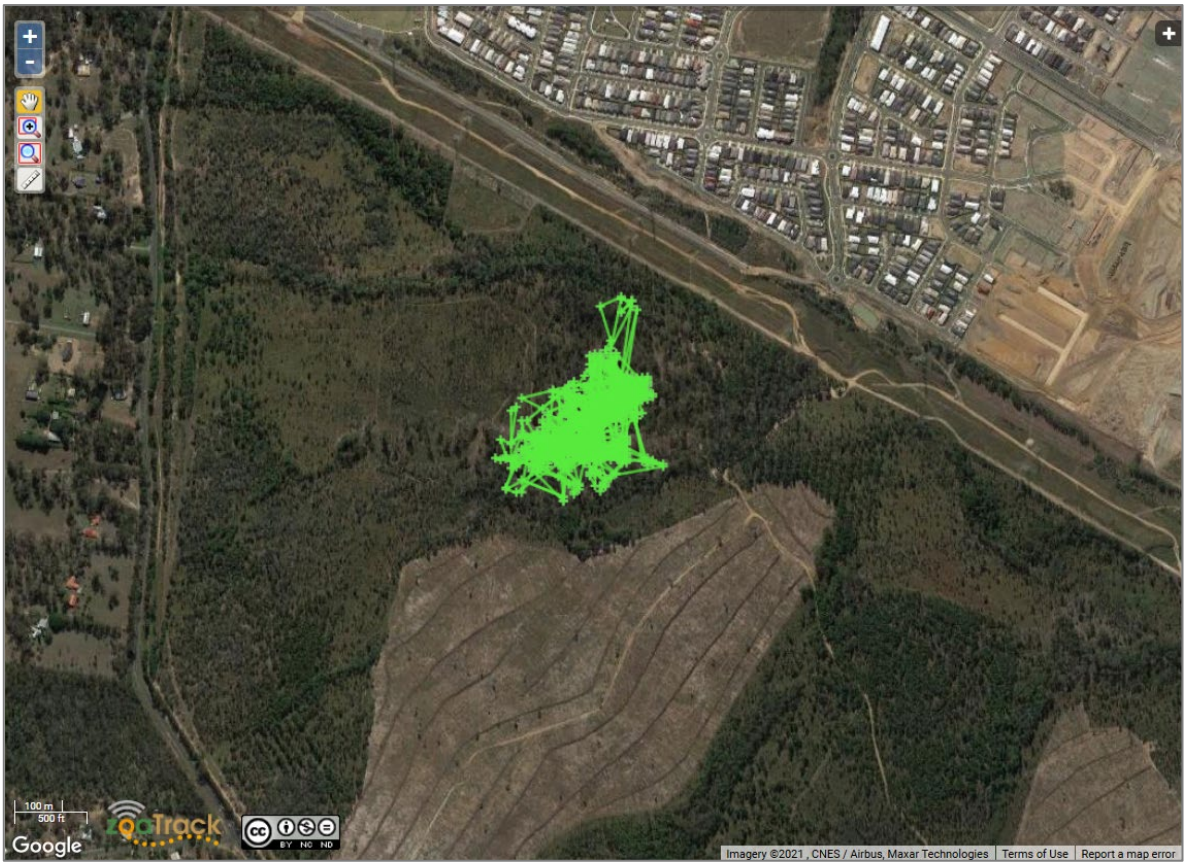
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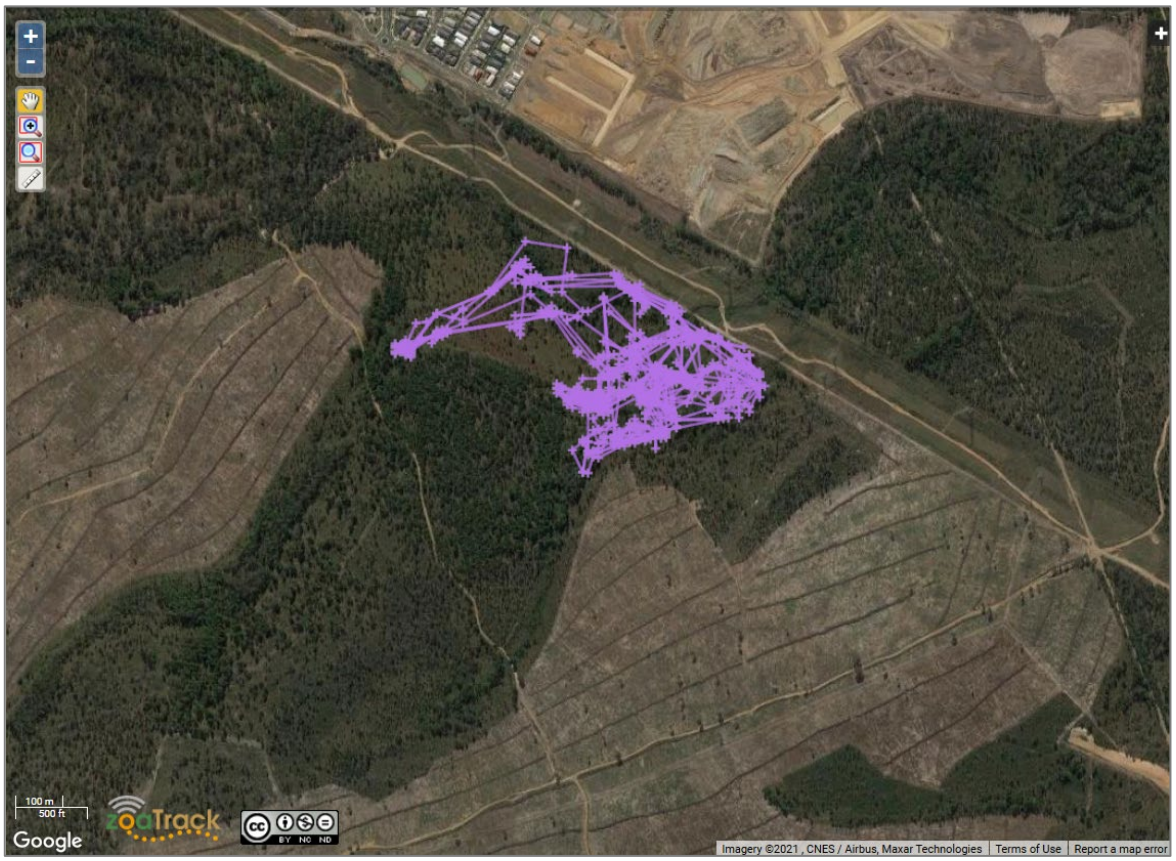
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