Cool Country Koala project 2018/2019
Final Report

Prepared for Northern Tablelands Local Land Services

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

Dr Romane Cristescu, Katrin Hohwieler, Dr Riana Gardiner, Dr Deidre deVilliers, Dr Ben Vincent and Dr Celine Frere

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List of Acronyms

ALA	Atlas of Living Australia
DDC	Detection Dogs for Conservation
NT	Northern Tablelands
NT KRS	Northern Tablelands Koala Recovery Strategy
NT LLS	Northern Tablelands Local Land Services
SD	Standard deviation
USC	in this report: University of the Sunshine Coast's Detection Dogs for Conservation team
TSR	Travelling Stock Route

Executive Summary

Purpose

The purpose of this study was to determine the status of the koala (*Phascolarctos cinereus*) and describe the tree species used by koalas on the Northern Tablelands of New South Wales in areas earmarked as koala strongholds around Tenterfield and north of Glen Innes. This information should assist Northern Tablelands Local Land Services in making informed management decisions. The study aimed in particular in establishing, for the area of interest, 1/ presence/absence at random sites, 2/ the intensity of habitat utilisation and 3/ tree species that are used by koalas (from where koala scats were found). The priority areas covered in this report were identified by the Northern Tablelands Koala Recovery Strategy. Especially, random points targeted Travelling Stock Routes which management can be influenced by NT LLS.

Survey Methods

Field-based surveys of koala scats and flora surveys to record tree species were conducted in priority areas that were identified in the Northern Tablelands Koala Recovery Strategy. Survey sites were randomly generated using GIS and were constrained to Travelling Stock Routes within or in proximity to identified priority areas, at the exclusion of any zone with risk from 1080 baiting. Koala scat surveys were conducted using detection dogs trained to locate koala scats (faecal pellets), while tree species (with and without koala scats) were established by a botanist. Systematic survey sites comprised 30 trees the closest to a random point, all 30 trees were searched for the presence of koala scats and identified. Trees were also checked for the presence of koalas. Field surveys were conducted on the following dates: 5th - 18th of November 2018.

Limitations

The sites were surveyed on only one occasion; therefore, the results presented here provide a snapshot of the population during this period and it can be noted that evidence of koalas found within the study areas are likely to change with increased sample size as well as seasonally.

A negative site might reflect that koalas are not using the area (true negative) or that koalas are using the area but the survey failed to detect any scat (false negative), which could occur for example if koalas have not deposited any scat in the 30 trees searched during each survey or if scats have decayed before the survey occurred. We decreased the risk of false negatives in this project by the fact that if no koala scat was found in the systematic survey, the team performed a second survey nearby. This second survey, referred to as casual survey, was less geographically constrained and the dog was allowed to search more freely.

Summary of Findings

USC conducted 121 koala surveys across the northern part of Northern Tablelands, with a focus around Tenterfield and Glen Innes. Simultaneously, 104 flora surveys were conducted.

We detected koala presence at 30 of our 121 surveys (24.8%), however, no koala was found during our surveys. Koala presence in the Glen Innes area was low (13.8%), whereas the area around Tenterfield had a larger number of sites positive for koala presence (33.3%).

For each systematic site, we calculated the activity level which is the number of trees used divided by the number of trees searched. We found that the average activity level per positive site was 15.7% (SD = 10.9).

The tree species, and the presence of scats under them, were ascertained for 2082 trees (71 different species). In total, we found scats under 102 trees (4.9%). Altogether, 28 different tree species were recorded being used by koalas. Tree species commonly used by koalas for this project included: *Eucalytpus caliginosa* (New England Stringybark), *Eucalyptus deanei* (Mountain Blue Gum), *Eucalyptus blakelyi* (Blakely's Red Gum) and *Corymbia maculata* (Spotted Gum).

These results are put in context of the whole NT LLS Cool Country Koala project (2016 and 2018 surveys) and additional recommendations are proposed – these recommendations are additional to the 2016 Cool Country Koala reports (USC and Stringybark) and are purposefully more targeted. Recommendations in this report were selected for their potential for rapid and achievable implementation.

1. Introduction

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 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). The combined koala populations of Queensland, New South Wales and the Australian Capital Territory are listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (Shumway et al. 2015). In New South Wales, the koala is listed as Vulnerable under the *Threatened Species Conservation Act 1995*. Koala conservation is emphasised heavily in policy and planning at both Federal and State levels, as is demonstrated by the development of the *National Koala Conservation Management Strategy 2009-2014* and the *New South Wales Recovery Plan for the Koala 2008*. Recently, NSW has developed new documents and funding scheme that especially focus on threats to koalas and management per area of NSW (Figure 1): the "NSW Koala Research Plan 2019–28, A 10-year plan under the NSW Koala Strategy NSW", "Securing the Koala in the wild in NSW for 100 years, Saving Our Species Iconic Koala Project 2017–21" and the "Koala Research Plan: Expert Elicitation" (Office of Environment and Heritage 2017, Hemming et al. 2018, Office of Environment and Heritage 2019).

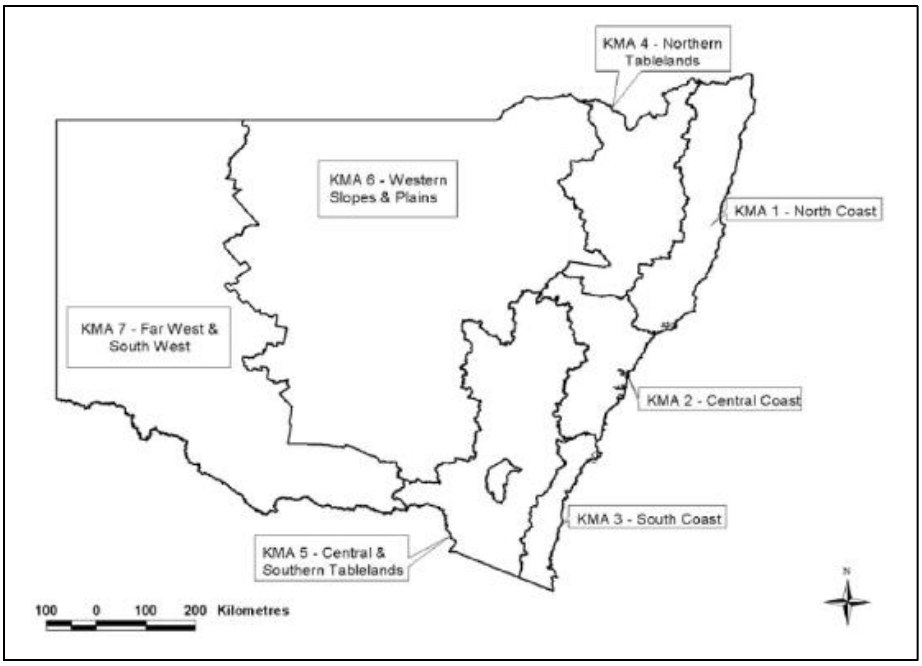


Figure 1: Koala Management Area defined in the Recovery plan for the koala (NSW 2008, Hemming et al. 2018)

From these documents, habitat loss is consistently ranked as the top threat to koala survival (Figure 2), and other highly ranked threats include: climate change (heatwaves, drought), disease (especially, chlamydia) vehicle strikes and predation by domestic or roaming dogs and fires (Office of Environment and Heritage 2017).

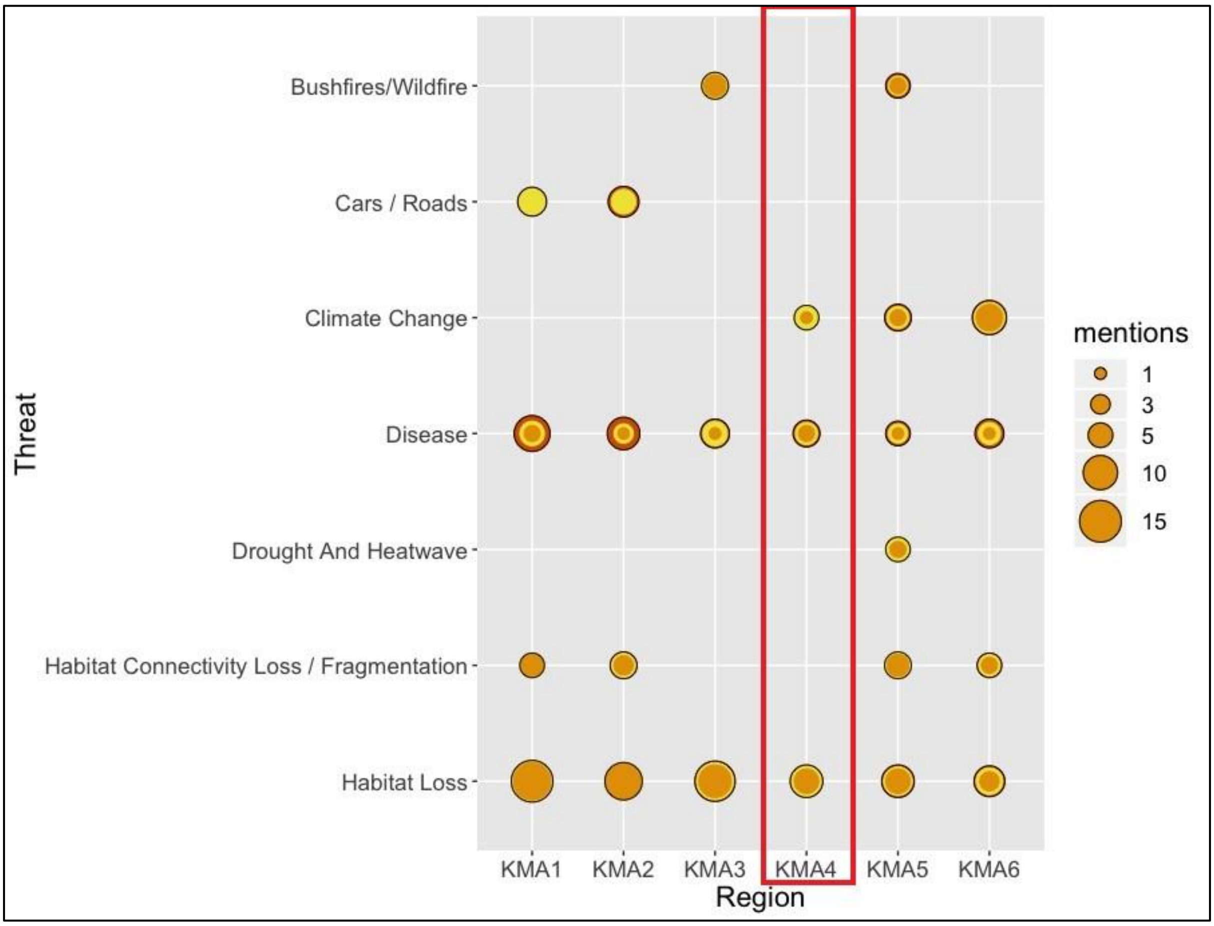


Figure 2: Key threats, in the Northern Tablelands (KM4), to koala persistence, by koala management area (KMA) and as mentioned by koala experts (Hemming et al. 2018)

The University of the Sunshine Coast's Detection Dogs for Conservation team (USC) was engaged by the Northern Tablelands Local Land Services (NT LLS) to deliver the Northern Tablelands Koala Habitat Project in 2016. The University of the Sunshine Coast team focused on the Northern NT (Delungra and Ashford), in parallel to Stringybark, who focused in the South NT, on Armidale, Uralla and Nowendoc – both projects delivering a comprehensive analysis of the presence of koalas in the main priority areas as defined in the *Northern Tablelands Koala Recovery Strategy* (NT KRS). As a whole, the *Cool Country Koala project*

2016 (i.e. both Northern and Southern) contributed to the objectives of the NT KRS to gain a baseline knowledge of koala distribution and abundance, promote recovery, avert any ongoing decline and minimise the risk of extinction of koalas within the Northern Tablelands region in New South Wales while building community engagement. To gain further information on koala presences in areas that fall under direct NT LLS management, USC was engaged again in 2018 for an additional study for the Cool Country Koala project.

The Northern Tablelands is a highland region of the Great Dividing Range in northern New South Wales. The region has a temperate climate with mild summers and cold winters. The major towns of the Northern Tablelands are Armidale, Glen Innes, Guyra, Inverell, Tenterfield, Uralla and Walcha. Beef and sheep grazing are the predominant land uses in the region, as well as wool. Other minor land uses include forestry, cropping (cereals, legumes and oil seeds), fruit, vegetables, dairy, alpacas and wine (New South Wales Department of Industry).

The headwaters of the Murray-Darling Basin are on the western side of the Northern Tablelands and the streams on the eastern side of the Northern Tablelands supply the New South Wales north coast (New South Wales Department of Industry). The geology of the Northern Tablelands region is diverse, comprising a mixture of basalts, granites and alluvial soils. This geology, combined with the soils, topography of the region and the variation in rainfall from east to west, supports a diverse range of vegetation communities.

Koala surveys were needed in the Northern Tablelands because the status of the koala in this region was previously unknown. Limited scientific information was available regarding the status of koalas on the Northern Tablelands (Hawes et al. 2016). Until recently, the Armidale Regional Council was the only Council that maintained a record of koala sightings. In 2016/2017, USC performed 267 surveys across the identified priority areas and found relatively high levels of koala activity in some areas such as Inverell/Delungra, but a very low activity in other such as Ashford, an area with many historic koala records. This suggested a large decline in koala activities since 2010 and called for further action.

In 2018, USC performed further field-based surveys of koalas in additional priority areas of the Northern region of the Northern Tablelands. USC used highly-trained detection dogs to locate koala faecal pellets (scats) in sites in the priority areas, a method which was proven to be accurate and efficient (Cristescu et al. 2015).

Surveys were conducted in a two-week period from November 5th – 18th 2018. USC surveyed sites for koala scats in and around the following localities: Amosfield, Bald Nob, Beaury, Boonoo Boonoo, Boorook, Deepwater, Drake, Dumaresq Valley, Dundee, Emmaville, Mann River Reserve, Mole River, Wellington Vale, Willsons Downfall, Tarban and Tenterfield.

2. Objectives of the Northern Tablelands Koala Recovery Strategy and Aims of the "Cool Country Koala project"

The Northern Tablelands *Cool Country Koala project* contributes to the objectives of the Northern Tablelands Koala Recovery Strategy, which are to:

- Consolidate and improve baseline knowledge of koala distribution and abundance, threatening processes and impacts upon koala populations on the Northern Tablelands;
- Develop a recovery strategy in collaboration with stakeholders that prioritises actions for koala protection and areas for effective investment on the Northern Tablelands; and
- Build community capacity and engagement across the region through community monitoring of koala populations (Hawes et al. 2016).

