Maroochy Regional Bushland Botanical Gardens project

Koala surveys report

Prepared for the Sunshine Coast Council

By the University of the Sunshine Coast, Detection Dogs for Conservation

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Detection Dogs for Conservation

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Detection Dogs for Conservation

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Acronyms

Acronym	Meaning
DDC	Detection Dogs for Conservation
SCC	Sunshine Coast Council
USC	In this report: University of the Sunshine Coast's Detection Dogs for Conservation team
QLD	Queensland
SEQ	South-East Queensland

Executive Summary

The aim of this study was to expand the knowledge of koala (*Phascolarctos cinereus*) presence at the Maroochy Regional Bushland Botanic Gardens, Tall Gums Environment Reserve, Tanawha Tall Gums Conservation Area and five neighboring private properties in Sunshine Coast Council (SCC). Koala surveys were conducted by the Detection Dogs for Conservation (DDC) team at the University of the Sunshine Coast. The expected outcome was to refine the number of koalas that are present in the precinct at a point in time, and to assess koala characteristics in terms of sex, health, and relatedness.

Thermal imaging drone surveys were conducted between 30th March 2022 and 2nd of April 2022, and 14 individual koalas were detected. Drone surveys were followed by detection dog surveys which collected a total of 28 koala scat samples near the drone detection sites. During the dog surveys, the team was able to visually observe three of the 14 individual koalas, with none presenting external signs of chlamydial disease. DNA was extracted from the scat samples at University of Sunshine Coast for genotyping analyses.

Through genetic analyses, 13 unique koalas were identified, while scats from one of the drone detection locations did not deliver sufficient DNA for analysis. Of the 13 identified koalas, six were females, and seven were males. The Chlamydia pathogen was present in five of the individual koalas.

Results from the thermal drone surveys and genetic analyses indicate that there were 14 koalas using the study site at the time of the surveys, and that the chlamydial pathogen is at medium prevalence, warranting further monitoring for any impact of disease within this koala population.

1. Introduction

1.1 Project scope

The University of the Sunshine Coast's Detection Dogs for Conservation team (DDC) was contracted by the Sunshine Coast Council (SCC) to undertake a koala assessment on the Maroochy Regional Bushland Botanic Gardens, Tall Gums Environment Reserve, Tanawha Tall Gums Conservation Area and five neighboring private properties (Figure 1). The assessment aimed to increase knowledge about the number of koalas present on this site, as well as their health, sex, and relatedness.

1.2 Background

The koala (*Phascolarctos cinereus*) is an iconic Australian marsupial that is broadly distributed across south-eastern Australia, particularly in regions that have experienced high levels of habitat fragmentation due to human agricultural, residential, commercial and industrial activities (Martin and Handasyde 1999). Despite their iconic status and global appeal, koala conservation has become a growing national concern (McAlpine et al. 2015). In February 2022, the combined koala populations of Queensland (QLD), New South Wales (NSW) and the Australian Capital Territory were listed as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (Department of Agriculture Water and the Environment 2022).

On the Sunshine Coast, SCC and DDC have been working in collaboration since 2017 to thoroughly assess the local koala population with the aim to further enhance conservation efforts. The Maroochy Regional Bushland Botanic Gardens and adjoining Tall Gums Environment Reserve and Tanawha Tall Gums Conservation Area form part of a wildlife corridor for the koala population, with connections south toward Glenview, north toward Buderim, and west toward Ilkley. Furthermore, the site provides valuable koala habitat, as it contains several eucalyptus food tree species, such as *Eucalyptus propinqua*, often called grey gum, and *Eucalyptus microcorys*, commonly known as tallowwood (Eco9 Pty Ltd 2011). Koalas have previously been spotted in the garden by visitors, but also by members of the

Friends of Maroochy Regional Bushland Botanic Gardens, who have been closely following a resident koala named Lizzie since 2017.

This project integrates into our larger aim of helping to protect the endangered local koala population through a greater understanding of local threats to their conservation. With this type of research, we hope to further understand the connection between the health of the koalas and their genetics and connectivity to other populations, as well as the type of pathogens they harbour.

Figure 1: Map of the Maroochy Regional Bushland Botanic Gardens, Tall Gums Environment Reserve and Tanawha Tall Gums Conservation Area showing the site boundaries and the adjacent land. Source: Fire Management Plan (Reif 2015).

2. Objectives of the *Maroochy Regional Bushland Botanical Gardens project*

The objectives of the koala surveys were to:

- Determine the number of koalas present at the site at one point in time through drone surveys,
- Assess health, sex, and relatedness of koalas inhabiting the site through non-invasive (scat) sampling and molecular analyses.

This report describes the outcomes of the 2022 drone and detection dog surveys and addresses both aims.

3. Methodology

Surveys were conducted between the 30th of March 2022 and 2nd of April 2022. A drone equipped with thermal camera was used to locate koalas at night and a specially trained detection dog was then used the following morning to help locate fresh koala scats at these locations for genetic sampling. These koala scat samples were used for DNA fingerprinting and to determine sex, presence of the chlamydial pathogen and relatedness amongst individuals.

3.1 Drone surveys

Thermal imaging drone surveys were undertaken using current cutting-edge equipment and technology comprising a quadcopter drone (DJI Matrice 210) and thermal camera (Zenmuse XTS). This provides a real-time thermal video stream of the highest possible quality. Drone surveys were conducted at night to maximise thermal contrast between the koalas' body heat and their environment and to increase chances of them being positioned in the upper tree canopy, both of which combine to ensure higher koala detection rates and accuracy of results. Furthermore, the drone operator (Kye McDonald) is experienced (>5 years of koala detection with thermal imaging drone) and his high accuracy and consistency has been verified in populations of known koala density (through GPS collars).

The drone was systematically flown at a slow and steady speed at a height of approximately 30 metres above the tallest tree canopy (altitude adjusted with terrain). For this survey, a lawn-mower pattern was used to cover the entire survey area with a 50% overlap between passes (at canopy level) to ensure each tree canopy was viewed at least twice from opposing angles.

Once a koala was detected, a thermal video was captured (for verification) and accurate GPS coordinates were recorded.

Limitations

The accuracy of thermal drone koala surveys performed by drone operators will vary with:

- drone and thermal camera equipment,
- pilot experience,
- speed at which the drone flies (as reflected in the area covered/hr of flight),
- overlap between drone transects,
- the use of a grid pattern,
- environmental conditions at time of survey.

In an area with continuous forest cover extending beyond the boundaries of the area surveyed, as was the case in this project, koalas move freely in and out of the surveyed site. This means that it's likely that more koalas use the site than the specific individuals detected during a single survey. Repeat surveys with genetic analyses would enable a better assessment of the total number of individual koalas frequenting the site. Similarly, repeat independent thermal drone koala surveys (e.g. 2 weeks apart) are required to provide a more accurate and precise estimate of koala density that would be suitable for monitoring any significant changes in koala numbers at this study site over time (e.g. annually).

3.2 Detection Dog surveys

Following the thermal drone koala surveys, a team consisting of one dog handler (Katrin Hohwieler) and one fresh scat detection dog (Billie Jean) was deployed. The team was supported by volunteers of the Friends of the Maroochy Regional Bushland Botanic Gardens group. The aim was to locate koalas that were identified through the drone surveys to both visually assess them for external signs of illness or injury, and to find and collect fresh scats at the drone detection locations.

The detection dog team navigated to the position of each drone detected koala using the recorded GPS location and performed a search for the koala. The detection dog team was used because 1) koalas can move from their night location and 2) fresh scats are difficult to find and not always deposited at the exact location of the koala drone detection. Fresh scats found by the dog were collected and frozen. On locating the koala or koala scats, the GPS coordinates were confirmed or updated, and if the koala was visible a visual assessment was conducted. Visual assessment consisted of observation with binoculars or a camera with zoom lens with which digital photos were taken. Particular attention was given to the external signs of chlamydial disease, which is the main disease threat to koalas. Indeed, chlamydial disease has been singled out as the number one etiology in hospital admissions (Gonzalez-Astudillo et al. 2017) and a critical threat, that if adequately addressed, could reverse population decline (Rhodes et al. 2011, Beyer et al. 2018).