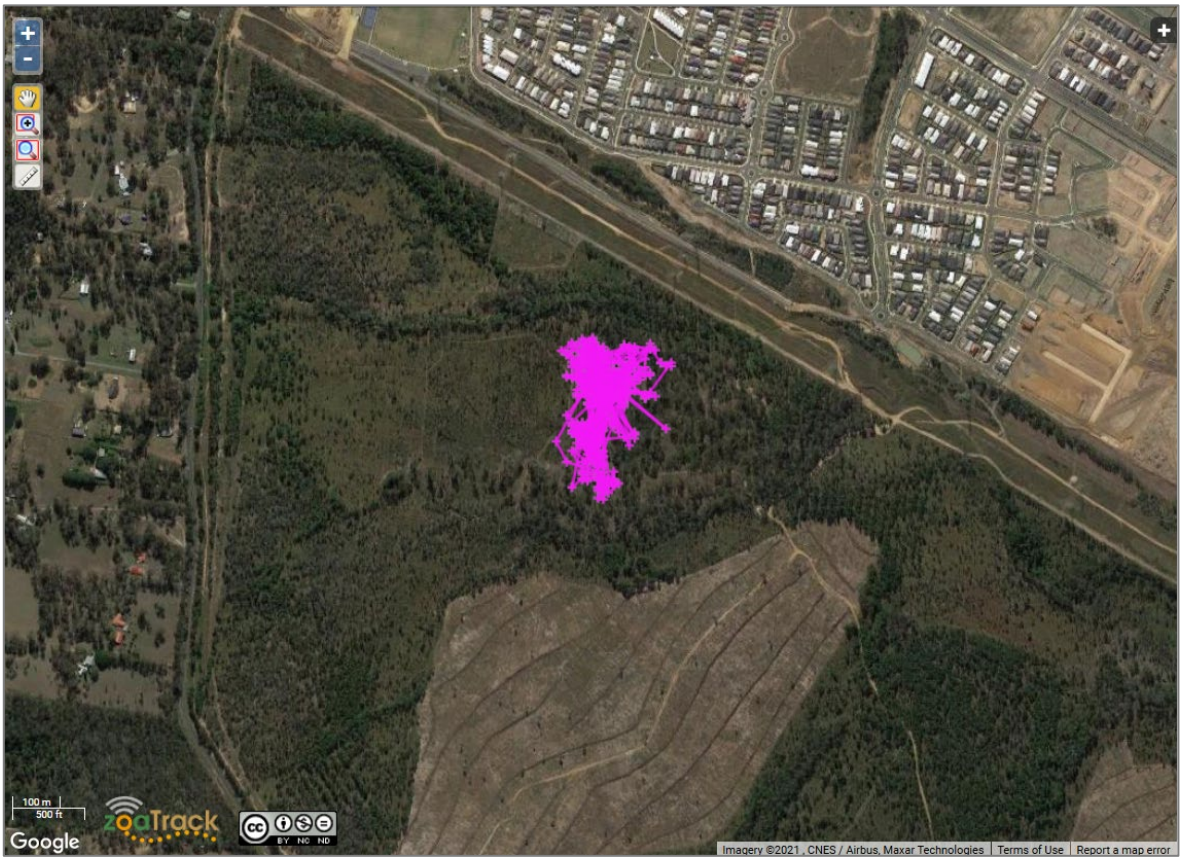
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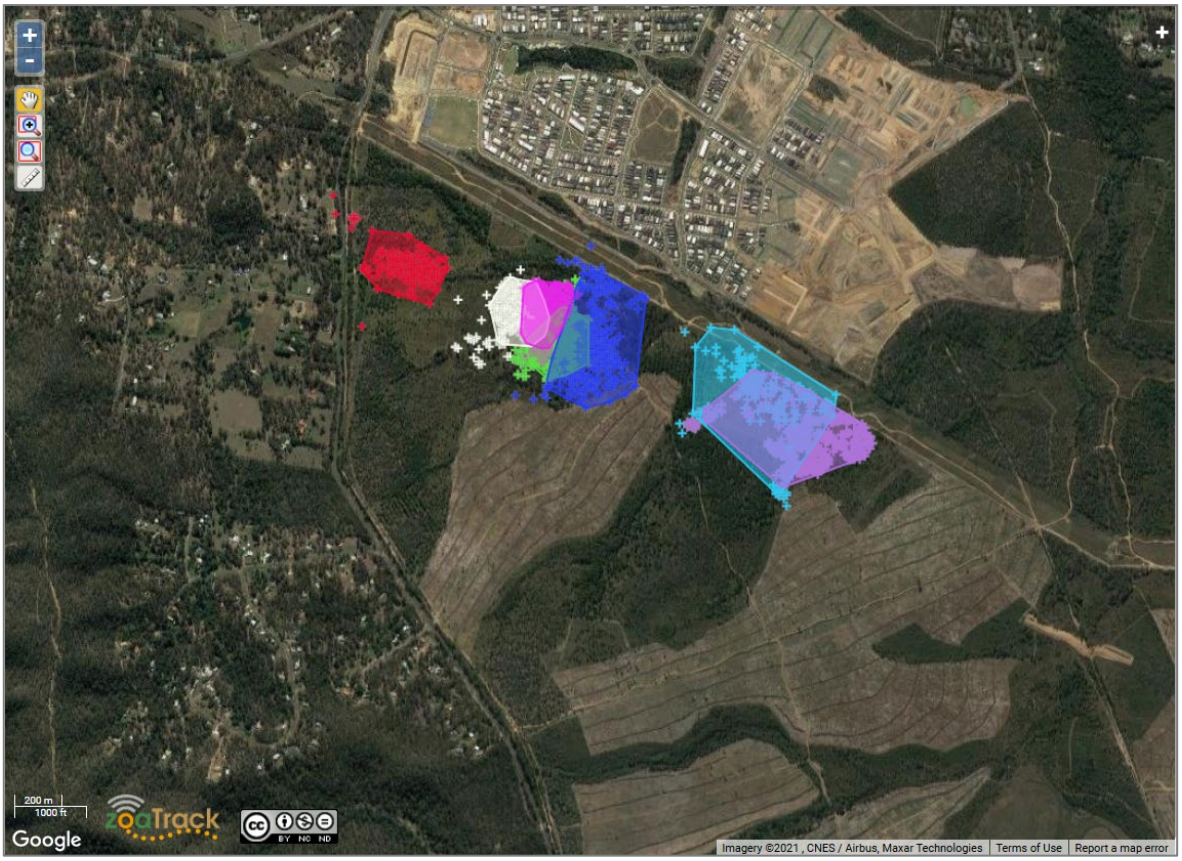

Figure 26. Plot of 95% Minimum Convex Polygon (MCP) home range estimates for seven koalas at the site in 2021.

Colour key: Bomber (dark blue), Millie Mae (red), Nyunga (light blue), Ella (green), Jana (purple), Gladys (white), Bilba (pink).