As defined by the NT LLS, the aims of the Northern Tablelands *Cool Country Koala project* are:

- To address data deficiencies through systematic, field-based surveys in priority areas (as identified in the Northern Tablelands Koala Recovery Strategy) – this year in particular, we focused the effort on areas that were not covered in the 2016 NT LLS surveys;
- To inform future investment in koala habitat restoration and revegetation; and
- To build a platform of community engagement to initiate community monitoring programs for threatened species and communities, via private/public landholders where surveys are undertaken as part of this project.

This report 1/ describes the outcomes of the 2018 field-based surveys in TSRs in or close to priority areas that were not covered in the 2016 NT LLS surveys, 2/ provides a summary of all NT LLS surveys to date, and 3/ discusses specific (and additional to recommendations made in association with the 2016 surveys) recommendations for koalas and land management.

3. Community Engagement

Community workshops were held in March and November 2018 to engage and inform the public and residents (see Table 1). Workshop participants were given presentations that covered the following:

- Ecology of the koala.
- Threats to koalas.
- NT LLS koala surveys – results from the 2016 surveys.

- What can members of the public do for koalas, including how to identify, and report to the Atlas of Living Australia, signs of koala presence and health.

Workshop attendees were then given the opportunity to observe a detection dog demonstration.

Approximately 235 members of the community from Armidale, Uralla, Emmaville and Tenterfield areas attended the six workshops.

Three different presentations were developed, one for the public, one for school and an additional for government. The school presentations were shorter but covered similar aspect, the government presentation was focused on survey results only.

Table 1: Community events delivered as part of the Cool Country Koala project 2018 by USC

Event	Type of talk	Date	Topic
New England girls school talk, Armidale	School	23/03/2018	"Koalas around us", Koala Ecology and how we can contribute to their conservation, plus detection dog demonstration
NT LLS Cool Country Koala Happy Hour, Uralla	Public	23/03/2018	Cool Country Koala project NT LLS for landholders that opened their gates. About Koala ecology, Cool Country Koala outcomes and ALA use. Plus detection dog demonstration.
NT LLS Cool Country Koala update, Emmaville	Public	19/11/2018	Cool Country Koala Workshop - mapping and ALA reporting plus detection dog demonstration.
Emmaville school talk, Emmaville	School	19/11/2018	"Koalas around us", Koala Ecology and how we can contribute to their conservation, plus detection dog demonstration.
Filming with NT LLS	Media	19/11/2018	Filming for NT LLS with detection dog for koala strategy.
OEH talk Armidale	Government	20/11/2018	Present latest mapping of USC surveys done in NSW: 2016 NT LLS, 2017 west NSW with Phil Sparks, 2018 NT LLS.
NT LLS Cool Country Koala update, Tenterfield	Public	20/11/2018	Cool Country Koala Workshop - mapping and ALA reporting, plus detection dog demonstration.

The Atlas of Living Australia sightings records since the start of NT LLS community engagement (2016) show that many records seem to be occurring in areas where NT LLS has engaged the community (Figure 3).

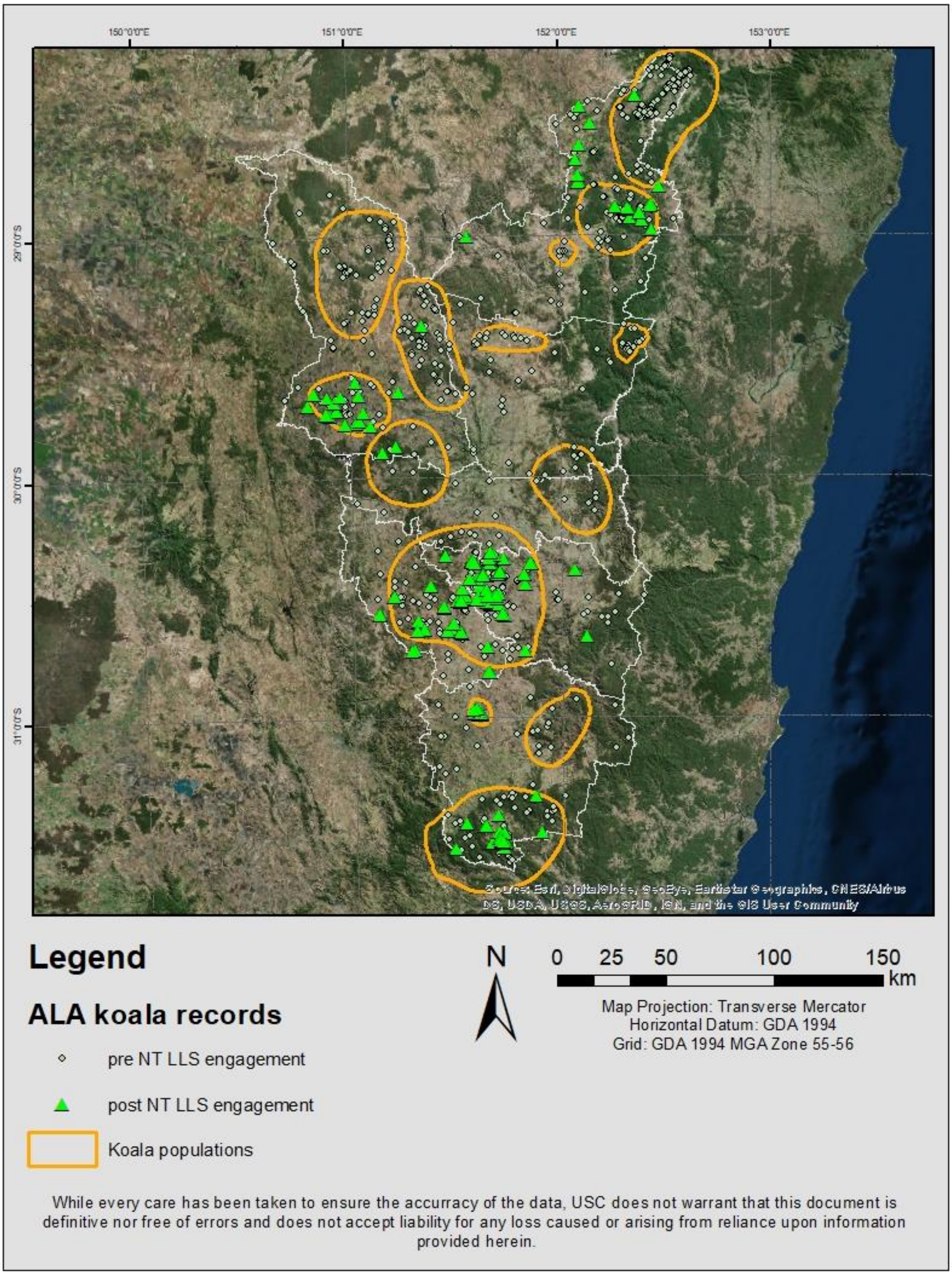


Figure 3: Records of koala sightings by the community through the Atlas of Living Australia

4. Methodology

4.1 Priority Survey Areas / Survey Site Locations

Priority areas for surveys were taken from the *Northern Tablelands Koala Recovery Strategy* (layer provided by NT LLS, Figure 4). The priority areas were determined by a panel of experts gathered by NT LLS in 2016. For the scope of this study, only two priority areas - Tenterfield and Glenn Innes - were chosen to be surveyed. Survey sites were randomly generated by NT LLS in and around these priority areas using ArcGIS. Survey sites were constrained to fall in TSR lands that were further constrained to be at least 500m away from areas that were baited with 1080 dog baits within the past 12 months.

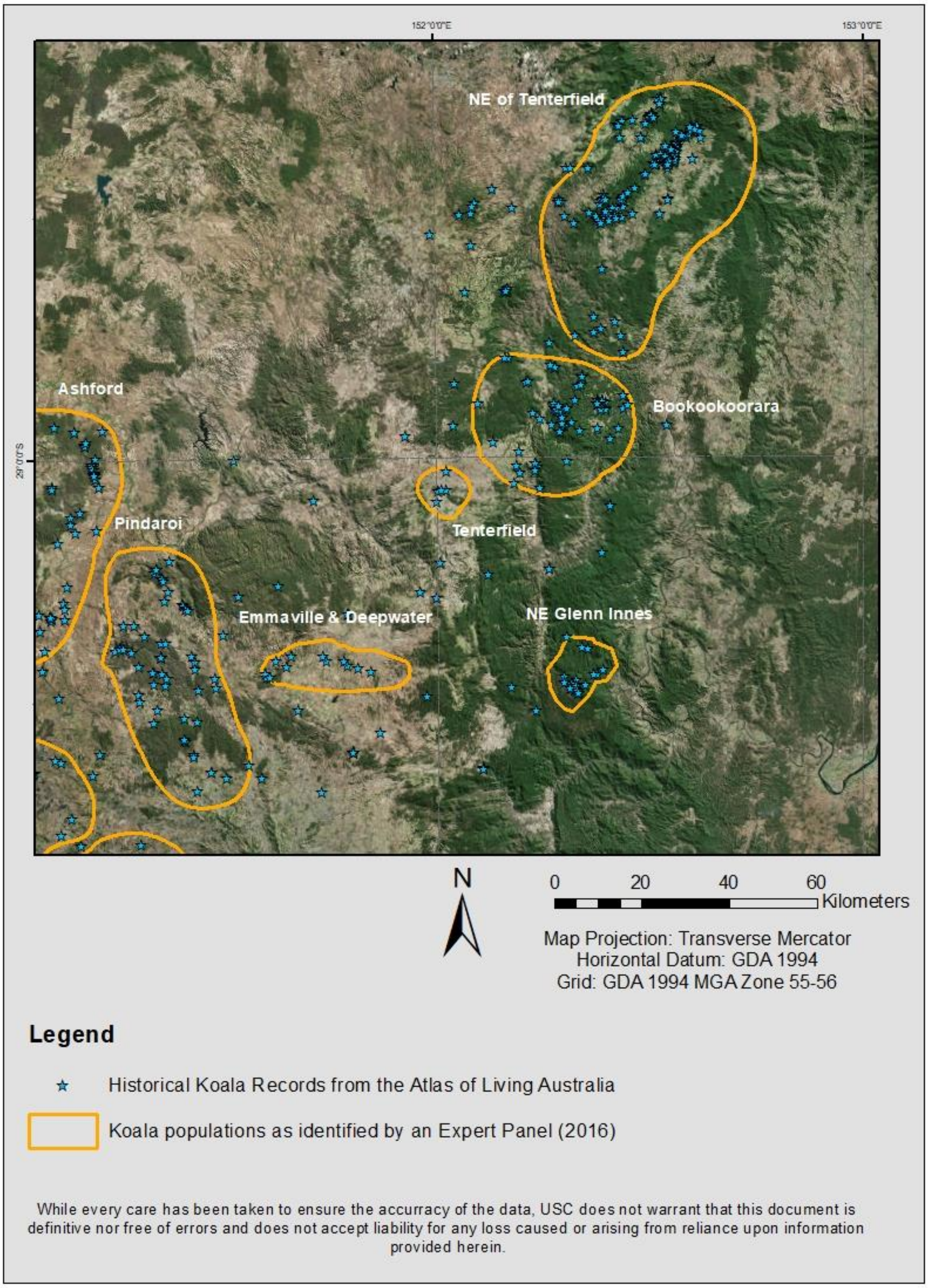


Figure 4: Priority areas in the Northern Section of the NT, taken from the Northern Tablelands Koala Recovery Strategy

4.2 Field Methods

4.2.1 Koala Surveys

Direct observation of animals is time-consuming, particularly for koalas, which have a cryptic nature, occur in low densities, and have large home ranges (Tyre et al. 2001, Kéry 2002). Locating secondary evidence of animals (fur, scats, feathers, tracks, etc.) is a common technique for establishing species occurrence across large areas because secondary evidence indicates species presence and use of the habitat even when the animal is not on site (Putman 1984, Wilson and Delahay 2001). The best method to confirm koala presence and habitat utilisation is to use detection dogs specifically trained on the odour of koala scats. USC has proven (and published in the peer-review Journal from Nature, “Scientific Reports,”) that the detection dog method surpasses human-only teams in both accuracy and efficiency (Cristescu et al. 2015).

Most of the survey effort in this project involved the deployment of a trained detection dog (Figure). Detection dog ‘Baxter’, a Border collie cross, was used for the koala scat surveys. Two dog handlers conducted the surveys, Nicola Kent (NK) and Russell Miller (RM), both Research Assistants with the University of the Sunshine Coast. The dog handlers were accompanied by Ben Vincent, the botanist in charge of flora data collection for all surveys.

Figure 5: Detection dog Baxter resting in between koala scat surveys (NT LLS “Cool Koala Project Field Day”)

Upon arrival at the survey sites and prior to the dog deployment, site information was recorded including location name and unique survey identifying number, and site photos captured. Any ecological characteristics that might have influenced the detectability and decay of scats were recorded (e.g. wet areas will increase decay rates; therefore, scats will be detectable for a shorter amount of time).

The dog was then fitted with a GPS collar, motivated with a tennis ball and given the command to search. The GPS tracking of the dog enables us to quantify the survey effort at each site. The dog was rewarded at the end of a survey in which no detections were made, with a planted "reward" koala scat, to ensure a high level of dog enthusiasm during subsequent searches was maintained.

Survey Type 1: Systematic koala scat survey

The survey protocol followed the Koala Rapid Assessment Method (KRAM), which was adapted for use with a detection dog as per Cristescu et al. (2015). At each survey site, 30 trees with a diameter at breast height of more than 10 cm were searched for the presence of koala scats using the detection dog. The trees were centred around the random survey point.

Typical koala scats (Figure) have the following characteristics (Triggs 1996):

- symmetrical and bullet-shaped (not jelly-bean shaped);
- generally about 1.5 cm long by 0.5 cm wide (adult koala scat size);
- even-sized and especially fine particles;
- absence of insect parts (koalas do not eat insects); and
- very compact.

Figure 6: Koala scats

When scats were found, the number of scats within a one square meter quadrat, their age category (Table) and their size (based on scat width, Figure 7) were recorded as well as their

GPS coordinates (GDA94). When only one size of scat and age class (see classification below) is present, the tree is considered less used than when scats of different age classes (indicative of repetitive visits) and sizes (indicative of different individuals) are present. Age of scats allowed us to classify sites as recently used or not.