3.3 Chlamydial disease

Chlamydial disease primarily affects the ocular and urogenital tracts in koalas and decreases both survival and reproduction rates (Brown et al. 1987). Inflammation of the bladder (cystitis) leads to incontinence and staining of the fur around the cloaca (the main externally visible sign of infection) which is also coupled with alopecia and ulceration in severe cases (Burach et al. 2014). The ocular form of the disease varies from inflammation of the mucosal surfaces of the eye, conjunctival hyperplasia, to the complete opacification and scarring of the cornea which can cause blindness (Cockram and Jackson 1981). Therefore, overt clinical signs of ocular infection include redness of the eyes, purulent discharges, and protruding conjunctiva which can block the ocular aperture. Finally, infection of the reproductive tract is common; in females it causes bursal cysts surrounding the ovary and upper reproductive tract pathology; while in males, orchitis and epididymitis can occur (Polkinghorne et al. 2013, Johnston et al. 2015).

Unfortunately, there are few overt signs of reproductive chlamydial disease. However, the reproductive disease can create a high rate of sterility in females in a population (McColl et al. 1984).

3.4 Koala scat genetic analysis

The purpose of the genetic study was to capture information on individual koalas. Scat surveys can be used to determine presence of koalas on site, however, in this case, the dog was used to locate the freshest koala scat for DNA extraction. Fresh scats were collected in a sterile tube without direct skin contact to avoid potential contamination and loss of DNA from the scat. Sample tubes were stored in a -20 degrees Celsius freezer from the field collection until the extraction. Scats collected during the field survey with the fresh scat detection dog were analysed for the following:

- Genetic fingerprinting (i.e. determining unique individual's identity)
- Sex of individuals and thus sex ratio
- Relatedness
- Health (presence of chlamydial pathogen)

Genetic fingerprinting allows for each scat sample to be allocated to an individual. Therefore, while the drone survey identified koalas present in one night, koala genetic fingerprinting added additional value by enabling identification of: 1/ any additional individuals present near the drone detection locations within a few days prior to the drone surveys, and 2/ individual koalas that were potentially double-counted by being detected in different locations two nights in a row (if they moved, by chance, from the area surveyed the first night to the area surveyed the second night).

Sex ratio is the relationship between the number of males to the number of females. Typically, the sex ratio in natural populations is expected to be 1:1. Risks of extinction are increased if population sex ratios deviate from 1:1. However, a small bias of sex ratio towards females can sometimes be desirable, especially in very small or rapidly declining populations.

Relatedness, in genetics, defines the degree of consanguinity between individuals. Typically, offspring receive half of their DNA from each parent, and have therefore a coefficient of relatedness of 0.5 with each of them. This measure is of interest, identifying relationships between specific koalas and also providing an insight into koala movements (or lack thereof) through the landscape during breeding.

The prevalence of *Chlamydia* (percent of koala with the pathogen) is an important population characteristic for informing conservation management. Note, however, that the severity of the disease varies greatly between individual koalas (as well as populations) (Ellis et al. 1993, Waugh et al. 2016). Notably, individual koalas can shed large numbers of chlamydial organisms without clinical signs of disease (Wan et al. 2011) and populations can have high chlamydial prevalence (infection) with low noticeable health impact [90% of koalas in the Mt Lofty ranges were *Chlamydia* positive but had a low prevalence of clinical disease (Polkinghorne et al. 2013) see also Weigler *et al.* (1988)]. Therefore, quantifying *Chlamydia* prevalence is only part of understanding the threat that this pathogen presents to an individual and a population.

3.5 DNA Isolation and SNP Genotyping

3.5.1 DNA Isolation

DNA from scats was extracted using a next-generation sequencing protocol described in Schultz et al. (2018). To summarise, koala DNA was isolated from the intestinal epithelial cells present on koala scats, this provides both koala and chlamydial DNA, as chlamydial bacteria are intracellular (i.e. within koala cells). Epithelial cells from the surface of each scat were separated by slicing off the top-most layer of the scat using a scalpel. These surface slices were then used to extract DNA using the QIAamp PowerFecal Pro DNA Kit (Qiagen), following the manufacturer's protocol, with the following variations: after adding CD1 buffer, samples were incubated at 65° C for 10 minutes, and then vortexed for seven minutes at maximum speed using Genie 2 Vortex Mixer (Scientific Industries). Final DNA isolates were eluted in 100µl of C6 elution buffer. Each isolate was tested for quality using the Thermo Scientific NanoDrop

2000 Spectrometer (Thermo Fisher Scientific, Victoria). Extracted DNA was stored at -80°C until being shipped to the genotyping provider.

3.5.2 Single nucleotide polymorphism (SNP) genotyping and *Chlamydia* detection

Please note that the genotyping method below is given for completeness but is not essential to the understanding of the genetic results. The reader might choose to skip the genotyping section altogether.

Genotyping of single nucleotide polymorphism (SNP) genetic markers was conducted by Diversity Arrays Technology, Canberra, using proprietary DArTseq™ technology. DArTseq™ represents a combination of DArT complexity reduction methods and next-generation sequencing platforms (Kilian et al. 2012, Courtois et al. 2013, Von Mark et al. 2013, Raman et al. 2014). Specifically, SNP genotyping was conducted using a DArTtag approach, which is a targeted application of DArTseq™ technology allowing for the sequencing of targeted markers. DArTtag is used in similar applications as DArTseq, but it applies a selective step after complexity reduction to genotype specific markers from DArTseq representations. This selection is achieved with the use of the nucleic acid "capture probes" that bind to restriction fragments in the representations carrying the specific DArTseq markers.

Capture probes included 30 specific sex markers and 30 specific *Chlamydia* markers. The presence of the chlamydial pathogen was assessed based on the detection of these specific SNPs, and a koala was classified as chlamydial positive above a specific threshold (>9 out of the 30 SNPs detected). If this threshold was above 9, Chlamydia is "likely", if it is around or just below 9 it is "possible". Note again that the presence of *Chlamydia* does not necessarily mean koalas are diseased, as they can be passive carriers of the bacteria, or have recovered (Robbins et al. 2019).

3.6 Data Analysis

All survey results were mapped in ArcGIS v10.2. Genetic data was analysed using GenAlex 6.5 (Smouse and Peakall 2012) and the R packages *dartR* (Gruber et al. 2019) and *related* (Pew et al. 2015).

3.7 Health, Safety and Permits

A Job Safety Analysis was completed. The wellbeing of the detection dogs was assessed by Animal Ethics (USC: ANA21181). Billie Jean has been regularly treated against ticks and thoroughly checked for bites after each survey. Surveys were conducted only after it was confirmed that no known wild dog baiting occurred in the areas to be surveyed. The dog was always on the lead or in view of the handler, which means the risk of the dog escaping and getting lost or injured was remote. Surveys were conducted under valid wildlife and scientific research permits (SPP WA0025289, P-SPP-100067113) and Council permit (Maroochy Bushland Botanic Gardens (97SP269566)).

4. Results

4.1 Drone Surveys

Three night-time drone surveys were performed over the following dates:

- 30th – 31st of March 2022
- 31st March – 1st of April 2022
- 1st – 2nd of April 2022

Figure 2 shows an example of a koala detected by the thermal camera mounted on the drone. A total of 14 different koalas were detected (i.e., reference koalas) and, in some instances, the same koalas were most likely detected on multiple nights (Figure 3, Figure 4). With a total site area of 175 ha, the density of koalas was estimated to be 0.08 koalas per ha.

Figure 2: Example of a koala located using drone-mounted thermal camera.