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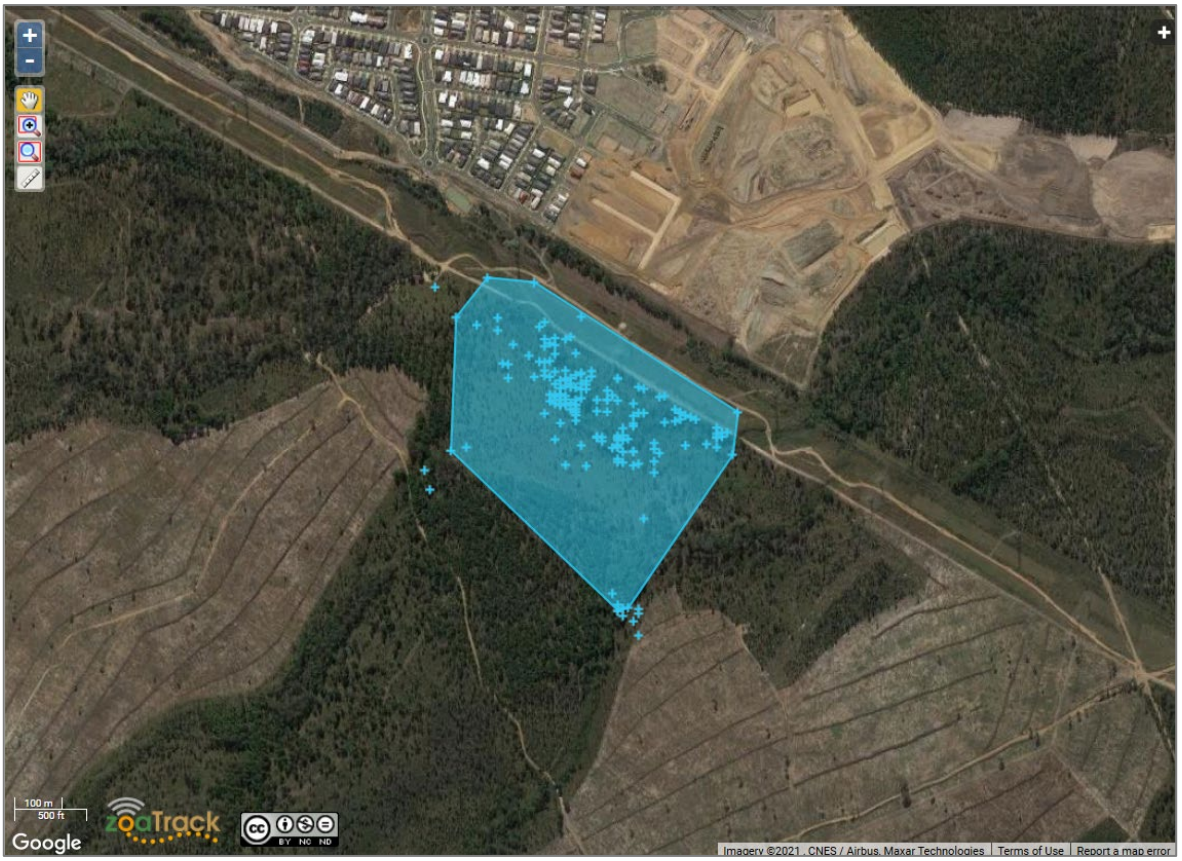
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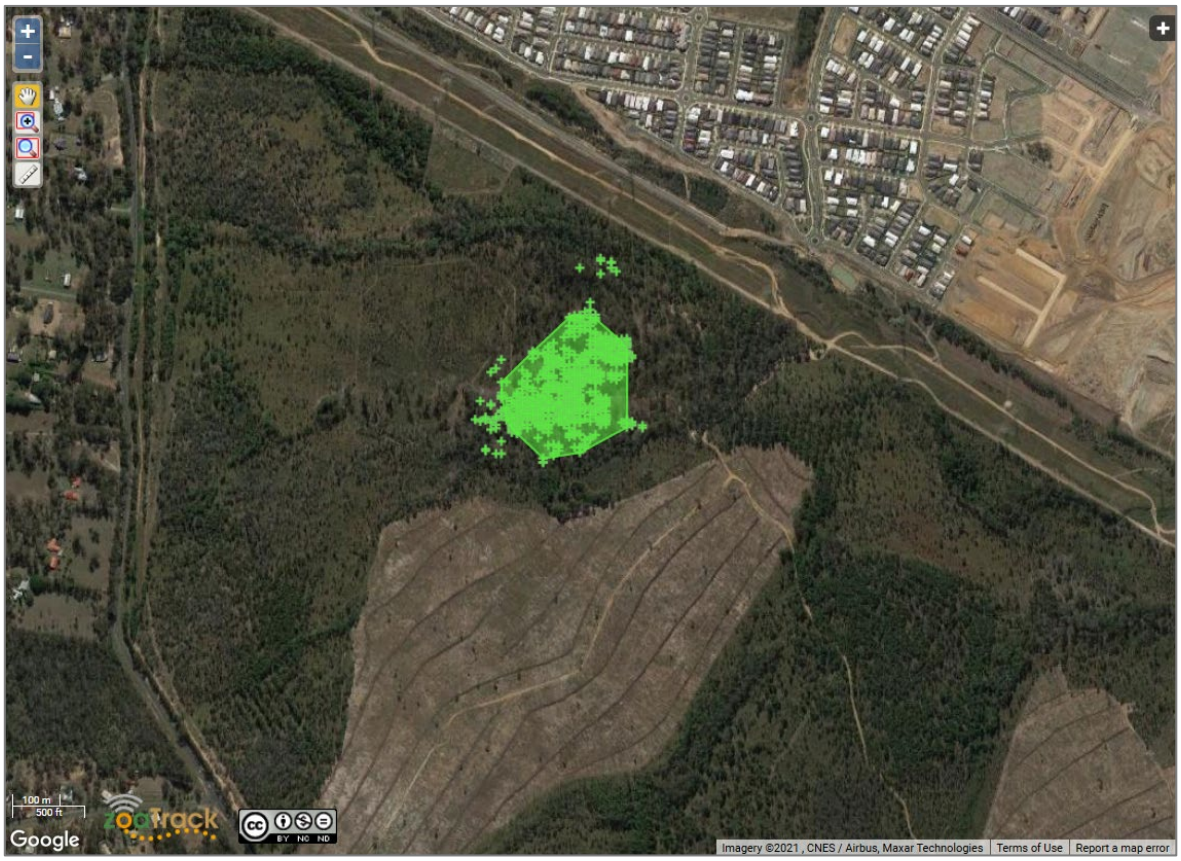