Table 2: Koala scat age categories

Scat age categories	Characteristics
1	Very fresh (covered in mucus, wet)
2	Fresh (shine and smell)
3	Medium fresh (shine or smelly when broken)
4	Old (no shine, no smell)
5	Very old and discoloured

Figure 7: Koala scats of different sizes (widths)

All trees that were searched were identified to species level to determine what tree species were used by koalas compared to all the tree species present.

If the systematic koala scat survey was positive (i.e. koala scats were detected at the site), the team proceeded to the next random survey site scheduled. If the systematic koala scat survey was negative, a casual survey was conducted.

Survey Type 2: Casual koala scat survey

The casual surveys, in contrast to systematic surveys, cannot be compared in space and time, nor do they give insight into utilisation rates of the habitat. The casual surveys are however an excellent and fast way to determine whether koalas are present at a specific site. This method is indeed designed to maximise the chance of detecting koala presence in the minimum amount of time. In this project, casual surveys were used to decrease the risk of false negative after one negative systematic survey.

In the casual surveys, the dog is not constrained by the handler to check 30 trees, and can follow its nose roaming over an area of up to two hectares within an approximate 30-minute timeframe, or until the handler deems the search to have covered the site thoroughly. The search duration is usually less than 30 minutes, and can be as short as a couple of minutes if koala scats are detected. The start point of the survey can be determined by the handler, on site, and rely on the handler's assessment of the potential for the area to be used by koalas (this increases the chances of finding koala scats but also increases bias); or can be random.

The same scat details (age and size of scats) recorded for systematic surveys were recorded for casual surveys. Only the specific trees with koala scats underneath were recorded (GPS) and identified to the species level in casual surveys.

Survey Type 3: Incidental koala / koala scat surveys

Researchers conducting the surveys are always on the lookout for incidental, or opportunistic, spotting of koalas and koala scats. These can happen while on foot or in the car, moving between survey sites; or thanks to information passed on to USC researchers from members of the public, property owners or passers-by. The public is always considered as a source of knowledge and individuals are questioned on koala presence, past and present, whenever possible.

When koala scats were located during incidental surveys, the same scats information were recorded. Tree species was again recorded.

4.2.2 Flora Surveys

Flora surveys were conducted in conjunction with both systematic and casual koala scat survey. For every tree that was searched during systematic surveys, and every tree with koala scats during casual surveys, the tree species was recorded.

4.3 Health and Safety

A Job Safety Analysis was completed. Baxter has been professionally trained so as not to pose a threat to wildlife. The wellbeing of the detection dog was assessed by Animal Ethics (USC: ANA18128 and ANS1752, valid until December2020). Baxter was regularly treated against ticks and regularly checked, as well as being insured in the event of a snake bite. Surveys were conducted only after it was confirmed that no known wild dog baiting occurred in the areas to be surveyed, additionally, the dog wore a muzzle. Baxter was thoroughly brushed before entering the area so that no weed propagules were introduced. The handler was always in view of the dog and controlled the movements of the dog by voice, 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 (OEH permits number SL101741 under Part 2 of the Biodiversity Conservation Act 2016, valid till January 2020).

4.4 Data Analysis

All data collected in the field were entered into the Detection Dogs for Conservation database. Additionally, an excel spreadsheet with all recorded tree species was created.

The habitat utilisation was described in terms of activity level (Phillips and Callaghan 2011), which was calculated by dividing the number of trees with scats by the total number of trees searched at the site (N = 30) for each site where systematic surveys were performed.

Strike rate for each tree species was also calculated by dividing the number of trees with koala scats by the total number of trees of that same species at all positive sites (Phillips and Hopkins 2008). This provides a measure of tree species use, which can be considered an indicator that koalas are actively selecting particular tree species.

Historical sightings from the Atlas of Living Australia database were plotted on maps of the Northern Tablelands and compared with the locations of positive scat searches during the study. This enabled us to examine changes in koala distribution on the Northern Tablelands. We compared our study with historical koala sightings to identify sites where koalas previously occurred and are no longer present, as well as sites where koalas have not been recorded in the past but where scats were found in the study.

All results were mapped in ArcGIS.

We specifically tested through our models whether these species of trees were statistically significant predictors of koala presence. To do this, we calculated, for each tree species, the proportion of times koala were present at a site where that tree species was also present. Then, we also calculated, for positive sites only, the proportion of times scat was found under each tree species. We then fit a model with this proportion as the response variable (binomial), and the explanatory variable was the specific tree species at these sites (with site as a random effect). These models were fitted using lme4 package in R.

4.5 Limitations

The sites were surveyed on only one occasion; therefore, the presence / absence results presented here provide a snapshot of the population during this period and it should be noted that evidence of koalas found within the study areas is likely to change seasonally [as koala movements vary with time (Ellis et al. 2009)].

Detection dogs are a powerful method to study koala presence/absence and its use could greatly improve our ability to protect and conserve the koala. However, results of accuracy and efficiency of detection dogs will vary with both the dogs' and the handlers' abilities. Constant training and testing are required, as conducted by the DDC handlers and dogs.

The rate at which scats decay may also vary significantly between sites due to varying ground layer structure, composition, moisture, sunlight, local weather events and invertebrate activity (Rhodes et al. 2011, Cristescu et al. 2012). Decomposed scats may lose their unique scent mark and the dog may no longer detect it – however this has not yet been proven to occur (Cristescu et al. 2015).

Failure to detect koala scats in an area is not necessarily conclusive. Failure to detect koala scats may suggest either of the following:

- Koalas are not present in the area (i.e. true absence) at the time of the survey. Note that true current absence does not infer that the site has not been used in the past, or could not be used in the future, i.e. it could still be potential koala habitat.
- Koalas occur in the area, however scats were not detected (false negative) because:
    - Scats were present at some stage but decayed and disappeared from the environment before the survey was conducted;
    - The dog did not detect the scat; and/or,
    - The dog indicated the presence of a scat, but it was too decayed to be confirmed.

"The presence of absence does not equal the absence of presence" – to infer true absence, multiple surveys through time are generally necessary (MacKenzie and Royle 2005), from this survey, only presence can be confidently ascertained. However, to increase certainty in our negative results i.e. to decrease false negatives, we performed a casual search at sites where the systematic search was negative.

5. Research Outcomes

5.1 Summary of Surveys

Field surveys occurred between the 5th and 18th of November 2018. A total of 121 koala surveys were performed, including 71 systematic, 48 casual and 2 incidental surveys. No evident signs of fast scat decay conditions were recorded.

Tree species were recorded for every tree searched during systematic surveys and every scat positive tree during casual surveys. A total of 2082 trees were recorded, which represent 71 different species (see Appendix 1).

Out of the total 121 koala surveys, 30 were positive for koala scats (24.8%, Figure 8). For sites that were positive for koala presence, koala signs were detected at 70% in the first systematic survey and 30% in the second, casual survey.

No koalas were sighted during or outside of our surveys. It should be noted though, that our priority is searching for scats and only little time is spent searching the trees for koalas.

5.2 Presence / Absence of Koalas in Priority Areas and Comparison to Historical Records

At survey sites between Deepwater and Glen Innes (Southern sites, see Figure 9), koala presence was low. Most sites were negative (50 sites, 86.2%) with no signs of koala activity and only 8 sites (13.8%) were found to be positive. In the areas around Tenterfield (Northern sites, see Figure 10), a larger number of sites (21) were positive for koala presence (33.3%) and 42 were negative (66.6%).

We compared locations where we found koala scats during surveys with (historic) koala records from the Atlas of Living Australia (1949-2018, see Figure 11). In the areas surveyed by USC in this study, records of koalas have been relatively sparse. The USC surveys identified several koala scat positive sites that had no recent (<20 years) records, for example west of Amosfield. However, several areas that showed historic koala presence were negative for koala signs in our study, for instance the area directly around Tenterfield, where no scats and thus no koala activity has been found. Also, very low koala presence could be confirmed in the area around Emmaville and Deepwater (only one positive site near the area), whereas historic koala records were more extensive. It has to be noted that there was not a large number of surveys in these two areas (Tenterfield and Emmaville / Deepwater). There is an area north of Tenterfield, that despite not being identified by the koala experts in the NT KRS, was already flagged in the 2016 USC surveys, that we confirmed is showing koala presence.

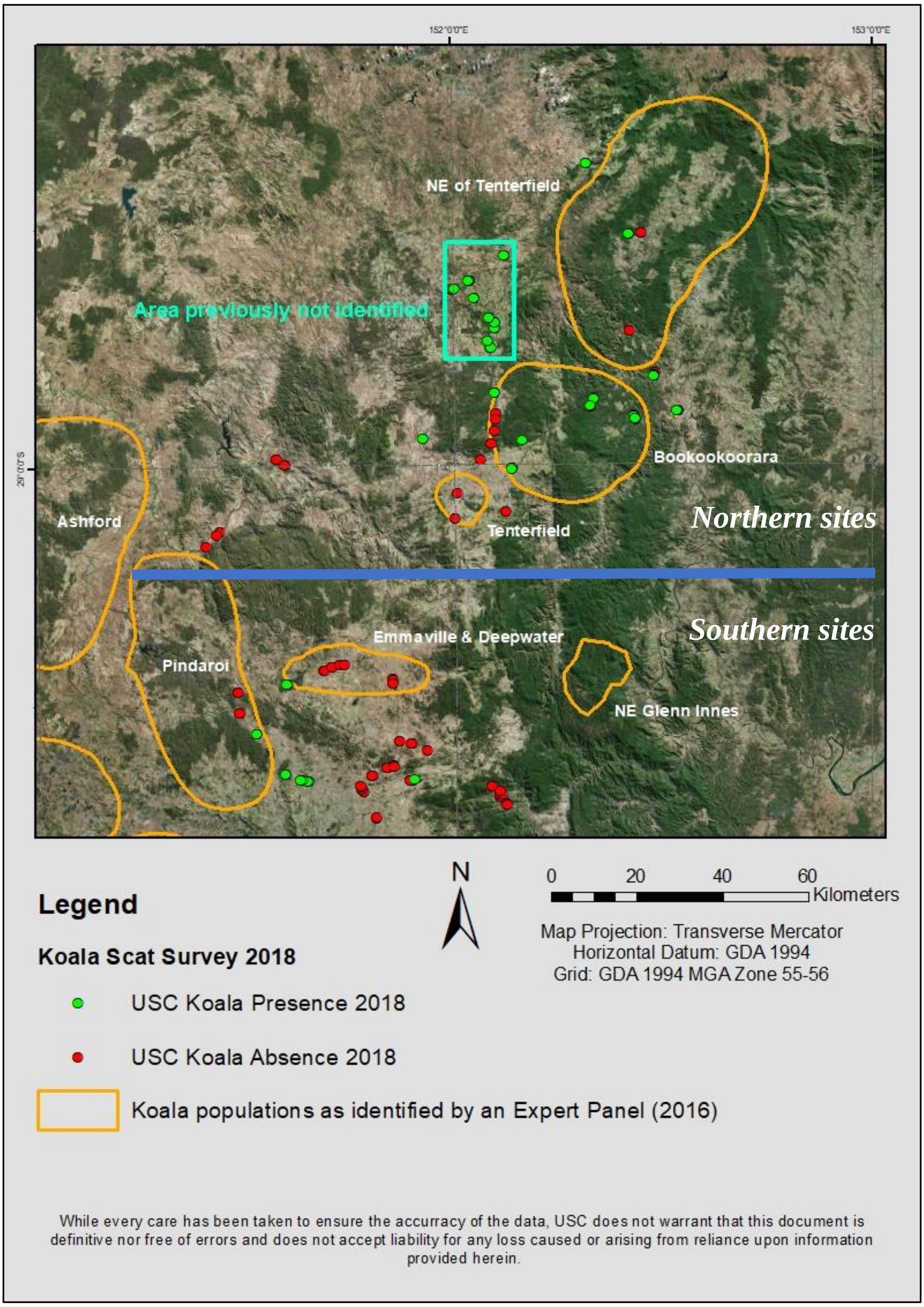


Figure 8: Koala scat survey conducted in 2018 where koala presence (green circles) and absence (red circles) was recorded, and highlighting a new population area previously not identified.

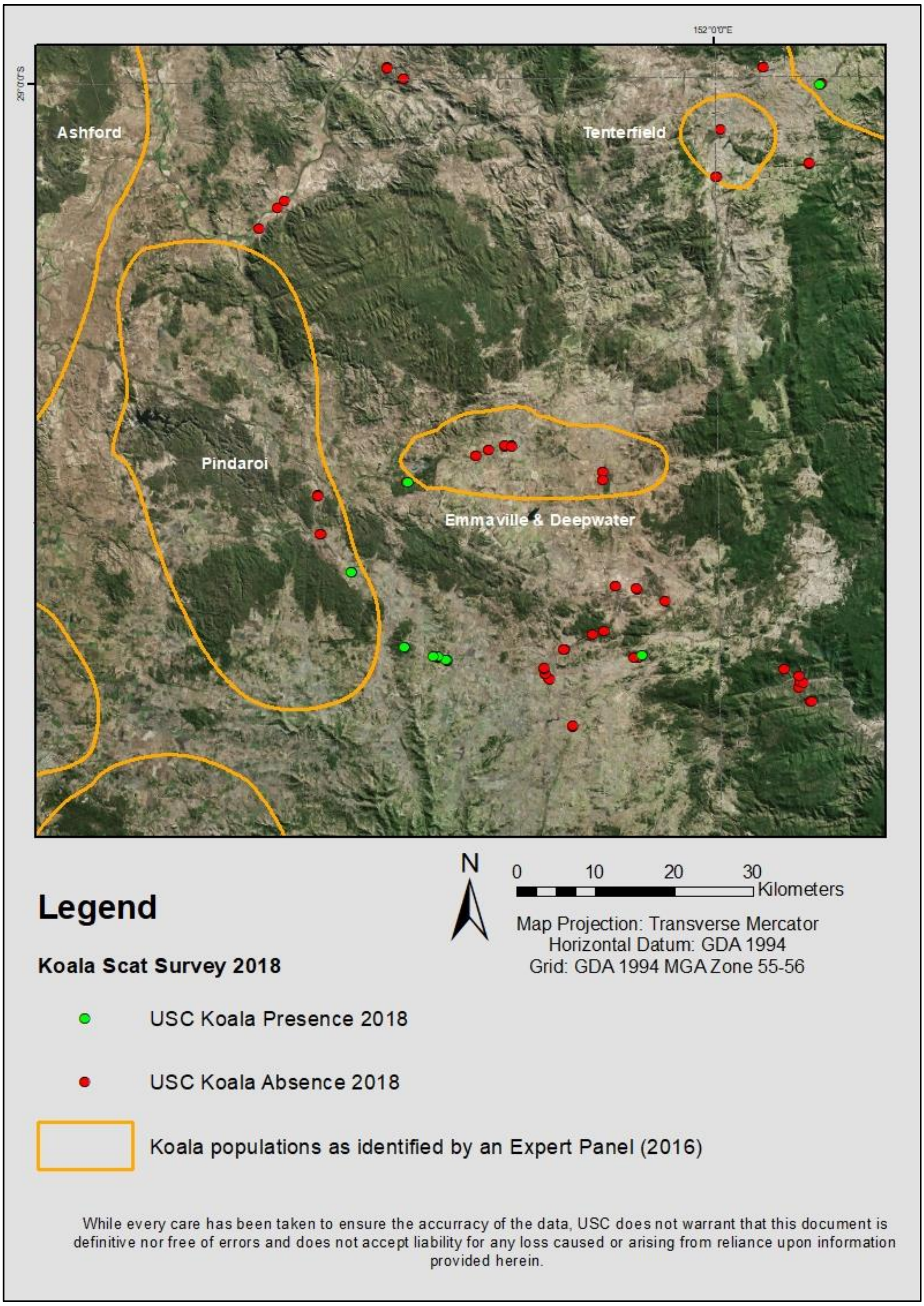


Figure 9: Koala sites where Koala presence (scats, green circles) or absence (red circles) was recorded around Pindaroi, Emmaville & Deepwater