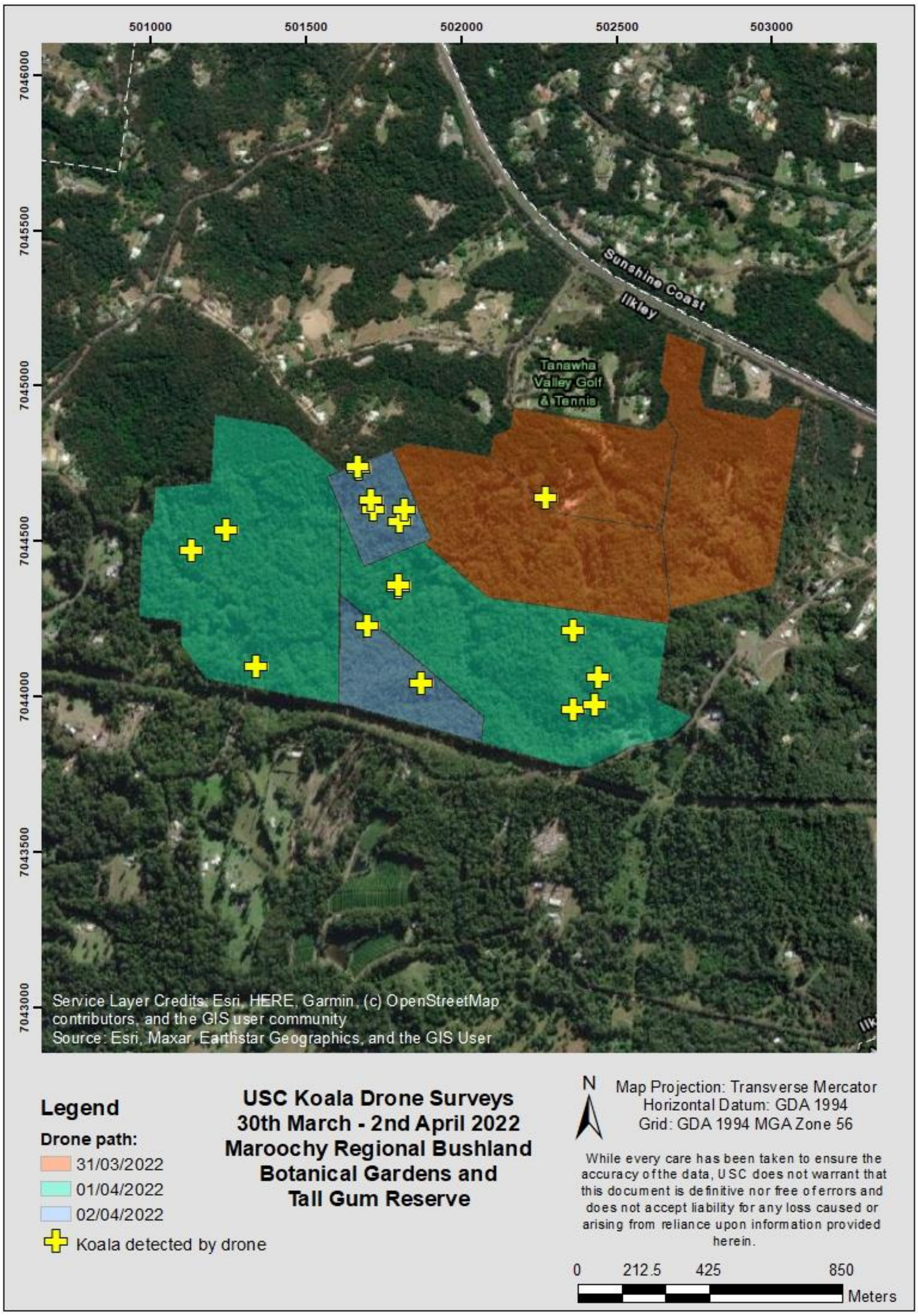

Figure 3: Koalas located using drone-mounted thermal camera (yellow cross) and the survey areas of the drone in the Maroochy Regional Bushland Botanic Gardens, Tall Gums Environment Reserve and Tanawha Tall Gums Conservation Area, and neighbouring private properties.

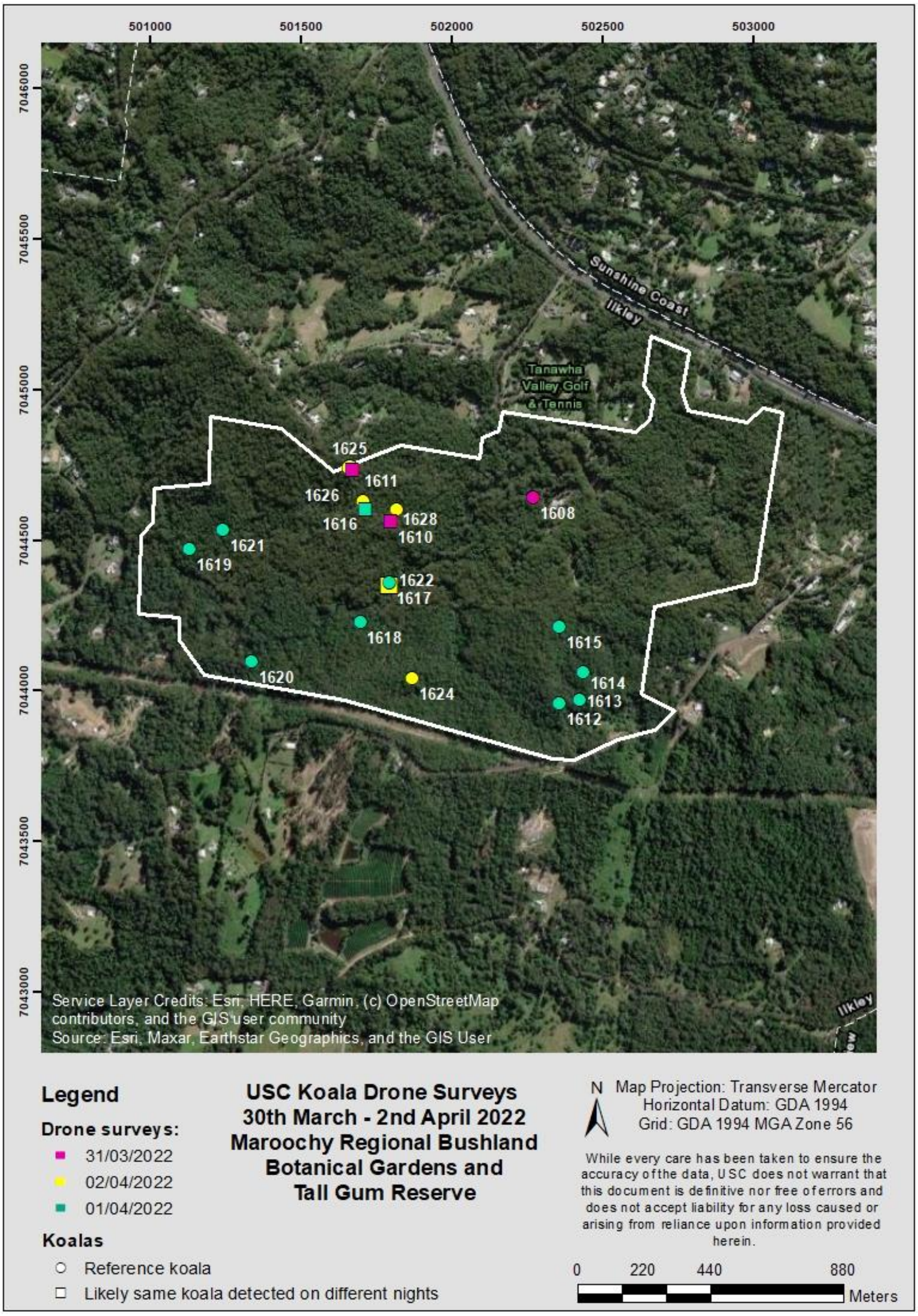

Figure 4: Reference koalas (circle) and likely same koala detected on different nights (square) detected using drone-mounted thermal camera in the study site. The three drone surveys are represented in different colours (i.e., pink, yellow and green).

4.2 Detection Dog surveys

Following the drone surveys, three of the 14 koalas were also sighted during the detection dog surveys (Figure 5). These koalas were close to the same tree they were detected by the drone the night before (i.e., within 50m) and nothing abnormal was visually detected that would indicate external signs of chlamydial disease or injury.