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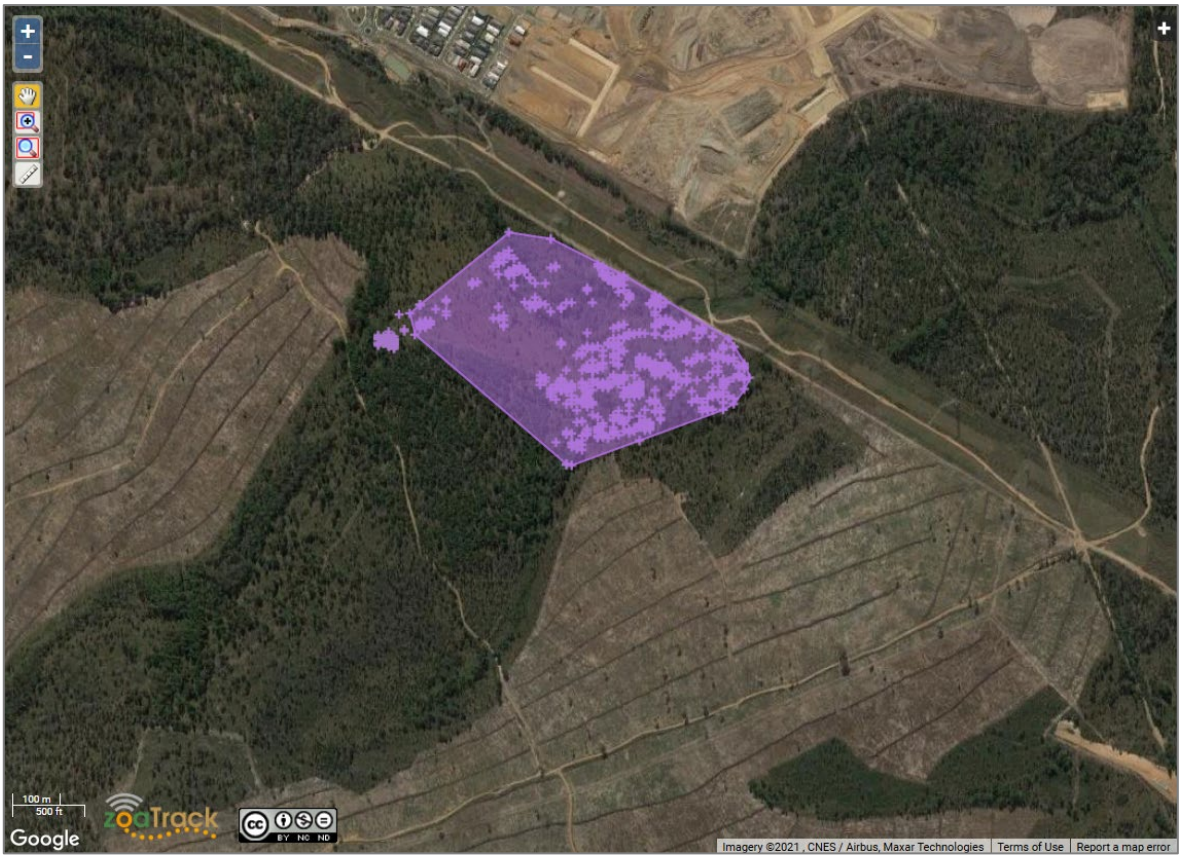
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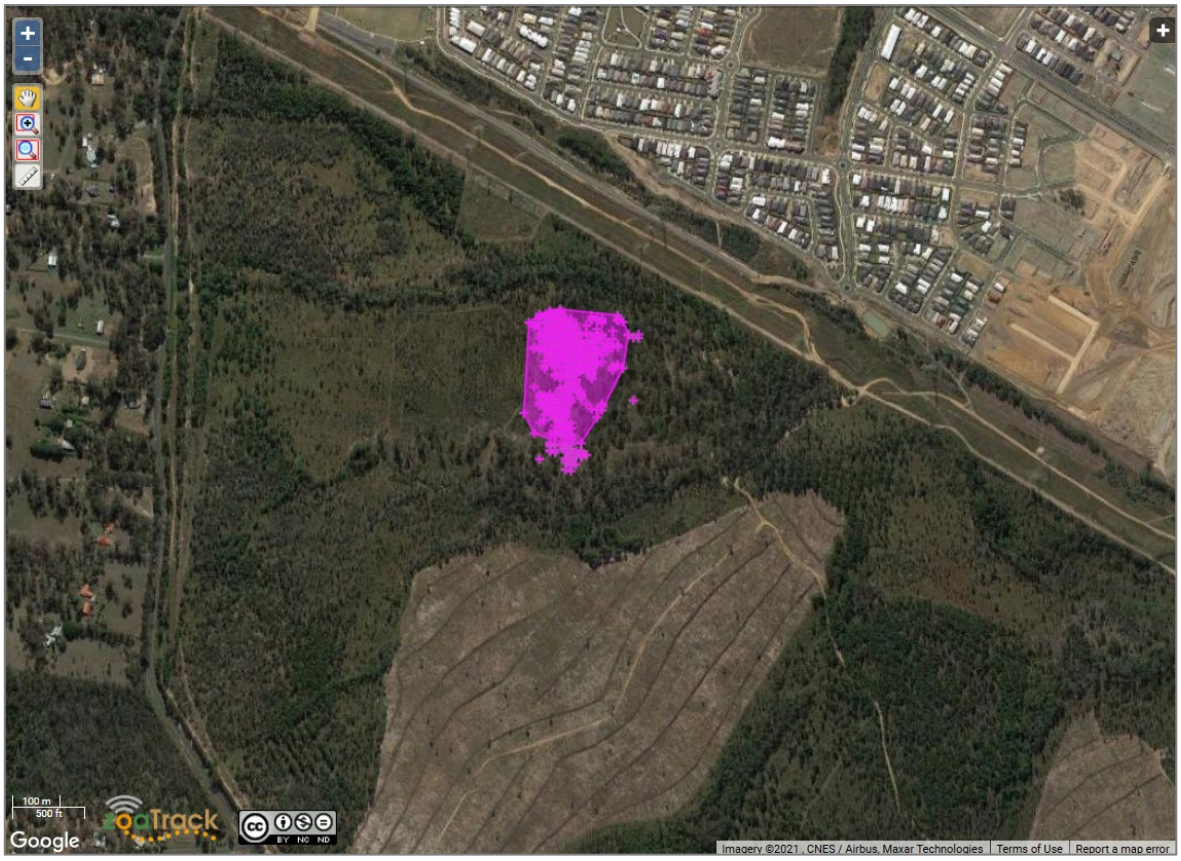
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Figure 