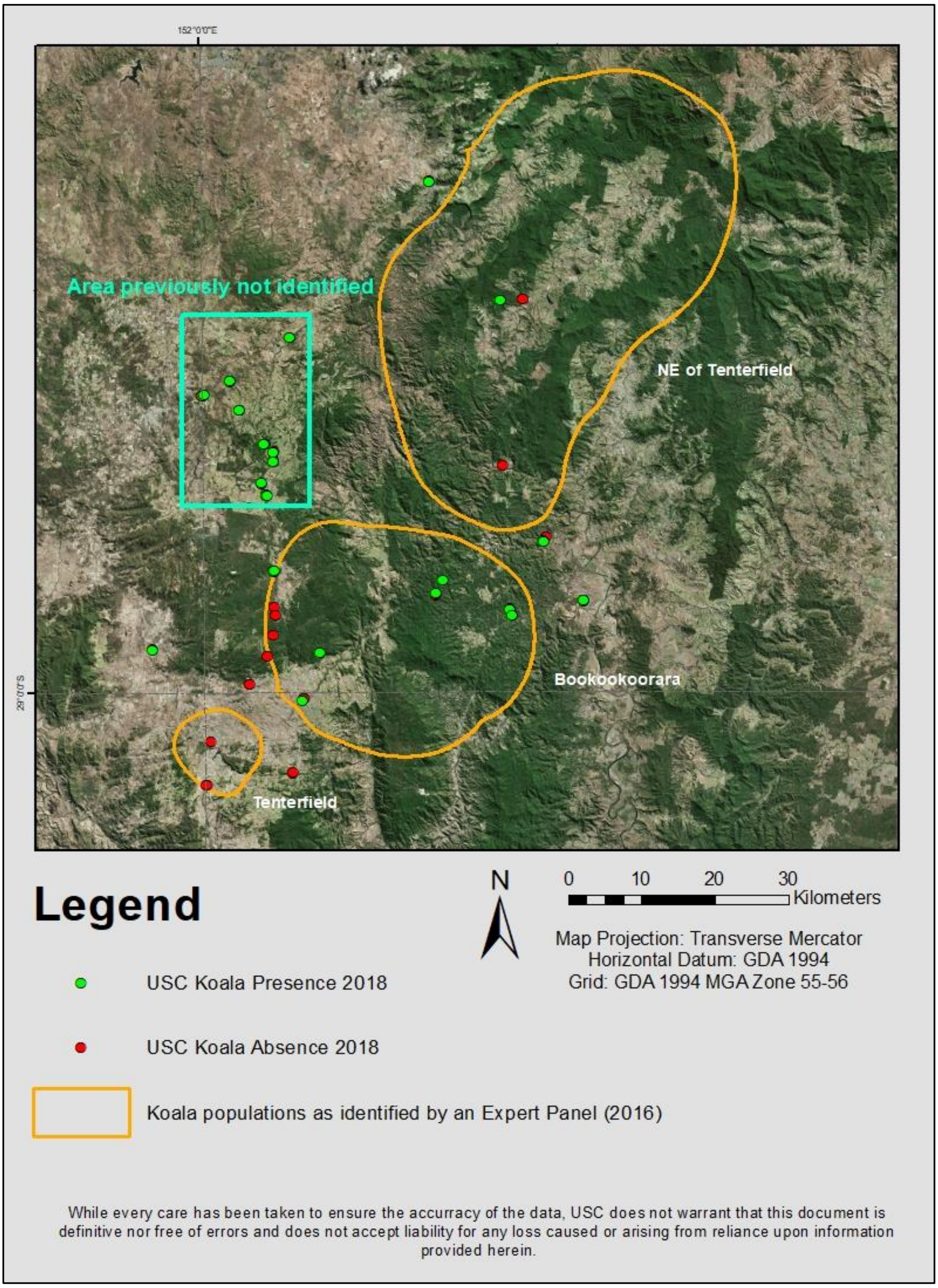


Figure 10: Koala sites where koala presence (scats, green circles) or absence (red circles) was recorded in the area around Tenterfield, including an area previously not identified.

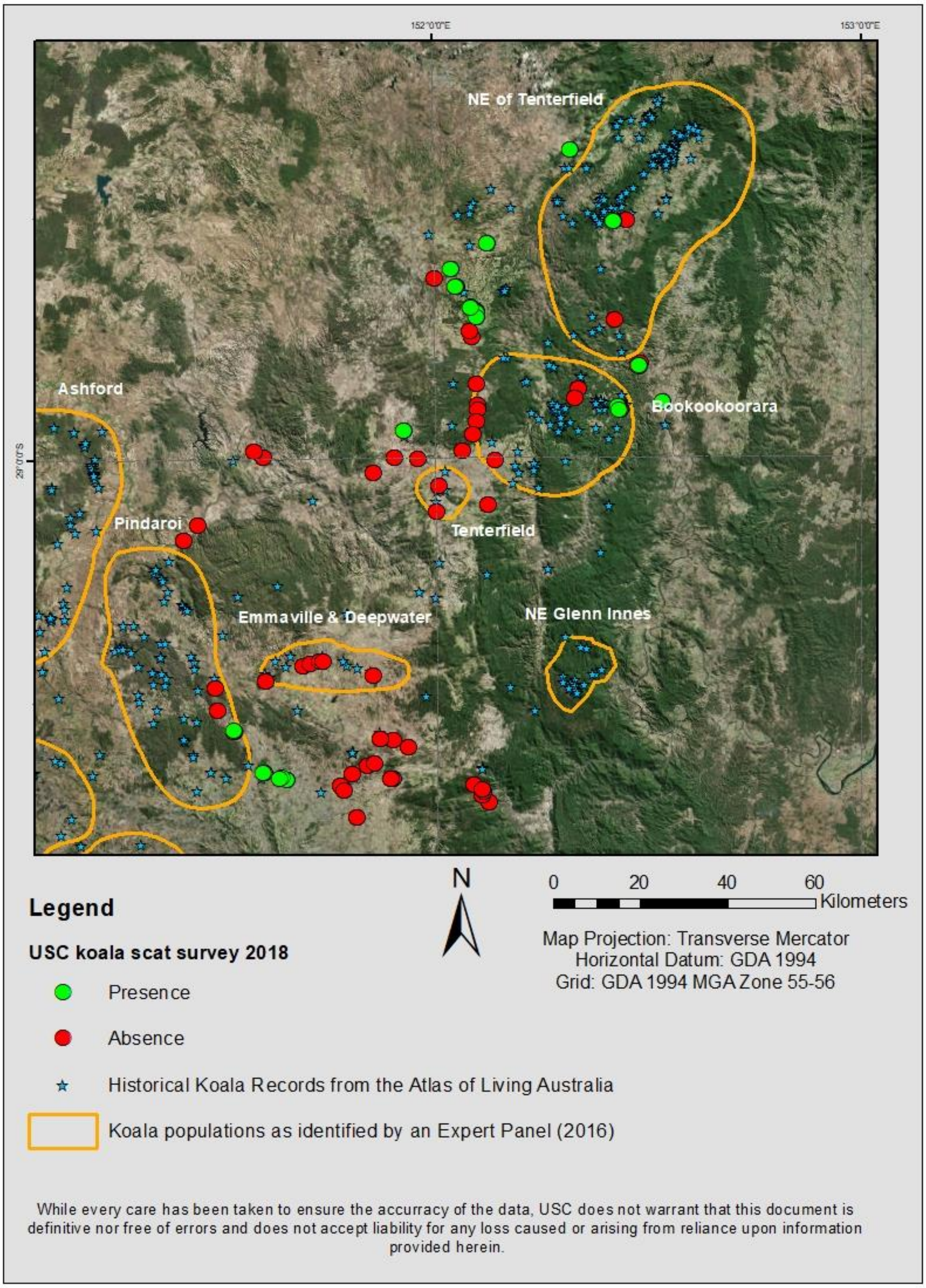


Figure 11: Historical records of koalas and recorded koala presence (green circles) and absence (red circles) recorded during surveys in 2018

5.3 Activity Levels

Overall, 2082 individual trees were recorded and identified to the species (See Appendix 1). During systematic surveys, 2069 trees were searched for the presence of koala scats. Of these, 85 were found to have scats, therefore the average tree use was 4.1%.

Activity levels ranged from 0 to 40% across all systematic surveys (see **Error! Reference source not found.**). Activity levels differed between sites: the area around Glen Innes (Southern sites) showed an average activity level of 1.2% (SD=3.4) whereas further north around Tenterfield (Northern sites), the average activity levels was 6.5% (SD=10.9).

For all positive systematic sites, the average activity level was 15.7% (SD 10.9). Overall, the surveyed region would be classified as low habitat use (see Table 3 from Phillips and Callaghan (2011).

Table 3: Table extracted from Phillips and Callaghan (2011) showing Activity Levels for positive sites in different surveys (East coast includes: Campbelltown, Port Stephens and Noosa ; Western plains comprises of Pilliga and Walgett)

Activity category	Low use	Medium (normal) use	High use
Area (density)			
East Coast (low)	-	≥ 3.33% but ≤ 12.59%	> 12.59%
East Coast (med – high)	< 22.52%	≥ 22.52% but ≤ 32.84%	> 32.84%
Western Plains (med – high)	< 35.84%	≥ 35.84% but ≤ 46.72%	> 46.72%

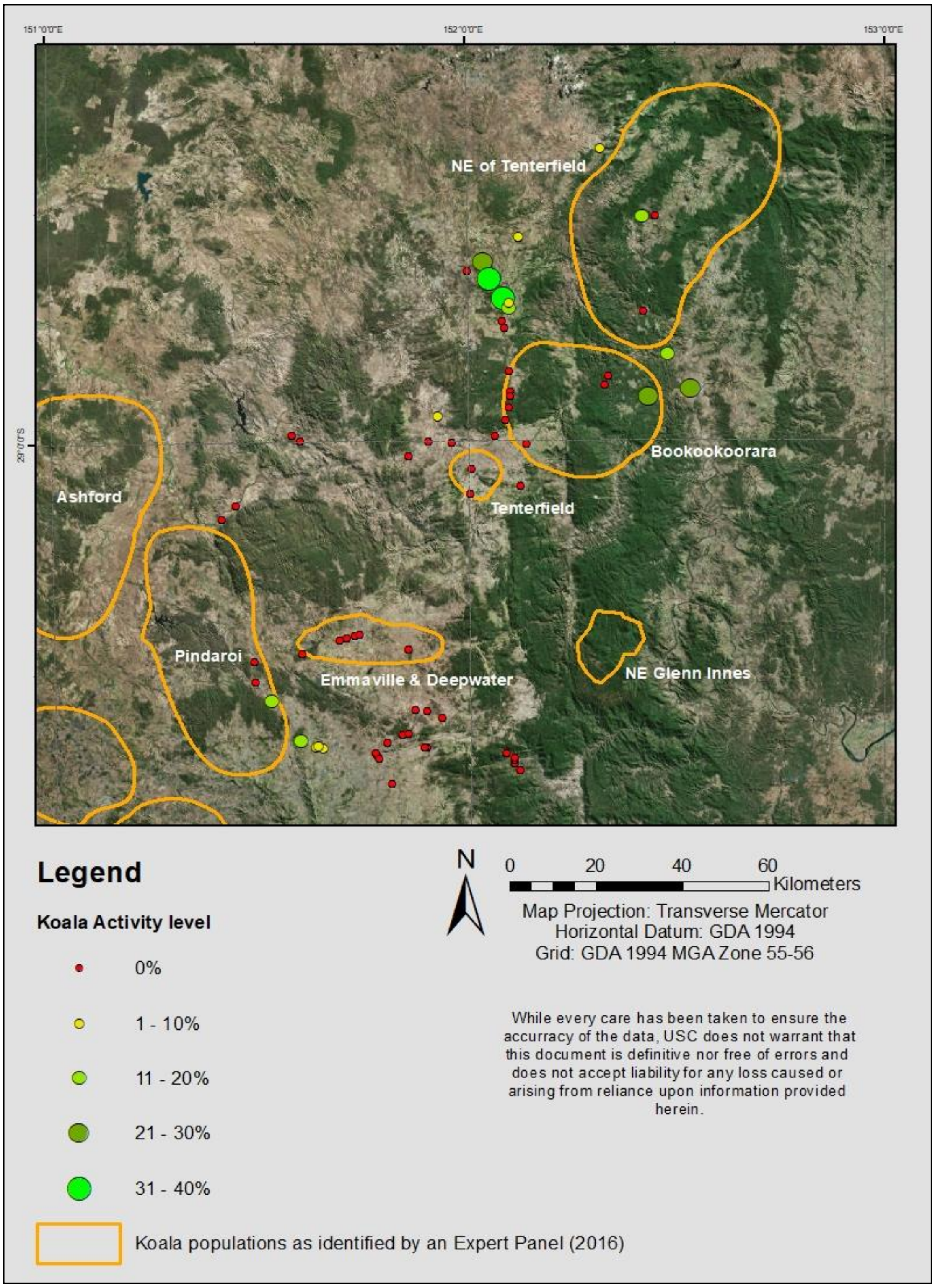


Figure 12: Activity levels (percent of trees with koala scats in 30 trees) checked during systematic surveys in 2018

5.4 Scat Age, Size and Density

Scat age was recorded because fresh scats indicate recent use of the area by koalas, whereas old scats can be several months to several years old (Rhodes et al. 2011). In all positive sites (casual, systematic, incidental), the age of the freshest scats found were: fresh scats for 5.5% of the sites, medium fresh scats for 14.8% of the sites, and old scats for 78.7% of the sites (Figure 13, and closer up around Tenterfield Figure 14).