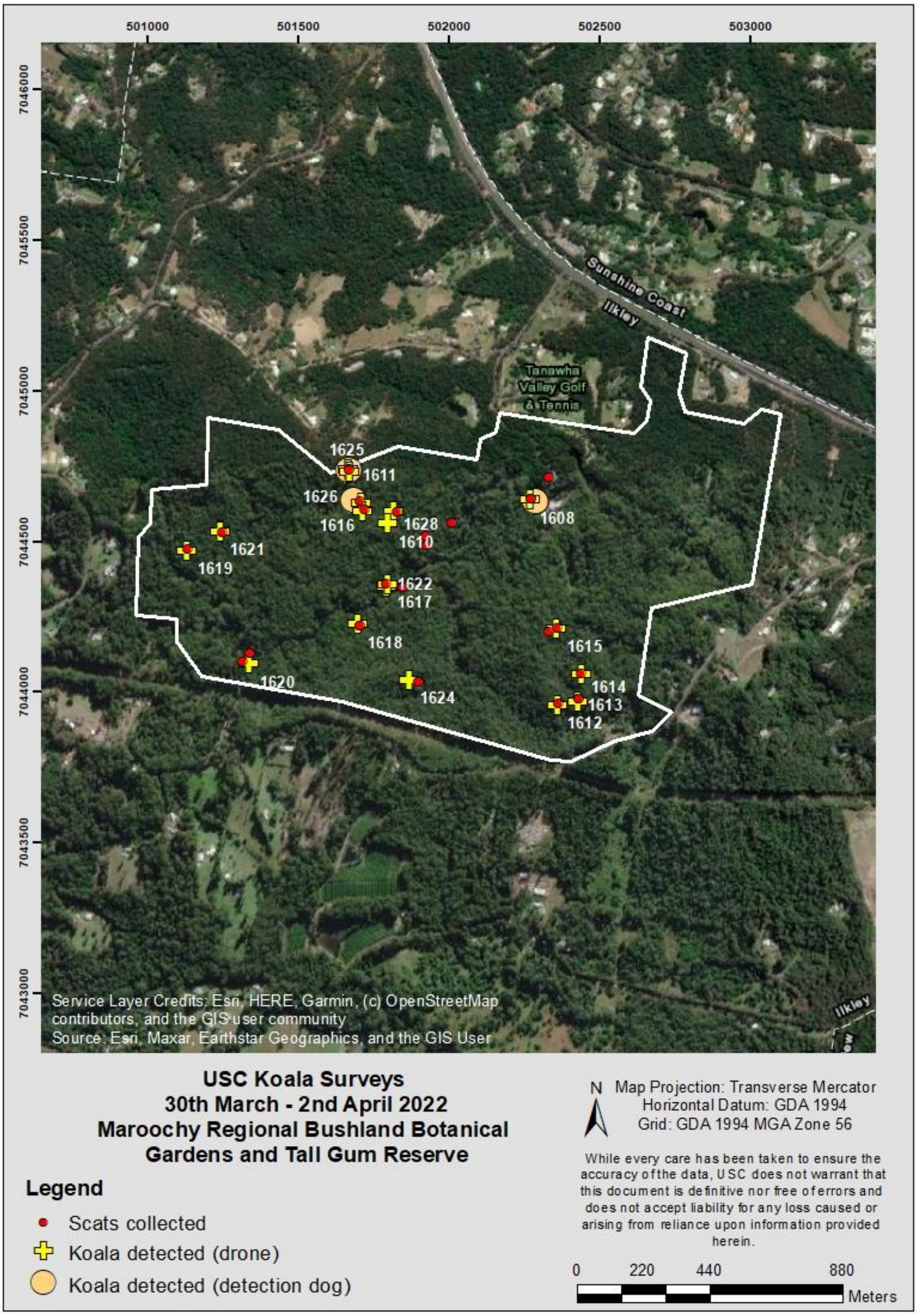

Figure 5: Koalas (orange circle) and scats (red circle, N=28) located by detection dog Billie Jean (fresh scat detection dog) and location of koalas found with the drone (yellow cross) in the study site.

4.3 Koala genetics

A total of 28 fresh scat samples were found and collected for genetic analyses. The DNA from these scats was extracted and processed for genotyping. After quality control (filtering for a minimal data quality), 21 samples were retained for analyses with 436 SNPs. Genetic analyses revealed that there were at least 13 unique individuals sampled in March/April 2022 (Figure 6). Although drone surveys detected 14 individuals, one of these koalas (most likely the koala at detection #1618, see Figure 5) was not captured genetically due to low quality sample data. Please note that some samples do not meet our data quality thresholds and are not included in the analyses. This is why we emphasise that we have genetically identified the minimum number of unique individuals, but not the maximum.

Genetic analyses showed that six of the 13 individuals were females, and seven were males (Figure 7). The sex ratio was 1:0.86 males to females, which is as would be expected in a healthy population (note our small sample size). Two of the males and three of the females had *Chlamydia* pathogen present (Figure 8).

Relatedness analyses revealed that individuals 1, 2, 3, 9, and 10 did not seem to be related to any other individuals present in the area (Figure 9), which suggests the existence of movement patterns in and out of the study site area. This could be natural or assisted movement (translocations), but could also suggest sterility/infertility. For instance, it is possible that koala number 1 is "Lizzie" who is known to have no to low fertility. In contrast, all other individuals exhibited relatedness values ranging from ~ 0.125 to ~ 0.50 (Table 1), thus indicating that individuals of the population have what we can consider a family relationship. The range of relatedness values observed here reflected various relationships among individuals present in the area. That is, values of ~ 0.5 indicated that individuals fostered a parent-offspring or full sibling relationship, while values of ~ 0.25 reflected a half sibling or grandparent-grandchild relationship. Furthermore, values of ~ 0.125 indicated that individuals were first cousins (Taylor 2015, Wang 2017).