34. Plot of 50% & 95% KUD home range estimates for seven koalas at the site in 2021.

Colour key: Bomber (dark blue), Millie Mae (red), Nyunga (light blue), Ella (green), Jana (purple), Gladys (white), Bilba (pink).


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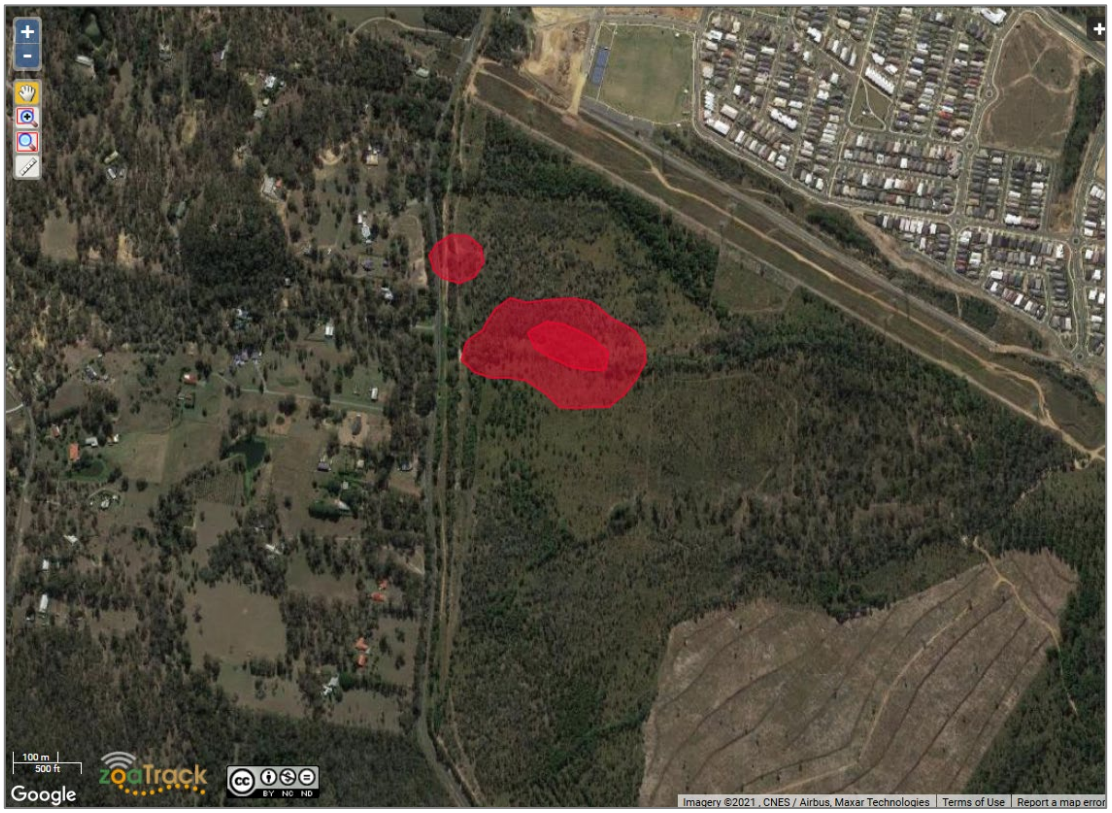
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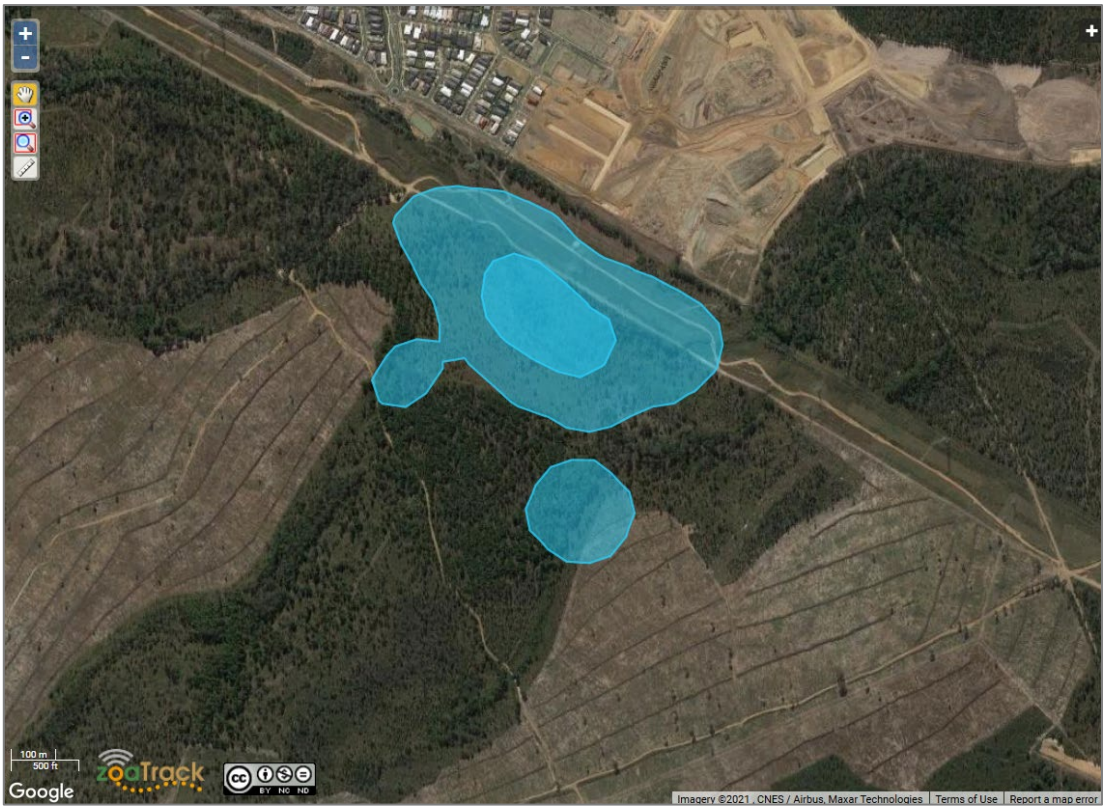