We recorded scats of more than one size in quadrats (indicative of different koala individuals using the same tree) at 17% of the trees. This needs to be considered a minimum number of trees used by more than one koala as it is based only on differences of koala scat sizes, therefore on differences in koala sizes.

Density of scats was calculated for positive, systematic surveys and ranged from 2 to 61 scats / m^2, with an average of 5.1 scats / m^2 (SD = 3.6). Average number of scats was lower for NT than previous USC projects in Gympie and Fraser Councils (note that the methods used for site selection differed, see **Error! Reference source not found.**).

Table 4: Scat density in this project compared to two projects in Queensland (USC, unpublished data)

	NT 2018	Gympie	Fraser
Max	61	56	60
Average	5.1	14.9	10.2
SD	3.6	12.4	11.0

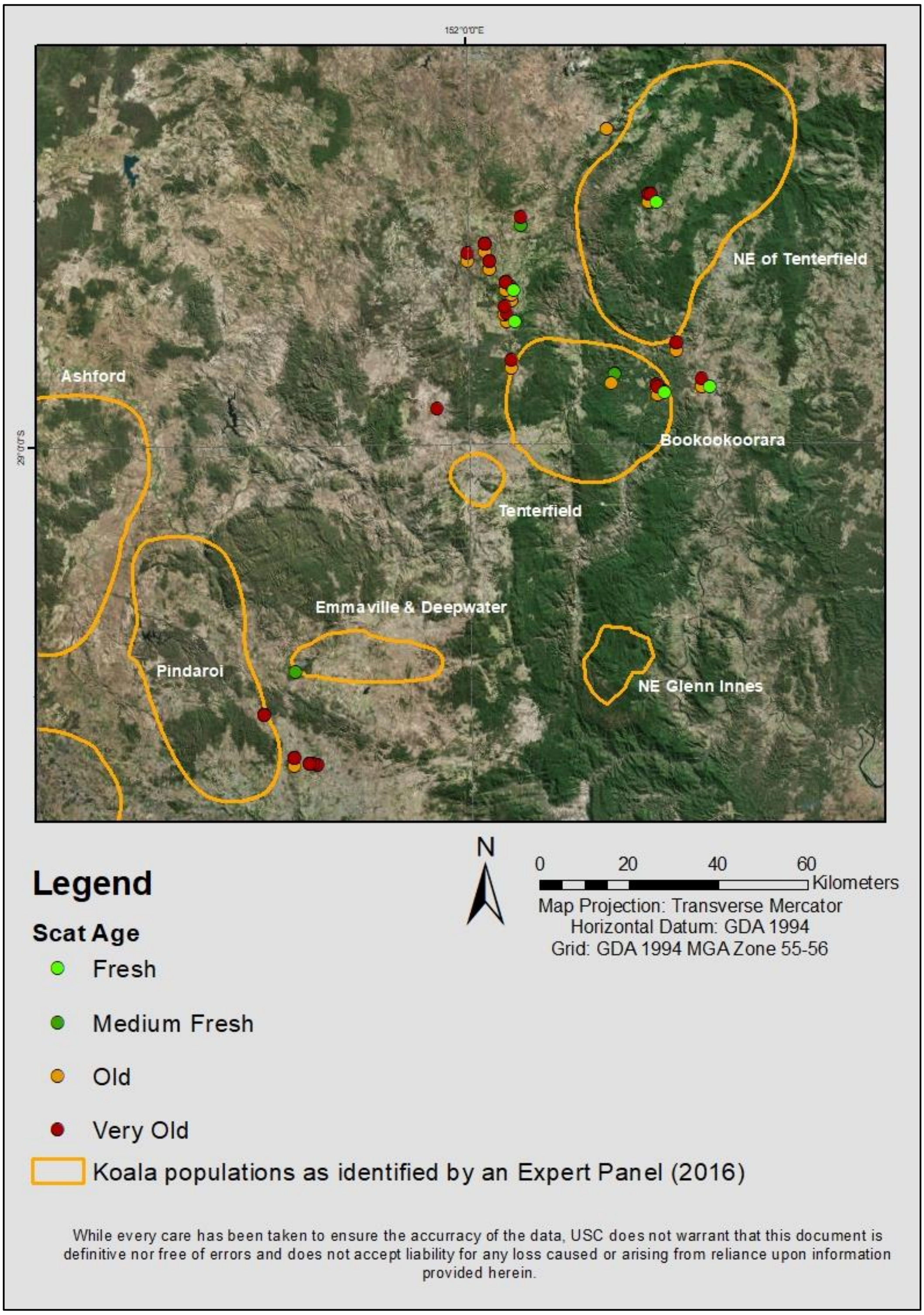


Figure 13: Age of scats detected at each site with koala presence for surveys in 2018 (NB: scats have been offset to improve visualisation).

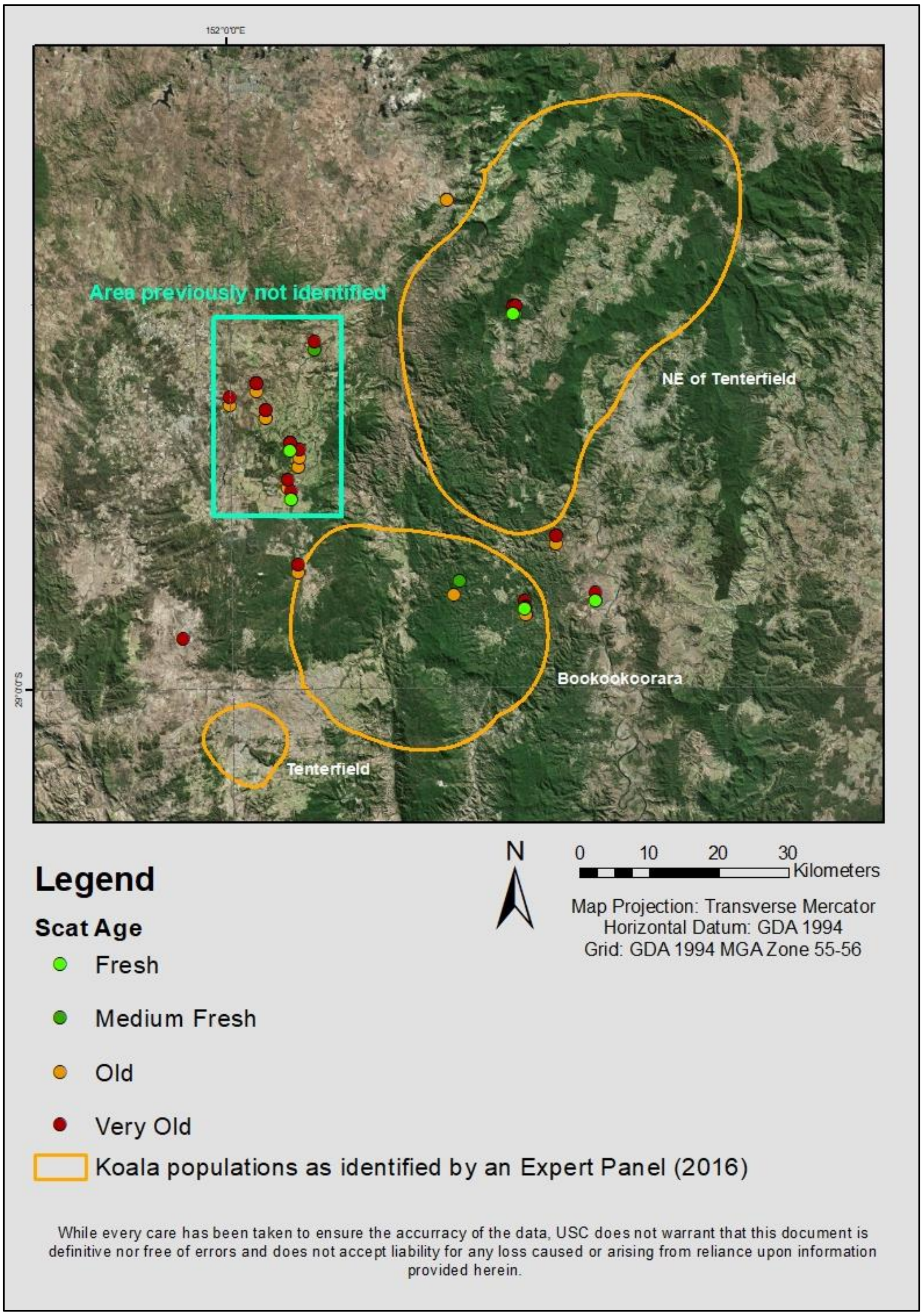


Figure 14: Age of scats collected during koala surveys in 2018 near the Tenterfield region, highlighting ages of scats in an area previously not identified (NB: scats have been offset to improve visualisation).

5.5 Tree and Plant Community Type Use

5.5.1 Tree Use across All Surveys

During the koala surveys (systematic, casual and incidental), we identified the species of 102 trees with koala scat. Altogether, 26 individual species were recorded as being used by koalas (Figure 2, Table). Tree species commonly used by koalas during this project included: *Eucalytpus caliginosa* (New England Stringybark), *Eucalyptus deanei* (Mountain Blue Gum), *Eucalyptus blakelyi* (Blakely's Red Gum) and *Corymbia maculata* (Spotted Gum).

It is worth noting that the presence of koala scats under a tree does not ascertain whether koalas used that tree for feeding (Melzer et al. 2014). This is because koalas sit in trees all day long but only feed for a small amount of time throughout the day, therefore their droppings can, for instance, be found under trees selected for shelter - for example, for thermoregulation (Briscoe et al. 2014). A common example of this is the use of native pine trees, *Callitris sp.*, which are favoured by koalas during the day (probably for their shady canopy) but rarely eaten (Cristescu et al. 2011).

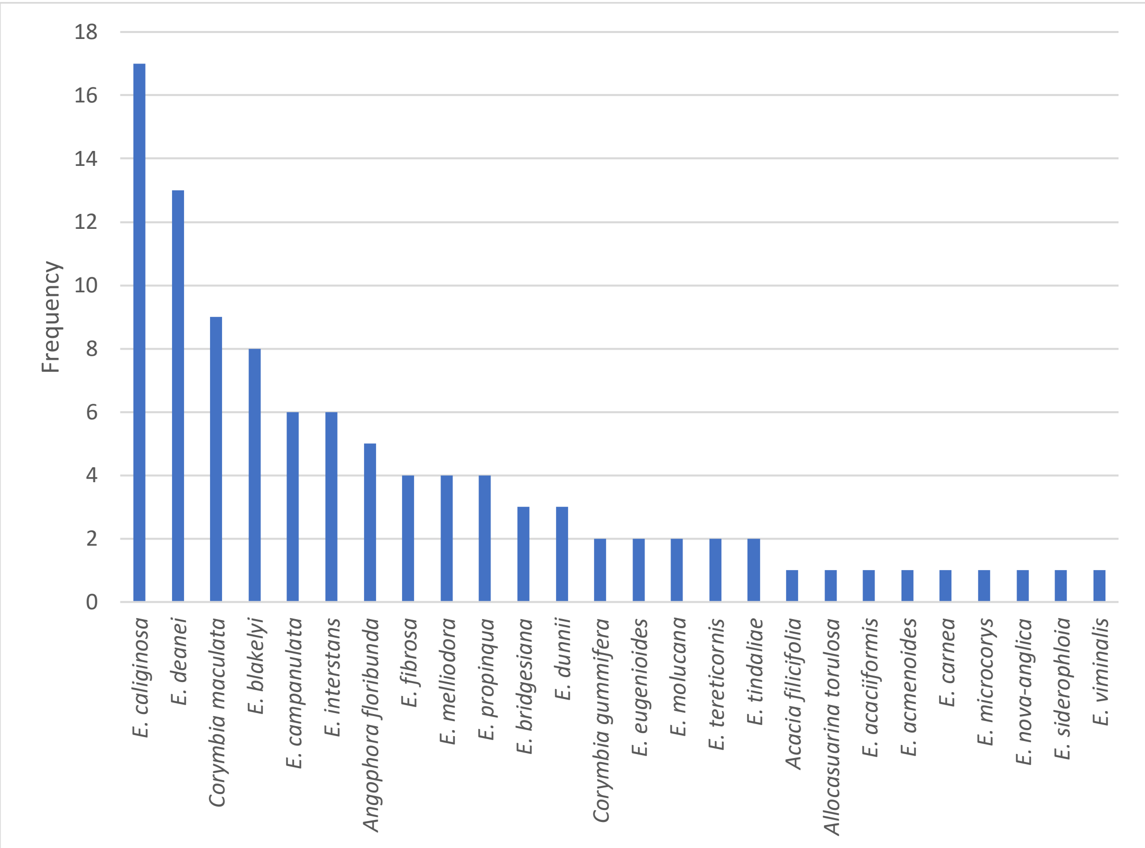


Figure 2: Tree species (and their frequencies) that were positive for koala scats for all positive sites.

Table 5: Tree species that were positive for koala scats

Tree species	Frequency
Eucalyptus caliginosa	17
Eucalyptus deanei	13
Corymbia maculata	9
Eucalyptus blakelyi	8
Eucalyptus campanulata	6
Eucalyptus interstans	6
Angophora floribunda	5
Eucalyptus fibrosa	4
Eucalyptus melliodora	4
Eucalyptus propinqua	4
Eucalyptus bridgesiana	3
Eucalyptus dunnii	3
Corymbia gummifera	2
Eucalyptus eugenioides	2
Eucalyptus mollucana	2
Eucalyptus tereticornis	2
Eucalyptus tindaliae	2
Acacia filicifolia	1
Allocasuarina torulosa	1
Eucalyptus acaciiformis	1
Eucalyptus acmenoides	1
Eucalyptus carnea	1
Eucalyptus microcorys	1
Eucalyptus nova-anglica	1
Eucalyptus siderophloia	1
Eucalyptus viminalis	1

Figure 16 describes the tree species composition, across all systematic surveys (i.e. regardless of whether sites had koala presence or absence) divided between sites with presence or absence of koala scats. This gives us an understanding of whether koala presence is more often associated with specific tree species. In this study it appears that especially *Corymbia maculata, Eucalyptus fibrosa*, *Eucalyptus viminali*s and *Allocasuarina torulosa* were more often present at sites with koala presence than sites without (also *Eucalyptus interstans*, *Eucalyptus deanei, Eucalyptus dunnii*, *Eucalyptus eugenioides*, *Eucalyptus acmenoides*, *Grevillea robusta, Eucalyptus resinifera* subsp. *hemilampra* and *Eucalyptus microcorys*).