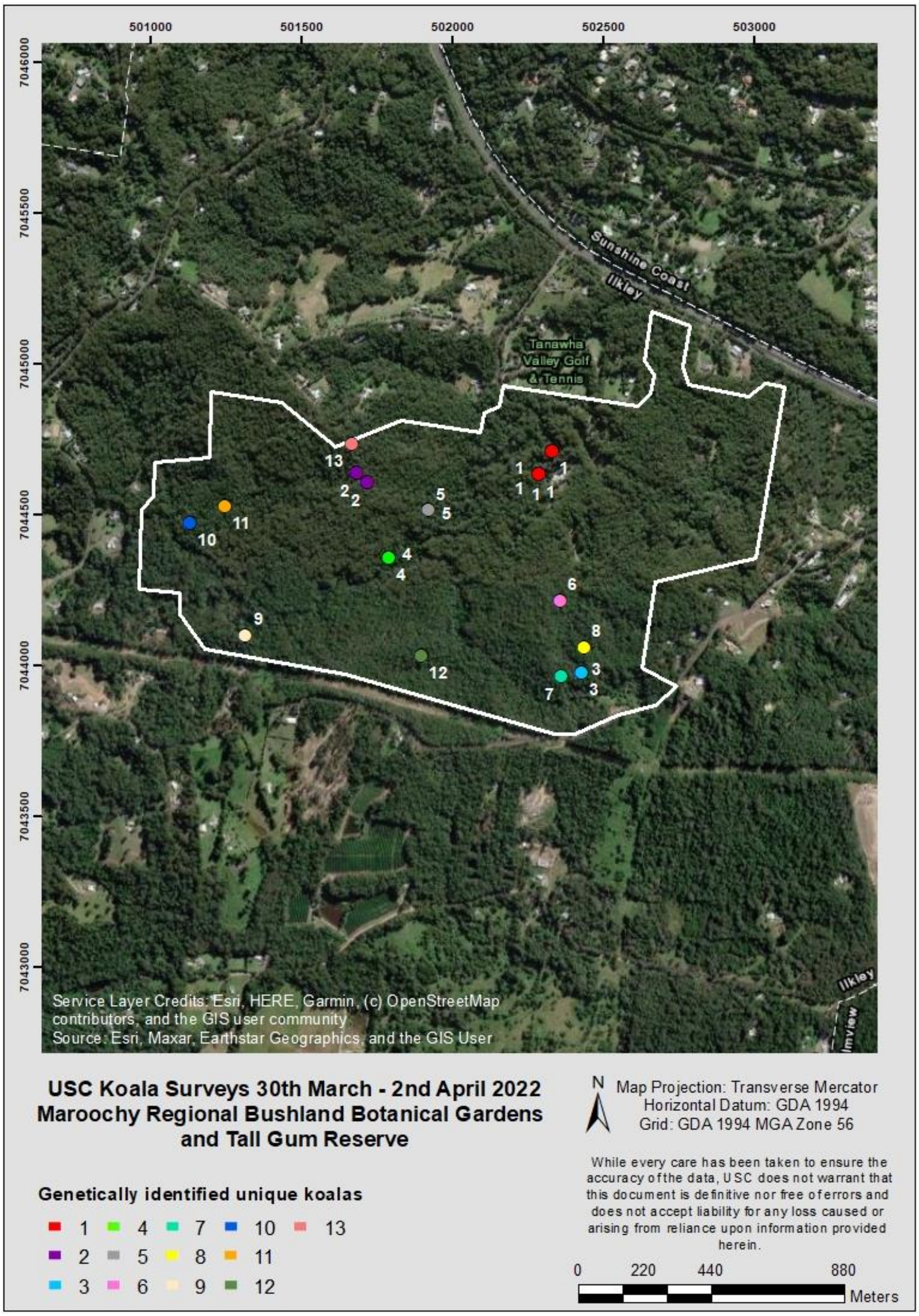

Figure 6: Genetically identified individual koalas within the study site in March 2022. The different colours represent different individuals. When multiple samples belong to the same individual (sampling duplicates), these samples carry the same colour and number. From 28 collected scat samples, 13 unique individuals were genetically identified.

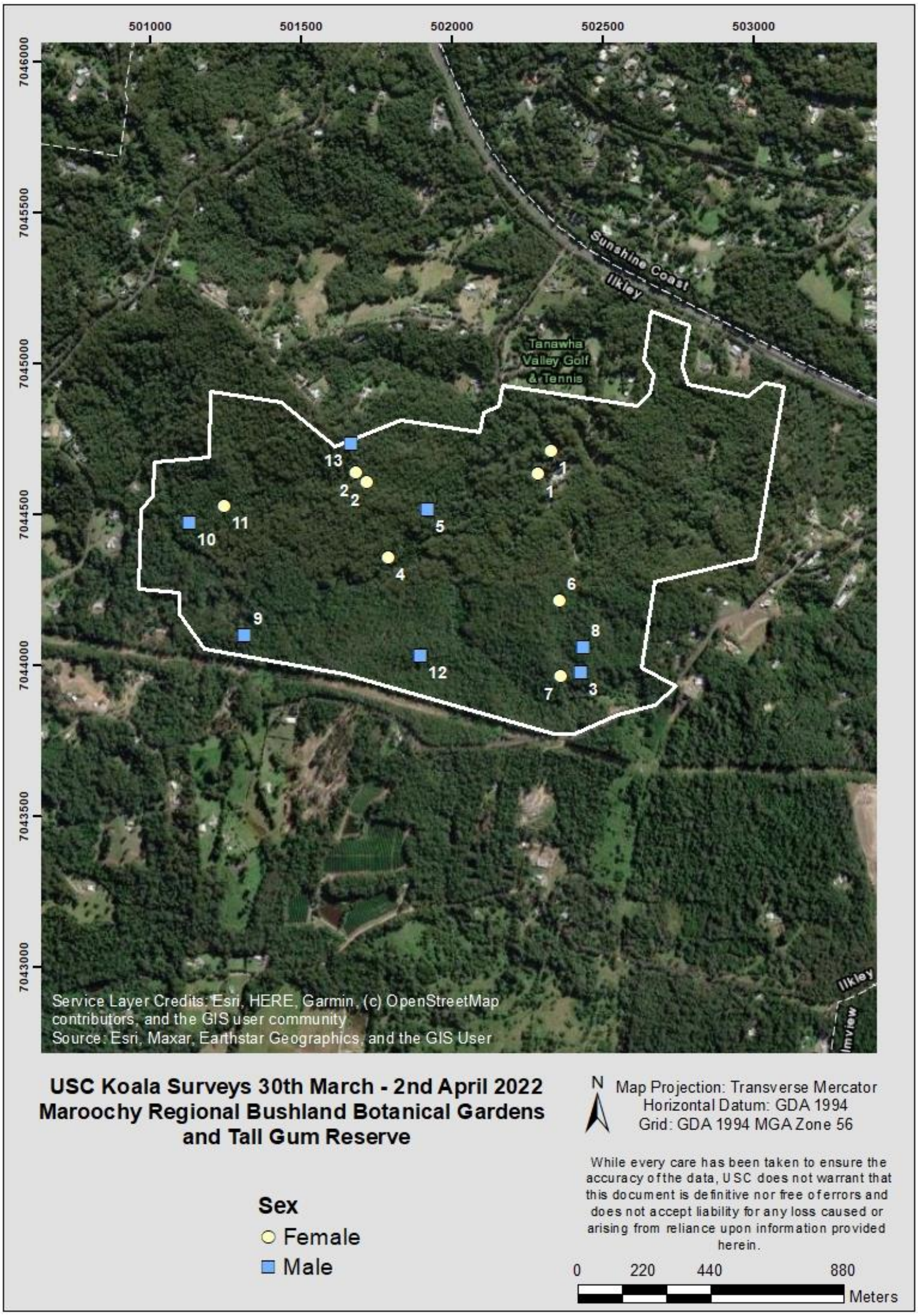

Figure 7: Male and female koalas within the study site in March 2022. Of the 13 unique individuals that were genetically identified, six were females and seven males.