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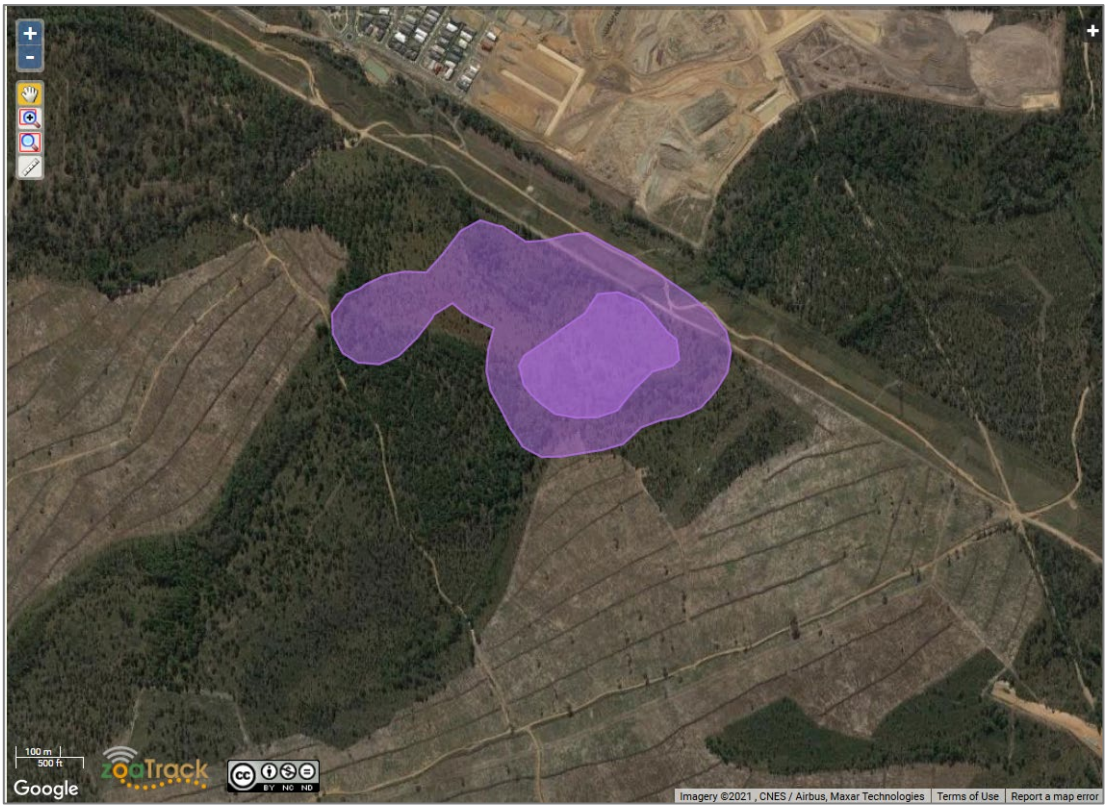
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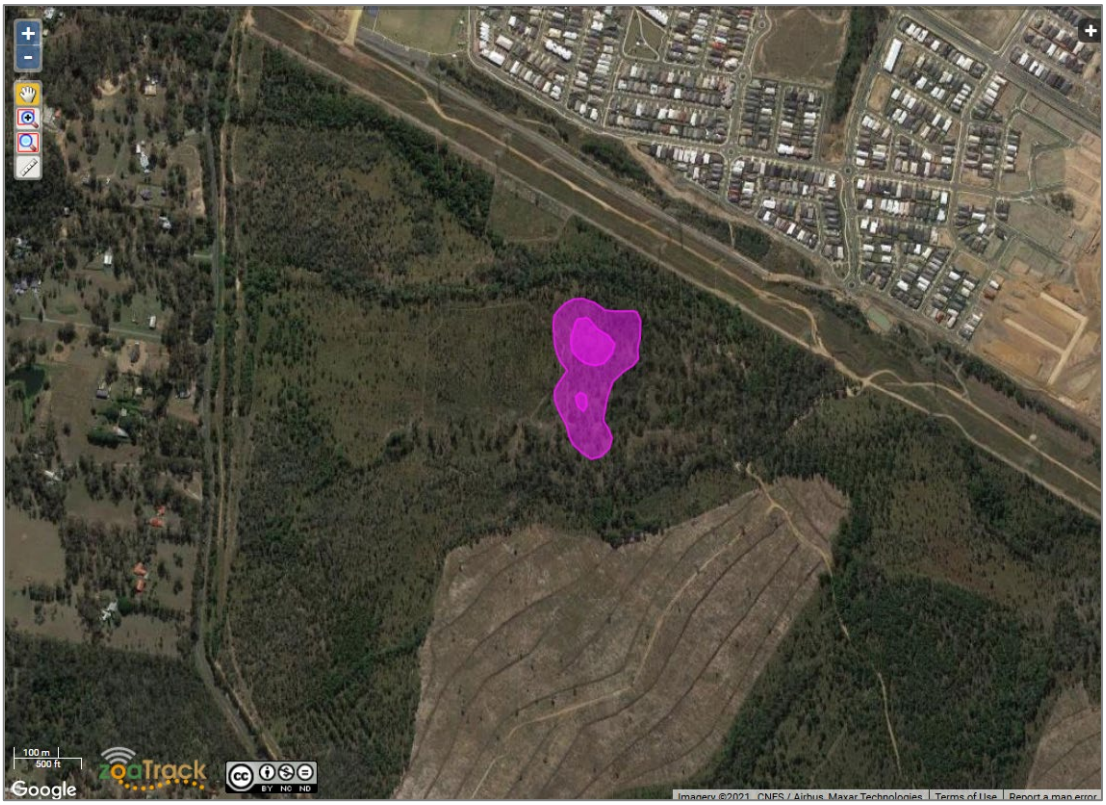
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