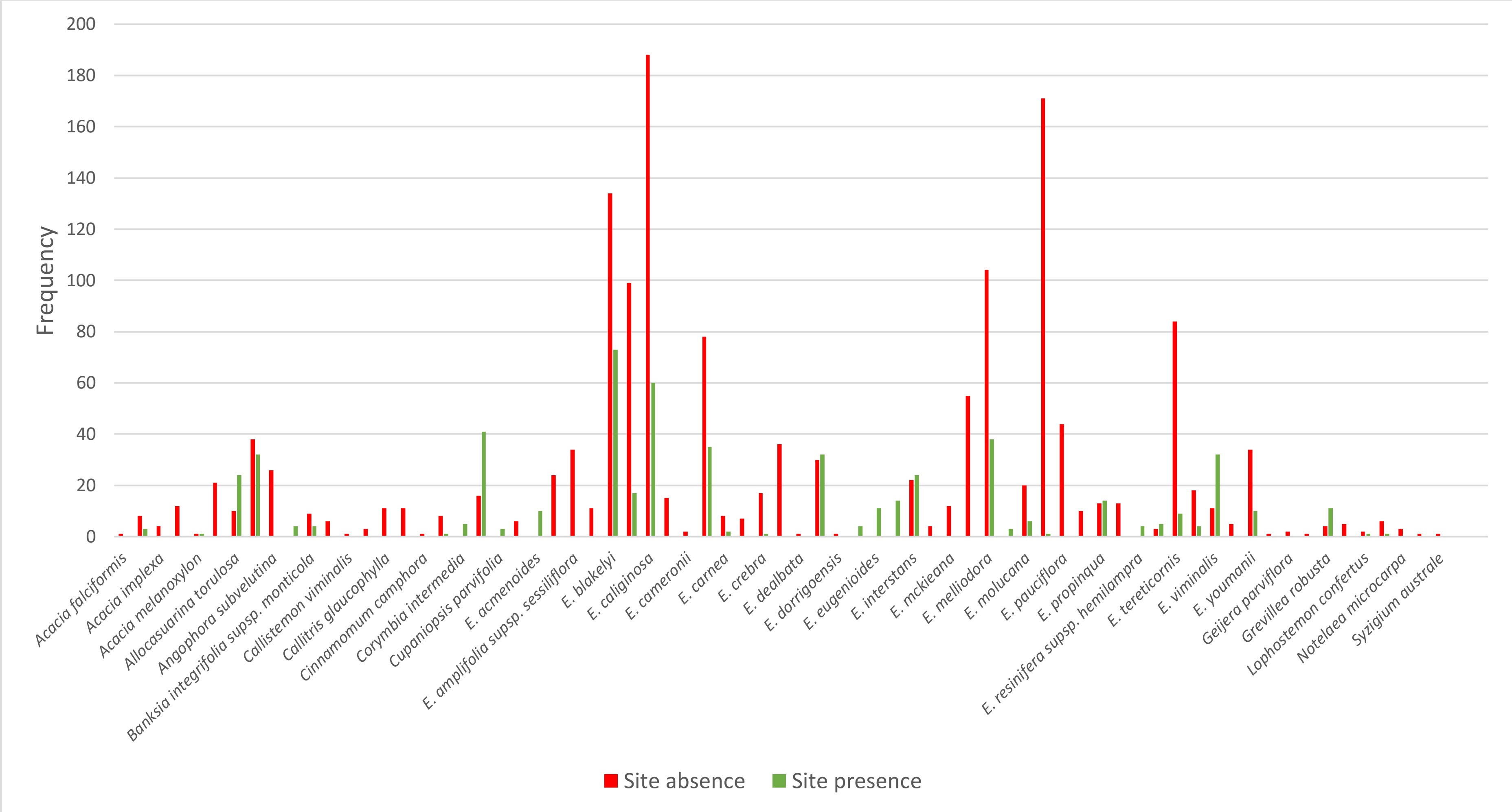


Figure 3: Number of individual trees, divided between sites with presence or absence of koala scats, per tree species, for all systematic sites

We specifically tested through our models whether these species of trees were statistically significantly associated with koala presence. The model had koala presence as the response variable (binary variable: 0 or 1), and the explanatory variable was the specific tree species at these sites (with site as a random effect, and taking into account the proportion of trees at each site). However, the model fitted the data poorly. Because of the poor fit, we also ran a model using a different approach. First, we excluded rare species (i.e. all species representing less than 1% of the trees encountered) as these had no statistical power. For the remaining species, we pooled presence / absence per species to generate a proportion of times a species was found at positive or negative sites. We ran this binomial model with tree species as the explanatory variable. This model was a better fit, however it no longer accounted for species co-occurrence (no random effect). The results showed that two eucalyptus species were more often associated with koala presence: *Corymbia maculata* and *Eucalytpus viminalis* (Table 6, note that *Allocasuarina torulosa* also has a potential positive effect). These results are to be taken with caution as the robustness of binomial models is difficult to ascertain. We suggest also that NT tree data from all NT LLS Cool Country Koala projects (2016 and 2018 surveys) be pooled together and analysed for tree analyses as this will increase power (due to a larger dataset).

Table 6: List of the tree species present at koala survey sites (for all tree species > 1%), and statistical results showing that two eucalyptus tree species were mildly significantly positively associated with koala presence (positive estimates and P-values < 0.05)

	Estimate	Std. Error	Pr(>|z|)	Significance
(Intercept)	-0.2	2.42E-01	0.400	
Angophora. subvelutina	-27.8	1.43E+05	1.000	
Allocasuarina luehmannii	-27.6	1.44E+05	1.000	
Allocasuarina torulosa	1.1	4.48E-01	0.016	*
E. albens	-27.7	1.43E+05	1.000	
E. amplifolia var. sessiliflora	-28.1	1.42E+05	1.000	
E. blakelyi	-0.4	2.82E-01	0.153	
E. bridgesiana	-1.6	3.57E-01	0.000	***
E. caliginosa	-0.9	2.84E-01	0.001	***
E. campanulata	-0.6	3.16E-01	0.059	.
E. conica	-26.6	1.52E+05	1.000	
E. deanei	0.3	3.51E-01	0.445	
E. interstans	0.3	3.82E-01	0.446	
Corymbia maculata	1.3	4.03E-01	0.002	**
E. melanophloia	-28.5	1.41E+05	1.000	
E. mollucana	-1.0	5.25E-01	0.057	.
E. nova-anglica	-4.9	1.03E+00	0.000	***
E. pauciflora	-28.3	1.42E+05	1.000	
E. propinqua	0.3	4.55E-01	0.542	
E. tereticornis	-2.0	4.26E-01	0.000	***
E. tindaliae	-1.3	6.03E-01	0.031	*
E. viminalis	1.3	4.25E-01	0.003	**
E. youmanii	-1.0	4.34E-01	0.019	*

5.5.2 Tree Use at Positive Survey Sites

Systematic koala surveys, for which 30 trees are checked, allowed us to calculate the strike rate (number of trees with scats / total number of trees) at positive sites for each available tree species (Phillips and Hopkins 2008). This enabled us to classify tree species that were more actively used by koalas (Table and Figure 4).

Strike rates calculated for small sample sizes need to be treated with caution until a trend can be ascertained for a larger number of trees (e.g. *Eucalyptus dunnii*, *Eucalyptus microcorys*, etc), nonetheless, the following species can be classified as trees more commonly used by koalas: *Eucalytpus deanei, Corymbia maculata, Eucalyptus propinqua, Eucalyptus interstans* and *Angophora floribunda*

Table 7: Tree species strike rates for Northern Tablelands USC 2018 survey

Tree Species	Presence	Absence	Strike Rate in %
Eucalyptus dunnii	3	1	75.0
Eucalyptus microcorys	1	2	33.3
Eucalyptus fibrosa	4	10	28.6
Eucalyptus deanei	13	49	21.0
Corymbia maculata	8	42	16.0
Eucalyptus eugenioides	2	11	15.4
Eucalyptus propinqua	4	23	14.8
Eucalyptus interstans	6	40	13.0
Eucalyptus siderophloia	1	7	12.5
Eucalyptus acmenoides	1	9	10.0
Acacia filicifolia	1	10	9.1
Angophora floribunda	5	65	7.7
Eucalyptus caliginosa	14	234	5.6
Eucalyptus tindaliae	1	21	4.5
Eucalyptus campanulata	5	108	4.4
Eucalyptus blakelyi	8	199	3.9
Allocasuarina torulosa	1	33	2.9
Eucalyptus viminalis	1	42	2.3
Eucalyptus melliodora	3	137	2.1
Eucalyptus bridgesiana	2	114	1.7
Eucalyptus tereticornis	1	92	1.1

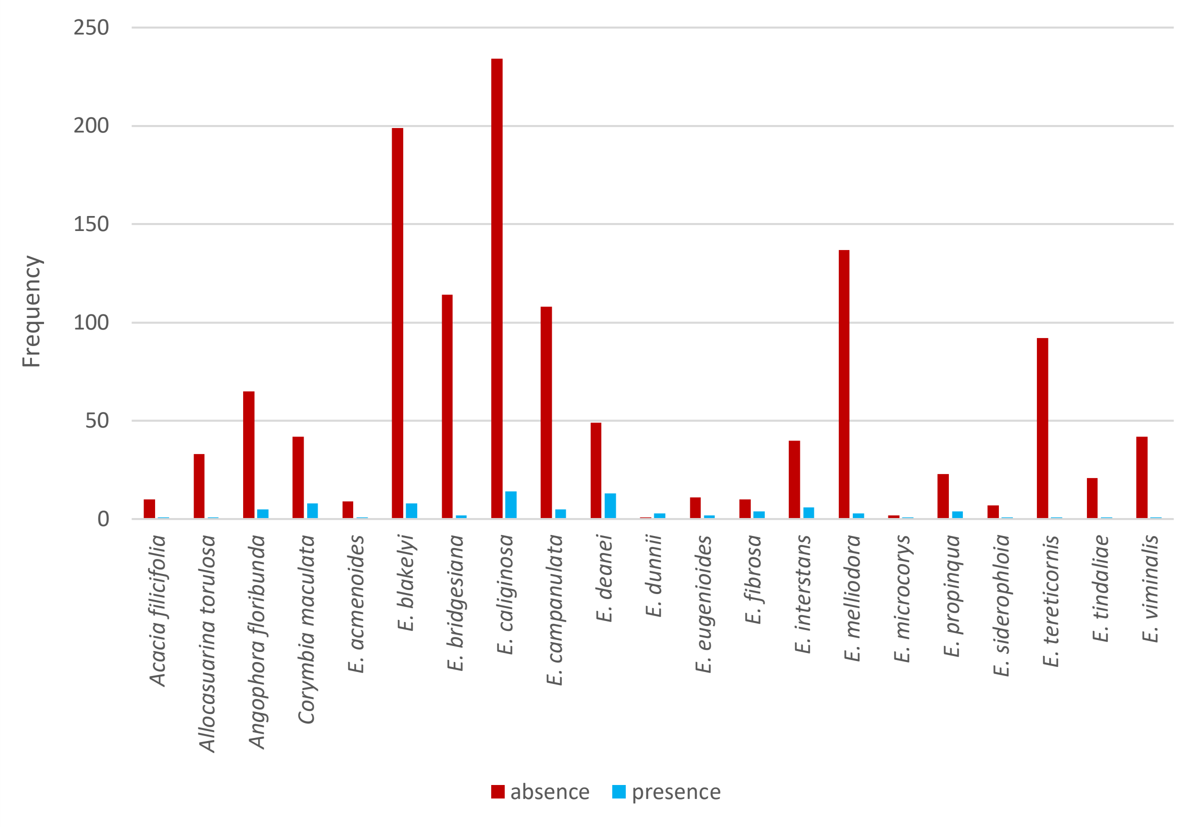


Figure 4: Number of individual trees with presence or absence of scats, per tree species, for all positive systematic sites (used to calculate strike rates)

One of our models tested whether some tree species were actively selected at sites where koalas were present (i.e. used more than expected by chance only). We found *E. deanei* was used more than expected at sites where koalas were present (Table 8).

Table 8: List of the tree species present at sites where koala scats were detected, and statistical results showing that no tree species was significantly more used than chance would predict (no P-values < 0.05)

	Estimate	Std. Error	Pr(>|z|)	Significance
(Intercept)	-1.9	5.36E-01	0.000	***
Allocasuarina torulosa	-1.2	1.15E+00	0.288	
Corymbia maculata	0.6	6.68E-01	0.352	
E. blakelyi	-0.2	6.54E-01	0.777	
E. bridgesiana	-0.1	9.24E-01	0.909	
E. caliginosa	0.7	6.17E-01	0.243	
E. campanulata	0.1	7.21E-01	0.870	
E. deanei	1.5	6.45E-01	0.018	*
E. interstans	0.8	7.14E-01	0.256	
E. mollucana	-23.8	9.35E+04	1.000	
E. nova-anglica	-22.7	1.31E+05	1.000	
E. propinqua	1.0	7.98E-01	0.213	
E. tereticornis	-0.2	1.19E+00	0.886	
E. tindaliae	0.8	1.27E+00	0.524	
E. viminalis	-1.5	1.15E+00	0.184	
E. youmanii	-24.2	9.00E+04	1.000	

5.6. Ground-truthing the Northern Tablelands KRS Tree Species List

5.6.1 Priority Study Areas

The present surveys aimed at assessing koala presence in the TSR in priority areas around Tenterfield and Glen Innes. Both areas show signs of koala presence to some degree, however, presence is much higher in the northern area (Northern sites around Tenterfield) compared to the southern area around Glen Innes. It has to be noted, however, that the level of koala presence overall was rather low in NT KRS priority areas covered by this survey (especially Emmaville / Deepwater priority areas), and that one of the areas more used by koalas was outside the originally defined NT KRS priority areas – this should be added as a koala population.