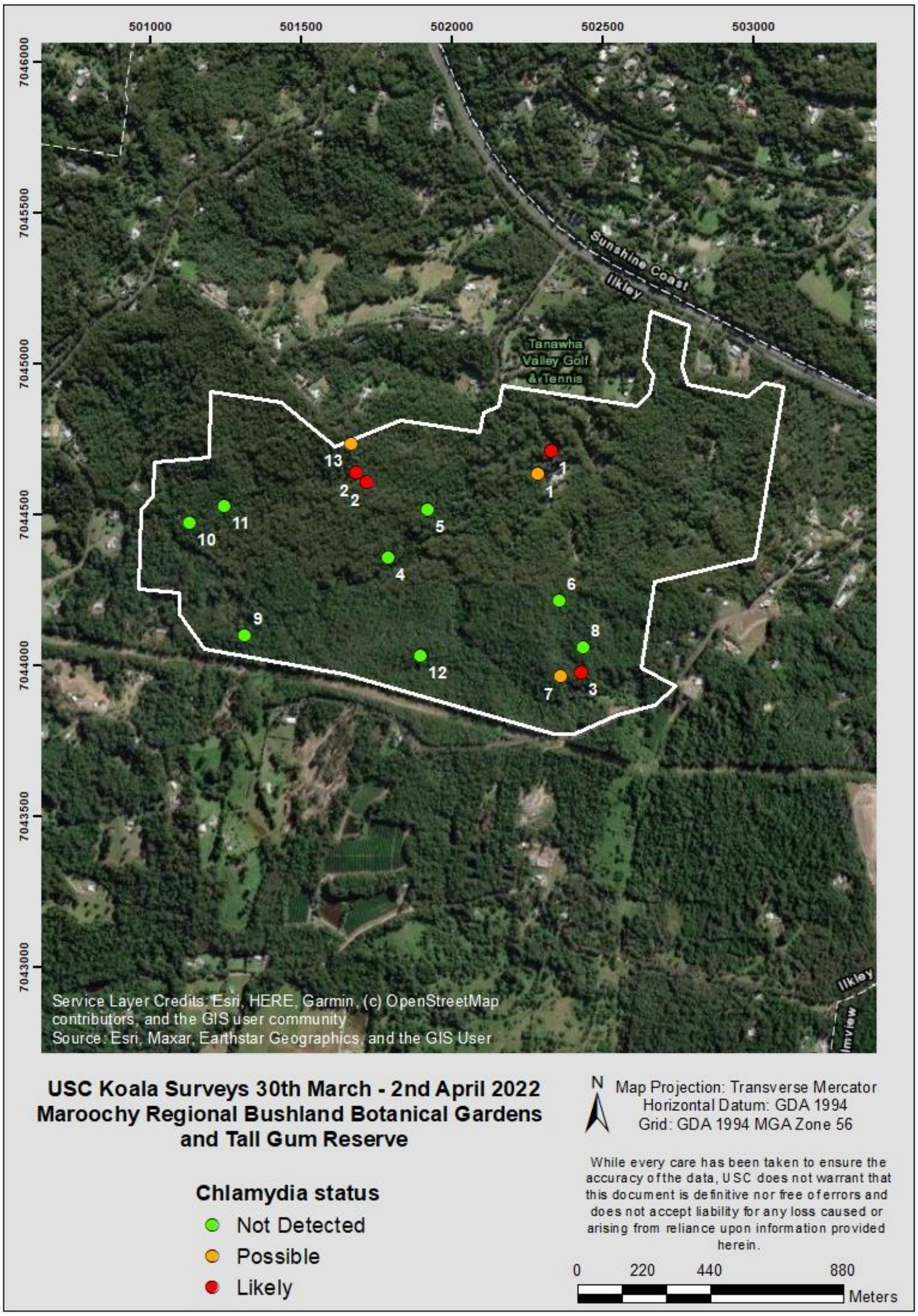

Figure 8: *Chlamydia* distribution within the study site in March 2022. Out of 13 individuals, five had chlamydial pathogen present – three likely and two possibly.

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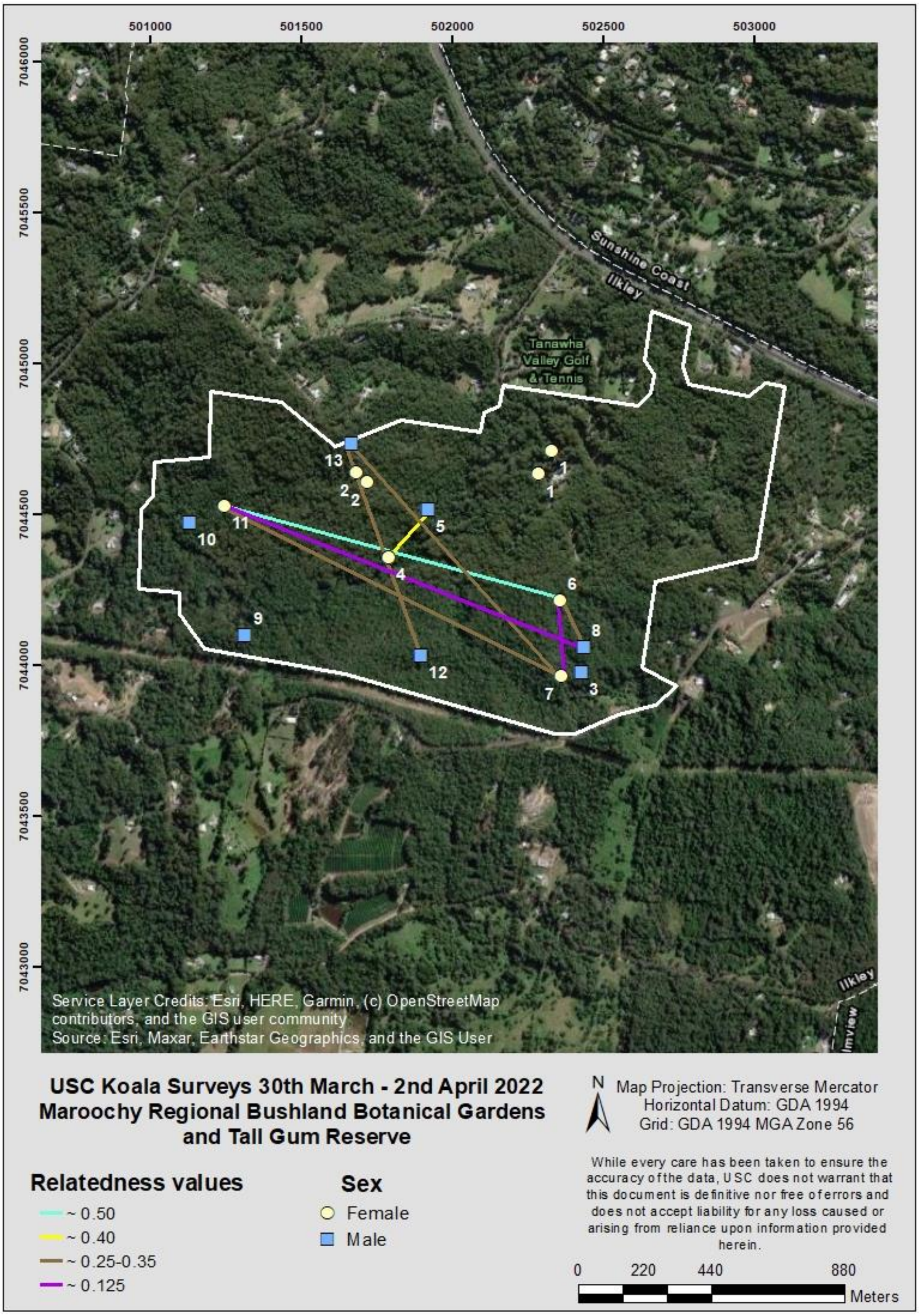

Figure 9: Koala relatedness within the study site in March 2022. Related individuals are connected to each other with a line. The colour of the connecting line indicates the degree of relatedness.

5. Discussion

A total of 14 koalas were detected in the study site through drone and detection dog surveys in late March 2022 and early April 2022. This equates to an estimated density of 0.08 koalas per hectare, which is double the estimated average koala density of 0.04 koalas/ha (ranging from 0 to 6.54 koalas/ha) within the eastern portion of the South East Queensland planning region (comprised of eight LGAs, including the Sunshine Coast Regional Council area) (Appendix A: Figure A1, Rhodes et al. 2015). Therefore, the habitat at this site should be considered very high value for koala conservation in a regional context. Additionally, it can safely be assumed that this site forms an important part of a koala movement corridor, with near continuous suitable habitat connecting south, toward Glenview, north toward Buderim, and west toward Ilkley.

In the study site, 38% of the koalas were carrying the chlamydial pathogen, which is similar to chlamydia prevalence found in other areas of SEQ, such as in Redland City Council (on average 35-38%, with prevalence across different suburbs ranging from 21% - 77%). Additionally, the fact that 38% of the koalas had the pathogen present does not necessarily translate into 38% chlamydial disease, as some koalas could have recovered, or carry the pathogen without symptoms. Indeed, the three koalas that were able to be visually assessed (to a limited degree) were all subsequently confirmed as having *Chlamydia* present in their scats, yet no overt signs of illness were noted for any of them. However, the prevalence of the pathogen is a sign that disease may potentially pose a threat to the koalas inhabiting this study site, and this confirms previous research by the University of Queensland and Friends of the Maroochy Gardens at this site. This potential threat is further supported by chlamydial disease causing the death of three previously tracked koalas from the park (pers. obs.).

Of the 13 genetically identified koalas, six were females and seven males, resulting in a 1:0.86 male to female sex ratio. In comparison, other South East Queensland areas, such as Redlands (mainland) and Minjerribah, exhibit a male to female sex ratio of 1:0.97 and 1:0.90 respectively. In New South Wales, previous studies showed male to female sex ratios of 1:0.56 in Armidale/Uralla, and 1:0.71 in Inverell/Delungra. Please note that our sample size (i.e., 13 individuals) is small and likely represents a part of a larger koala population. While the ratio is not in favour of females, there is currently no reason for concern, as it is possible that the larger, overall population could exhibit a more balanced sex ratio. If subsequent monitoring of koalas on this site continues, ongoing data collection can determine if this sex ratio is following a trend or if it is variation. Genetic sampling and inclusion of samples from the study site's surroundings could provide further insight.