5.6.2 Important Tree Species

Potential food and habitat tree species were identified in the Koalas on the Northern Tablelands Literature Review as part of the NT KRS. In Table , we compared the tree species that have been used by koalas in this project and the tree species list from the NT KRS:

- 11 species were used in this project but not in the listed in the NT KRS
- 10 species were identified in both this project and in the NT KRS

Table 9: Comparison of tree species used by koalas in this study and as identified in the NT KRS

Koala tree species identified in this project	Species identified for study area in the NT KRS
Acacia filicifolia	yes
Allocasuarina torulosa	yes
Angophora floribunda	yes
Corymbia maculata	no
Eucalyptus acmenoides	no
Eucalyptus blakelyi	yes
Eucalyptus bridgesiana	yes
Eucalyptus caliginosa	yes
Eucalyptus campanulata	no
Eucalyptus deanei	no
Eucalyptus dunnii	no
Eucalyptus eugenioides	no
Eucalyptus fibrosa	no
Eucalyptus interstans	no
Eucalyptus melliodora	yes
Eucalyptus microcorys	yes
Eucalyptus propinqua	yes
Eucalyptus siderophloia	no
Eucalyptus tereticornis	no
Eucalyptus tindaliae	no
Eucalyptus viminalis	yes

Of all the tree identified across all sites, 72.5% were tree species identified in the NT KRS as important for koalas (food and shelter, see

Table). This result is an indication that tree species present in TSR are of especially high value for koala conservation.

Table 10: Comparison of tree species that were identified as being important koala use trees in the NT KRS and whether the species was encountered during the USC surveys

Tree species important for koalas in NT (as per NT KRS)	Tree species identified in 2018 surveys	Proportion present
Eucalyptus caliginosa	yes	12.0%
Eucalytpus blakelyi	yes	10.0%
Eucalyptus nova-anglica	yes	8.3%
Eucalyptus melliodora	yes	6.8%
*Eucalyptus bridgesiana**	yes	5.6%
*Eucalyptus campanulata**	yes	5.5%
Angophora floribunda	yes	3.4%
*Eucalyptus deanei**	yes	3.0%
Allocasuarina spp.	yes	2.7%
*Eucalyptus melanophloia**	yes	2.6%
Eucalyptus youmanii	yes	2.1%
Eucalyptus pauciflora	yes	2.1%
Eucalyptus viminalis	yes	2.1%
Eucalyptus dalrympleana ssp. *heptantha*	yes	1.7%
Eucalyptus amplifolia subsp. *sessiliflora**	yes	1.6%
Acacia spp.	yes	1.5%
Eucalyptus propinqua	yes	1.3%
Eucalyptus albens	yes	1.2%
Eucalyptus moluccana	yes	1.2%
Eucalyptus camaldulensis	yes	0.7%
Eucalyptus radiata subsp. *sejuncta**	yes	0.6%
Callitris glaucophylla	yes	0.5%
Eucalyptus banksii	yes	0.5%
Eucalyptus prava	yes	0.5%
Eucalyptus acaciiformis	yes	0.3%
Eucalyptus conica	yes	0.3%
Casuarina cunninghamiana subsp. *cunninghamiana*	yes	0.2%
Eucalyptus williamsiana	yes	0.2%
Eucalyptus dealbata	yes	0.1%
Eucalyptus microcorys	yes	0.1%

Tree species important for koalas in NT (as per NT KRS)	Tree species identified in 2018 surveys	Proportion present
Eucalyptus chloroclada	no	0.0%
Eucalyptus laevopinea	no	0.0%
*Eucalyptus macrorhyncha**	no	0.0%
Eucalyptus nobilis	no	0.0%
Eucalyptus notabilis	no	0.0%
Eucalyptus obliqua	no	0.0%
Eucalyptus retinens	no	0.0%
Eucalyptus rubida	no	0.0%
Eucalyptus sideroxylon	no	0.0%
Eucalyptus stellulata	no	0.0%
Eucalyptus malacoxylon	no	0.0%
Eucalyptus michaeliana	no	0.0%
Eucalyptus nicholli	no	0.0%
Eucalyptus oresbia	no	0.0%
Eucalyptus quinniorum	no	0.0%

* These species were identified in the USC 2016 surveys, not in the NT KRS

6. Discussion of Results

6.1 Summary of 2018 Surveys

In this study, mainly Travelling Stock Routes were surveyed for koala presence. Priority areas were outlined around Glen Innes/ Emmaville and around Tenterfield. USC conducted 121 koala surveys across the northern part of Northern Tablelands, 104 flora surveys were conducted simultaneously. We detected koala presence at **30 of our 121 surveys (24.8%)**, however, no koala was found during our surveys. Koala presence in the Glen Innes area was low (13.8%), whereas the area around greater Tenterfield had a larger number of sites positive for koala presence (33.3%).

During systematic surveys, 2069 trees were searched for the presence of koala scats. Of these, 85 were found to have scats, therefore the average tree use was 4.1%. Activity levels differed between sites: the area around Glen Innes showed an average activity level of 1.2% (SD=3.4) whereas further north around Tenterfield, the average activity levels was 6.5% (SD=10.9). For all positive systematic sites, the **average activity level was 15.7%** (SD 10.9). Our findings show that the surveyed areas have well spread across the landscape, but sparse, koala activity. At sites where they are present, koala activity was also relatively low.

The tree species, and the presence of scats under them, were ascertained for 2082 trees (71 different species). Altogether, 28 different tree species were recorded being used by koalas. Tree species commonly used by koalas in the surveyed areas included: ***Eucalytpus caliginosa, Eucalyptus deanei, Eucalyptus blakelyi*** and ***Corymbia maculata.***

6.2 Cool Country Koala Project 2016-2019

Globally, the NT LLS "*Cool Country Koala*" surveys (both USC and Stringybark 2016 and USC 2018) achieved the following coverage, with the following results, in term of the NT KRS priority areas for surveys (Figure 18):

- Continuous and high koala use: Armidale-Uralla, Delungra, Nowendoc.
- Need boundaries to be redrawn: new koala area North of Tenterfield.
- Historical records but koala population seems to have severely decreased: Ashford, Emmaville.
- Areas poorly surveyed: Gilgai, Tingha southeast towards New Valley, North east of Tenterfield extending into Queensland and North Coast, Emmaville to east of Deepwater areas, Pindaroi and surrounds to the Qld border.
- Areas yet to be surveyed for koalas: NE Glen Innes, South-east of Walcha in and around Apsley River, in and around Mt Mitchell east of Ben Lomond.

For all the priority areas including Stringybark 2016 surveys, Table 11 compares the presence of koalas (number of site with koalas/number of sites surveyed), percentage of total tree found with koala scats, number of koala sighted during field surveys (note that teams did not look for koalas, so these are opportunistic sightings only), activity levels (a common measure in koala research that where number of trees with scats out of 30 trees are calculated), activity at positive sites (i.e., when koalas are present, how intensively do they use a sites), and percent of sites at which fresh, medium and old scats were found. Note that Stringybarks survey sites were not randomly chosen, which makes comparison with other surveys, including USC sites, difficult. In addition, USC and Stringybark used different methods (USC uses detection dogs), which renders comparisons more difficult.

We can compare areas covered by USC in 2016 and 2018 (Figure 19) – and based on all koala metrics – presence of scats, sightings of koalas, activity levels, how intensely sites were used and how recently sites were used – the areas covered in 2016 show higher koala metrics. Interestingly – koala scat density was similar between 2016 and 2018 (and also similar to other USC surveys see Table 12), which tends to indicate a similar use of individual trees (i.e., if we were finding higher scat density at trees, this might indicate koalas spending more time in specific trees which can indicate lack of availability of trees).

Table 11: Comparison of koala metrics calculated at sites surveyed during the NT LLS "*Cool Country Koala*" surveys (both USC and Stringybark 2016 and USC 2018)

	NT LLS / USC 2018	NT LLS / USC 2016	NT LLS / Stringybark 2016
Percent positive site	24.8% (30/121)	30.3% (81/267)	49% (N = 139
Trees with koala scats	4.9% (N = 2082)	7.2% (N = 5136)	NA
Koala sightings	0	29	NA (3?)
Activity levels	4.1% (N = 2082)	6.6% (N = 4980)	6.8% 3910
Activity levels at positive sites (i.e., when koalas are present, how intensively do they use a sites)	15.7%	21.0%	NA
Percent of sites with fresh scats	5.5%	18.6%	2%
Percent of sites with medium scats	14.8%	41.4%	25%
Percent of sites with old scats	78.7%	40.0%	75%

NA = Not available in report

Table 12: Comparison of scat density (available only for USC surveys)

	NT 2018	NT 2016	Gympie	Fraser
Max	61	58	56	60
Average	5.1	6.7	14.9	10.2
SD	3.6	8.9	12.4	11.0

We ranked different areas of NT that were targeted through the "*Cool Country Koala*" surveys from higher to lower koala activity (Table 13, Figure 20) – again, readers have to bear in mind that Stringybarks survey sites were not randomly chosen, and survey methods differ from USC surveys. However, clearly some areas of NT have robust koala populations: Armidale and

Delungra, some areas have substantial koala populations: Nowendoc, Tenterfield and Walcha, some area have fringe populations: Emmaville/ Glen Innes and one area seems to have experienced a substantial population reduction: Ashford.

Table 13: Comparison of presence of koalas and activity levels in priority areas studied in 2016 (Ashford / Delungra = USC, Walcha, Nowendoc, Armidale-Uralla – Stringybark) and 2018 by order of most used to less used area

	Armidale-Uralla	**Delungra**	**Nowendoc**	**Tenterfield area**	**Walcha**	**Emmaville/ Glen Innes**	**Ashford**
Percent positive sites	63% (NA)	54.4% (62/114)	35% (13/37)	33.3% (21/63)	31% (9/29)	13.8% (8/58)	1.3% (1/74)
Activity levels*	NA	8.3%	NA	6.5%	NA	1.2%	0%

* Can only be calculated for systematic surveys, NA = Not available in report

Interestingly, compared to the USC surveys in 2016, we identified an additional 8 tree species used by koalas (2018: 26 vs 2016: 18). Furthermore, an additional 31 different tree species were identified to be present in survey plots (with and without koala presence, 2018: 71 vs 2016: 37).

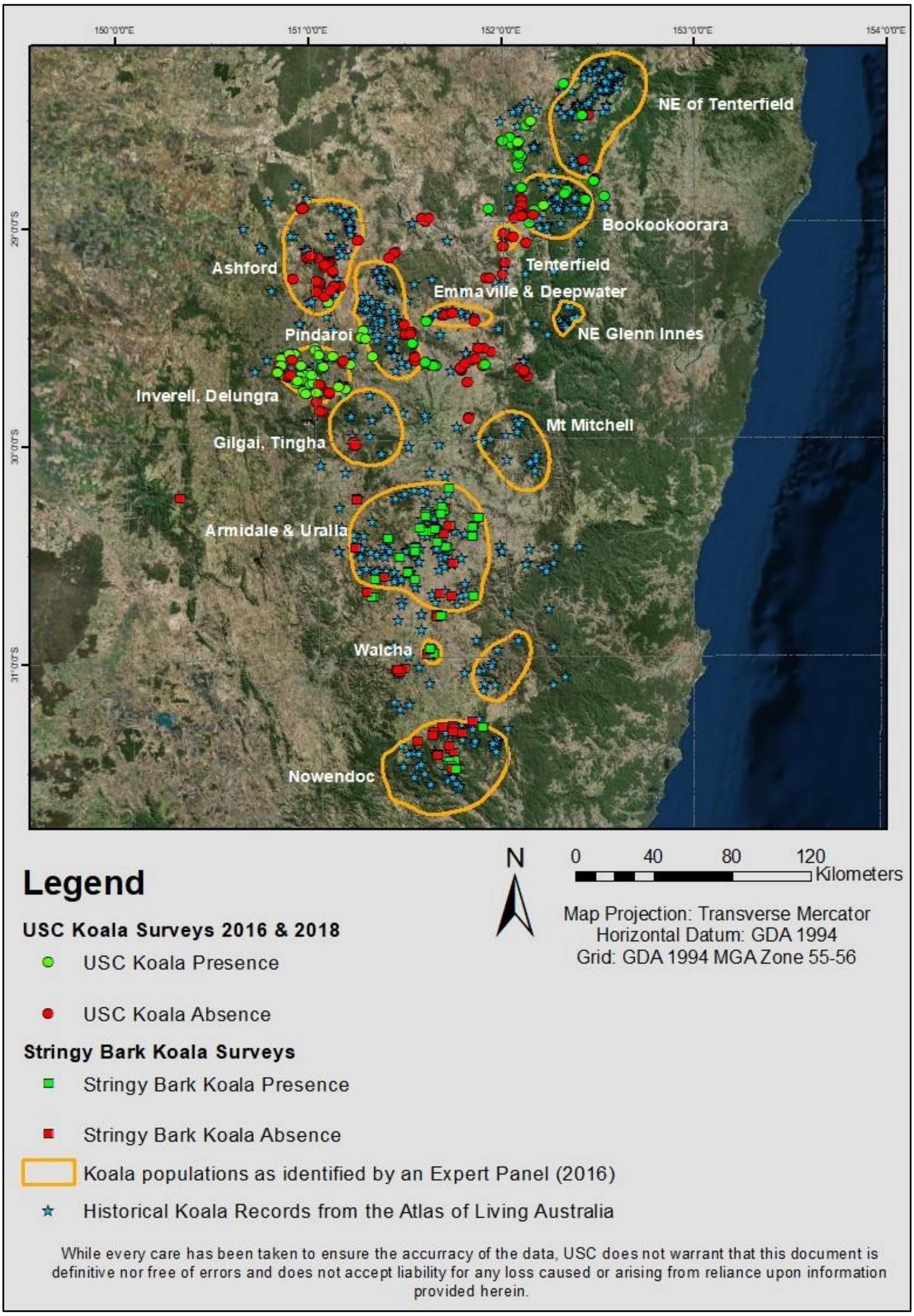


Figure 18: Koala survey sites where koala presence or absence was recorded for 2016 USC and Stringybark, and 2018 USC / NT LLS, surveys with the historical records for NT.