Relatedness data indicated that some individuals were genetically related, while others did not seem to be related to any other koalas present in this study site. These results suggest (1) that breeding events occur among individuals within the site, and (2) the existence of movement patterns in and out of the site or, potentially, also infertility of some koalas. Whether movement occurs naturally (e.g. migration and dispersal) or assisted (e.g. by active translocation) is not known.

6. Recommendations

Recommendation 1: Preliminary density and pathogen prevalence estimates at additional sites within Sunshine Coast Council

The Maroochy Regional Bushland Botanic Gardens, Tall Gums Environment Reserve and Tanawha Tall Gums Conservation Area, with its combined size and highly valuable koala food trees, represents important koala habitat in the Sunshine Coast Biosphere. Likely, it is also an important node for connection of other surrounding habitat patches due to its central location. Conducting similar studies in land surrounding the gardens, including east of the Bruce highway, could inform in more detail on the ability of koalas to move through the central Sunshine Coast bushlands and provide information on koala density and pathogen prevalence in adjoining areas. This could include, for instance, nearby private properties (e.g. Land for Wildlife properties) and other accessible surrounding Council bushland (e.g. Topview Bushland Reserve Network, Buderim-Palmwoods Heritage Trail Bushland Park and Frizzo Environment Reserve).

On a broader scale, very few studies have investigated koala density estimates on the Sunshine Coast (Appendix A: Figure A2, Rhodes et al. 2015). Therefore, similar "snap-shot" methodologies could be applied to additional sites within the Sunshine Coast Council. We suggest first targeting sites for koala density and pathogen prevalence estimates where koala presence has already been confirmed via DDC scat surveys carried out in 2017 (e.g. Conondale National Park, Annie Hehir Road Environment Reserve, London Creek Environment Reserve and Eumundi Conservation Park). Scat samples collected during these surveys could also be used to assess gene flow of koalas throughout the SCC area.

Recommendation 2: Monitoring koala density at this site (and potentially other sentinel sites within Sunshine Coast Council)

Reoccurring surveys with drones and genetics can be used to monitor the Maroochy Regional Bushland Botanic Gardens, Tall Gums Environment Reserve and Tanawha Tall Gums Conservation Area. The fundamental data required for conservation management is the number of koalas (i.e. periodically monitoring this via precise koala density estimates). This would allow for robust koala density data, followed by monitoring for any density changes. If a change is detected, especially a decrease in koala numbers, further resources can be allocated to identify and mitigate what the cause(s) may be.

An appropriate scientific monitoring design should take into account the temporal and spatial resolution required by management to trigger conservation actions, as well as statistical power analyses of sensitivity to detect a percentage change in koala density as well as the confidence that this change is real rather than just sampling variation. For example, managers may determine that they require sensitivity to be able to detect a 25% (or more) change in koala density with 80% (or more) confidence that it is an accurate result. Given that koala density estimates will vary according to natural movement of individual koalas in and out of the survey area, as well as variation in the detection rate of the survey method, multiple surveys are required to provide a koala density mean and standard deviation to statistically compare one time period to another (e.g. annual monitoring). This can be achieved by either performing a cluster of independent koala density surveys (e.g. 4 surveys, spaced 1-3 weeks apart) at the same monitoring location, or performing a single survey at a cluster of independent sites (e.g. 4 sites, spaced 2-5 km apart), or by monitoring for trends over time. For responsive (timely) and targeted (site-focused) koala conservation management, we recommend performing annual (at minimum) koala density monitoring that involves a cluster of surveys for each monitoring site. The number of sites able to be monitored is determined by budget constraints. For example, for the Maroochy Regional Bushland Botanic Gardens, this might involve koala density being measured within a 100 ha sample area (maximum area able to be reliably surveyed using thermal drone in one night) with a cluster of 4 surveys (performed 1-3 weeks apart) each year.

Trends around breeding and disease are also of interest for management – however this demands higher investment of resources as koalas often have moved from their drone detection location, or be in positions where visual health assessment and detecting presence of a joey is difficult. Collection and laboratory analysis of fresh scats from the drone detection location can somewhat overcome this limitation (e.g. determine sex, distinguish individual koalas and detect presence of Chlamydia infection).

Regular thermal drone and genetic surveys can also be coupled with disease management. This would require a larger team on the ground, and multiple pairs working in parallel to reach koalas rapidly after dawn in an attempt to visually assess their health prior to any change in their location. However, the best way to monitor koala health is still catching for veterinary examinations and monitoring via tracking. Stress associated with capture can be minimised by use of traps set at base of their tree overnight (monitored with SMS-enabled trail cameras to ensure quick collection from the field once trapped) and on-demand tracking capability can now be achieved via extremely small and light weight ear tags (approx. 3 grams) that are solar-powered (designed to be functional for life of koala once attached by veterinarians during health examination).

Recommendation 3: Train citizen science volunteers to monitor the health of some individual koalas at this site via radio ear tags

The level of pathogen prevalence observed (i.e., 38%) suggests that the koala population should be frequently monitored to allow early identification of sick individuals which have a higher likelihood of recovery if caught early for veterinary treatment. This could be done by tagging 4-6 of the more accessible koalas (e.g. either side of track running south from Maroochy Regional Bushland Botanic Gardens carpark to Wilsons Rd) with miniature solar-powered tracking ear tags (as mentioned above), coupled with monitoring through citizen science volunteers to regularly track such tagged koalas. There could be also in the future an option of installing small web-enabled sensor nodes along this track to automatically detect when a tagged koala is within accessible range (e.g. 200 metres).

If sick animals are detected, they will need to be caught by experienced koala catchers and treated at a wildlife hospital. Timing for initial capture, veterinary health checks and tagging could coincide with the repeat drone surveys (approx. 4, each spaced 1-3 weeks apart). This represents a high level of management, however, it is then possible to attain a C*hlamydia* free area, which can in some instances increase breeding success and population size (Beyer et al. 2018).

Recommendation 4: Continue to conserve, maintain and increase habitat for koalas in and around the Maroochy Regional Bushland Botanic Gardens, Tall Gums Environment Reserve and Tanawha Tall Gums Conservation Area

Maroochy Regional Bushland Botanic Gardens, Tall Gums Environment Reserve, Tanawha Tall Gums Conservation Area and neighbouring private properties are used by multiple koalas and the habitat in this area is likely of high quality for the Sunshine Coast and a broader regional context. Further, the connectivity to other habitat patches makes the site a valuable link for koala movement and dispersal and therefore gene flow. This area and its habitat should continue to be conserved and protected for koalas, and rehabilitated where appropriate, to increase carrying capacity. Carrying capacity could be studied and mapped using foliar chemistry, and this could also inform the selection of trees for rehabilitation. Appropriate fire management for the area should be discussed, as high intensity fire could be a threat to this population in the context of global warning and general increase of severe fire risks.

Recommendation 5: Continue promoting the Maroochy Regional Bushland Botanic Gardens, Tall Gums Environment Reserve and Tanawha Tall Gums Conservation Areas a flagship for koala conservation in the SCC

The involvement of the community and citizen scientists is recommended, especially the use of the Gardens as a flagship for education on, and conservation of, the species. However, it is important to note that access to the areas where many of the koalas were found can be challenging. This will require future discussion with SCC and interested stakeholders.

Recommendation 6: Communicate findings of this research to the community

Communicate this research findings to the community will better inform volunteers and the wider community of the value of the Maroochy Bushland Botanic Gardens as an important koala habitat on the Sunshine Coast. Additionally, Land for Wildlife neighbours who allowed researchers on to their properties could be invited to any events promoting the research findings. We also recommend a personal "Thank You" email to these landowners, attaching this report, or dropping the report in their mailboxes.

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8. Appendix A: Figures from Rhodes et al. (2015)’s report: South East Queensland Koala Population Modelling Study.

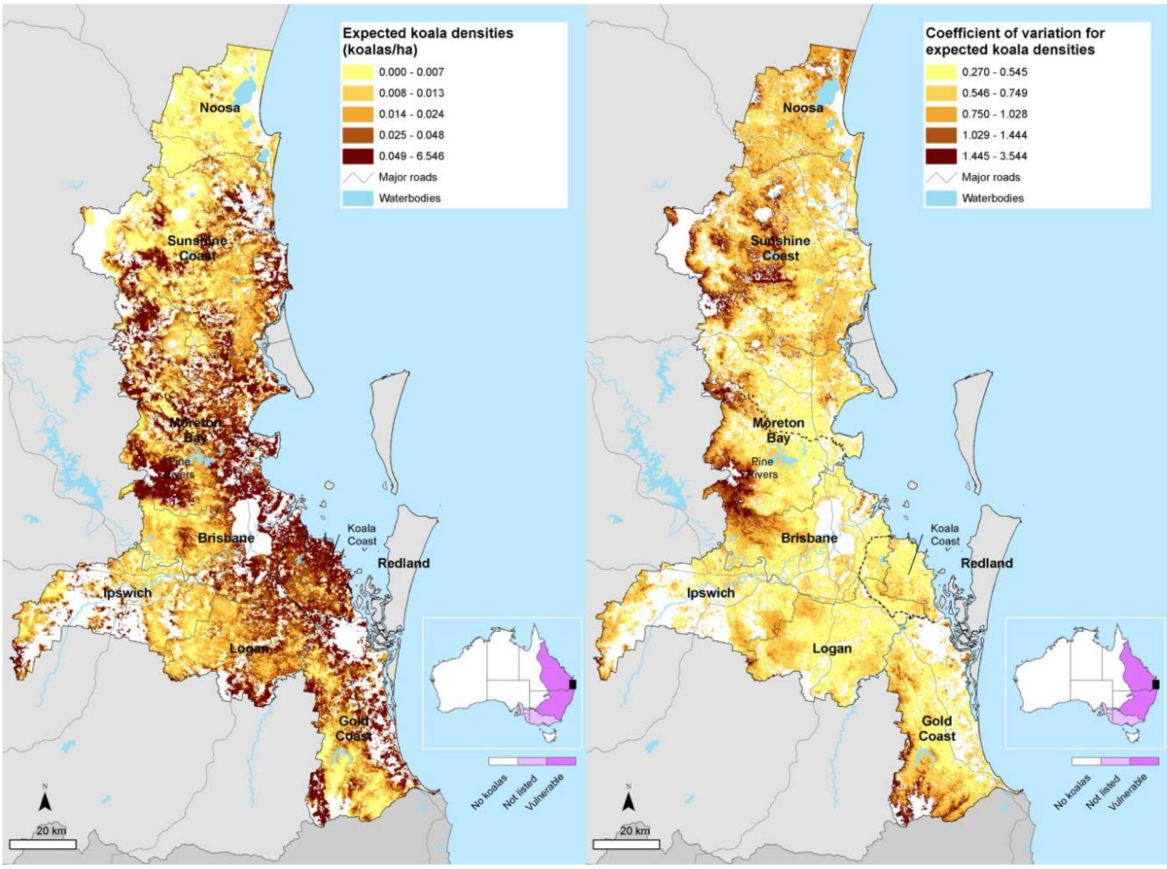

Figure A1. This figure from Rhodes et al. (2015)'s report illustrates the spatial distribution of expected koala densities based on their best spatial model and the coefficient of variation for those densities.

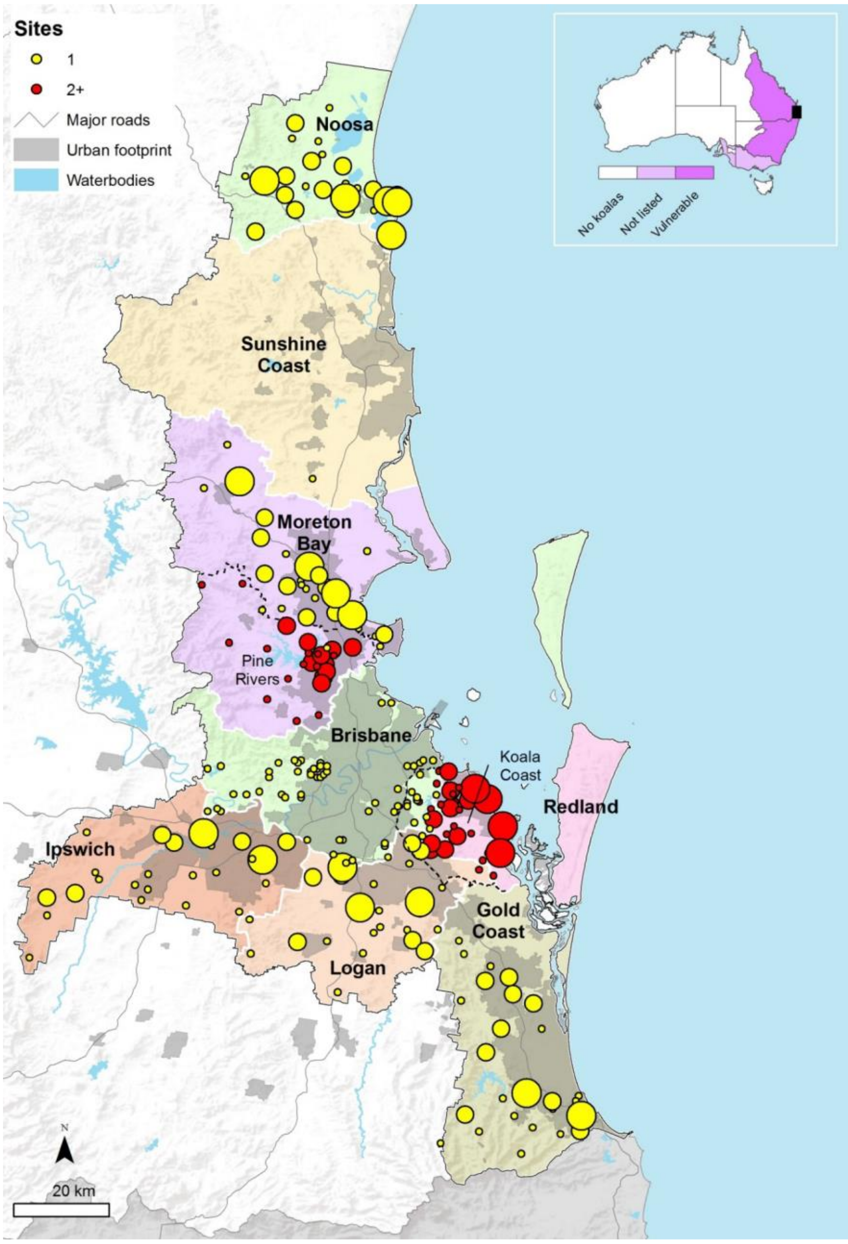

Figure A2. This figure from Rhodes et al. (2015)'s report illustrates survey site locations (circles) colour coded by the number of surveys (single survey or more than one survey). The sizes of the circles are proportional to the average survey effort (i.e. area surveyed) per survey (1996–2015).

9. Appendix B: Photos of the fieldwork in the Maroochy Regional Bushland Botanical Gardens and Tall Gum Reserve.

Figure B1: Photo showing fresh koala scat detection dog Billie Jean, indicating on fresh koala scats beneath a koala in the tree.

Figure B2: Photograph showing one of the koalas sighted in the Maroochy Regional Bushland Botanic Garden and Tall Gum Reserve.

Figure B3a: Displays created by Friends of Maroochy Regional Bushland Botanic Gardens and illustrating the Koala surveys undertaken in 2022.

Figure B3b: Displays created by Friends of Maroochy Regional Bushland Botanic Gardens and illustrating the Koala surveys undertaken in 2022.

Figure B3c: Displays created by Friends of Maroochy Regional Bushland Botanic Gardens and illustrating the Koala surveys undertaken in 2022.

Detection Dogs for Conservation

End of report