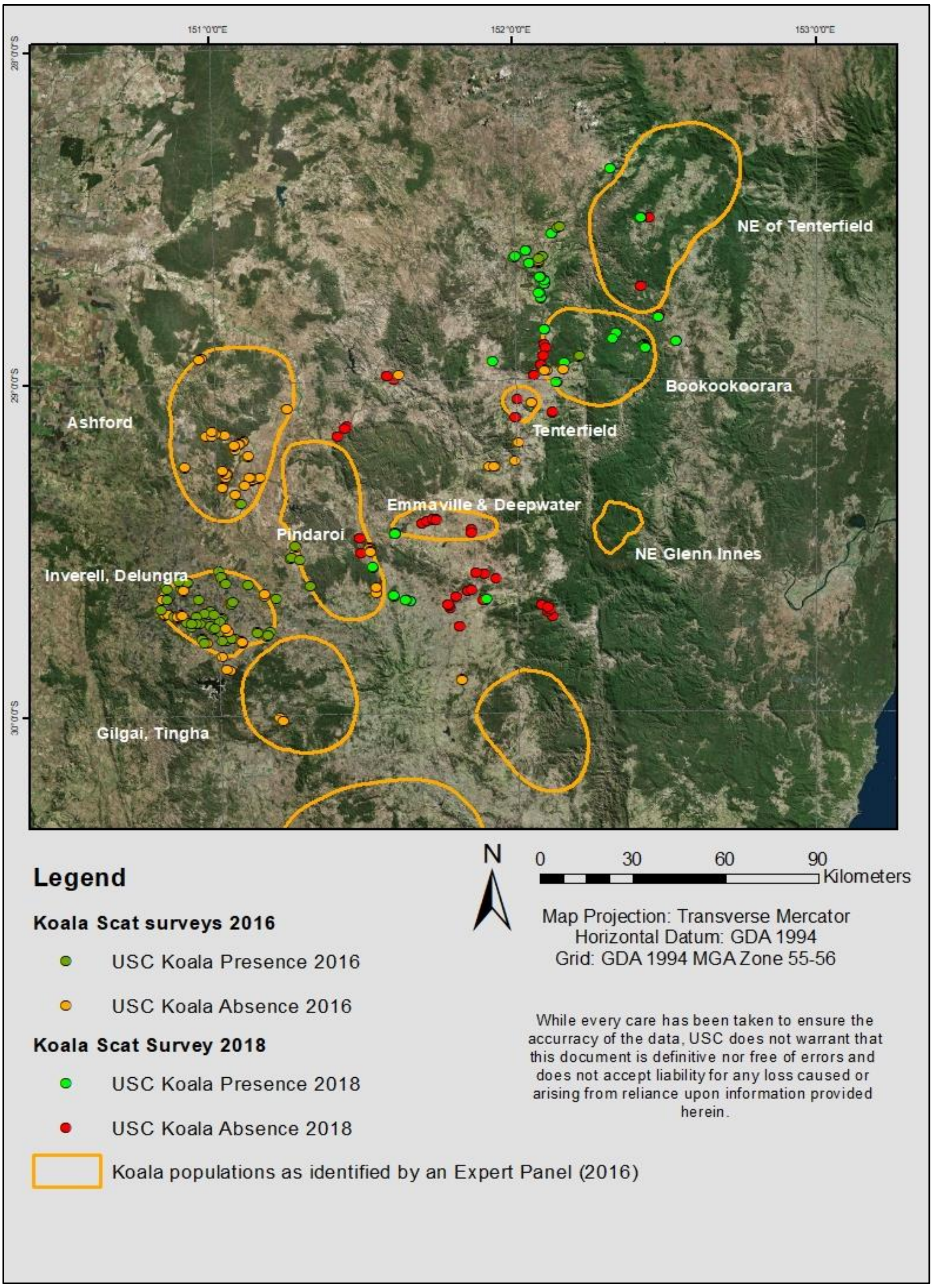


Figure 19: Koala survey sites where koala presence or absence was recorded for 2016 and 2018 USC / NT LLS surveys.

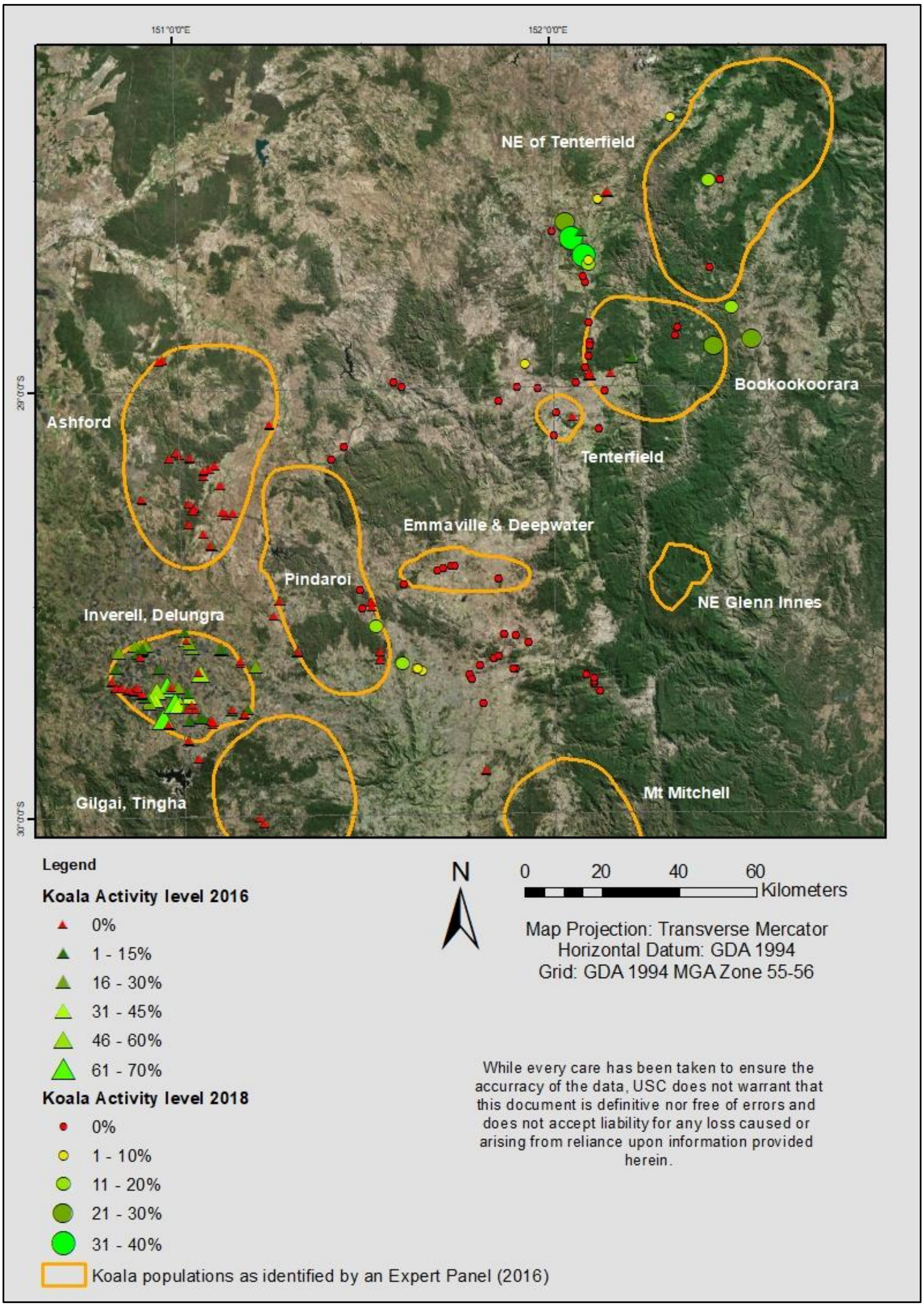


Figure 20: Activity levels (percent of trees with koala scats in 30 trees) during systematic surveys in 2016 and 2018 combined.

6.3 Management Recommendations from the 2018 "Cool Country Koalas Project"

Recent surveys indicate that koalas are present, but in low or medium abundance in the landscape covered by the 2018 USC surveys (Tenterfield / Glen Innes). Historical records indicate a long-term presence in the region and koalas are dispersed widely throughout the landscape, typically in low density with some localised medium to high density populations (see newly recognised population north of Tenterfield).

The longer-term management of NT koala population should make provisions for local and regional changes in the landscape as a result of land-use practices, anthropogenic threatening processes and climate change. Habitat loss was identified as the key threat to the persistence of the KMA4 - Northern Tablelands koala population (NSW 2008). As such, the primary management strategy to conserve this population was the restoration of habitat on public and private lands. Undoubtedly there are a suite of other threatening processes impacting on the Northern Tablelands koalas, resulting in the premature mortality of animals, such as wild and domestic dog trauma, vehicle strikes, trauma from livestock, and disease. However, the general paucity of data on which threats rank higher for each priority area koala population makes targeted management uncertain. As such, the impact for population viability of targeting other potential threats are less certain than the restoration and enhancement of habitat in the region.

The 2016 NT LLS reports (USC / Stringybark) contained many recommendations to NT LLS. In this report, USC seeks to add to the 2016 recommendations, and provide management actions that can be potentially more targeted and therefore easier to implement. However, and before any other actions – NT LLS priority should be to work with Local Councils and State Government so that the approach to koala conservation in the NT is coordinated and strategic.

We provide the following recommendations based on the results of this and past research in the region:

Recommendation 1 - Prioritise habitat rehabilitation

Typically, better quality habitat for koalas occurs in lower elevation alluvial soils on the plains that have been historically cleared for agriculture and grazing. This is consistent with the majority of the koala records and populations identified by the expert panel as west of the mountainous regions. There are multiple on-ground actions that can enhance habitat and linkages between populations, and has the dual benefit of enhancing the climate change proofing of the region:

- Trees on farms program
  A program to reduce salinity on rural properties in the Gunnedah region (to the south-west) through tree planting was also successful in restoring koala habitat in the area (Lunney et al 2012). Koalas can relatively quickly make use of regrowth vegetation (Cristescu et al. 2013), providing primary habitat and /or linkages between patches of habitat.

- Landcare grants / Nature Assist / Nature Refuge grants to encourage, with financial incentives, the restoration and enhancement of koala habitat on private tenure.

- Local council bushcare groups and other community rehabilitation groups to coordinate the rehabilitation of strategic linkages between townships and rural areas of koala habitat

- Community koala tree program to provide koala food and habitat trees to local residents.

- Community participation such as a propagators group could collect local providence seed and propagate preferred koala food and shelter tree species.

Recommendation 2 - Conserve habitat in Travelling Stock Routes

- Travelling Stock Routes (TSR) provide important remnant habitat and linkages in the landscape, and may often be the only patches of vegetation in areas of significant farming practices. They should be considered as unofficial reserves and managed as such, in isolation to the usual management practices on rural holdings.

Recommended management actions include:

  - weed control of invasive species such as Coolatai Grass and Ox-eye Daisy
  - reduce grazing pressure,
  - reinstall TSR fencing,
  - plant out native species,
  - remove rubbish,
  - control feral animals such as pigs, goats and deers.

- A review of all TSR survey data available should be conducted, and TSR with high conservation values should be identified. Management plans should be developed to preserve significant species, including koalas, on these high conservation value TSR.

- During this review, NT LLS should also identify well managed TSR to be used as case study for other landholders. This for example could showcase landholders with sound management plans of the TSR that demonstrate grazing and conservation of TSR can both work together.

- If there are information gaps, an additional survey of TSR and how they are treated across NT LLS should be conducted, as our personal observation is that some TSR are appropriated by landholders for private use.

Examples of suggested management recommendations for specific survey sites (sites are mapped in Appendix 2)

- Reduce livestock grazing pressure in over-grazed TSRs, e.g. site 2018-11-07-ba10.
- Reinstall TSR fencing where it has been removed/taken down by neighbouring landholders for grazing purposes, e.g. site 2018-11-16-ba2.
- Consider those TSR sites which are of high conservation value to be managed for conservation, e.g. 2018-11-14-ba1.
- Undertake tree plantings on good condition TSR sites with wildlife corridor potential, e.g. 2018-11-07-ba1.
- Manage understory weeds such as Coolatai Grass and Ox-eye Daisy (*Hyparrhenia hirta* and *Leucanthemum vulgare*) which are an emerging threat to good condition TSRs, e.g. 2018-11-16-ba5.
- Manage feral animals, such as goats, deer, pigs, that overgraze TSRs, e.g. 2018-11-14-ba9.
- Discourage the dumping of rubbish in TSRs, e.g. 2018-11-08-ba1.
- Stop the practice of tree clearing in or adjacent to TSRs of high conservation value, e.g. 2018-11-13-ba1.
- Undertake plantings of TSR sites that are susceptible to eucalyptus dieback, e.g. 2018-11-04-ba5.

Recommendation 3 - Ongoing monitoring of the regional population through targeted and Citizen Science programs

The longitudinal monitoring of the regional population is needed to understand factors affecting the distribution, abundance and viability of the regional population. Data collection can be targeted to understand particular aspects of koala biology or ecology, or more general and passive in nature. Data collected through incidental reporting, while somewhat biased, can provide compelling data on the trends and threats to koalas in the region – this is especially relevant in koala hotspots (Delungra / Armidale) that coincide with human populated areas. Citizen scientists are often a cost-efficient way to gain a greater understanding of the threats to koalas that are reported as sick, injured or orphaned and needing treatment and rehabilitation. It is a pro active monitoring that if the community is engaged can provide real-time monitoring of population status as well as monitor the success of management actions.

- Identification of source populations that are healthy and in relative abundance to ascertain the strategic management of these key populations.

- Gather baseline population data on the Delungra and Armidale populations, currently hotspots of signs of koala activity and likely two of the source populations in the region. Further in-depth investigation of the dynamics and ecology of the Delungra and Armidale populations will allow for a more targeted approach to the management of koalas in these areas.

- Monitoring of ‘insurance’ or source populations at a frequency to allow the detection of critical population changes and threats that may negatively impact on the viability of the local and regional koala populations

- Ongoing engagement of the community in koala citizen science programs to get the community actively engaged in koala conservation while providing incidental population data that may otherwise not be reported. These may include annual phone-in or online surveys encouraging the reporting of sightings at a particular time, community-based surveys, etc.

- Improve community awareness of threats to koalas and improve detection of emerging hot spots of mortality and disease in local populations for active management of threats.

- Identify appropriate partners to facilitate the collation of data obtained via citizen science programs for dissemination to regulators and local environmental groups to actively manage emerging threats and support strategies to conserve the koala and habitat in the region. For example, the Armidale Regional Council is actively encouraging their constituents to report koalas: "We urge people who have seen a koala to please register the details on Armidale's Koala Sightings Register. The sightings are then transferred to Bionet, the NSW Wildlife Atlas record of threatened wildlife that assists ecologists in researching and monitoring threatened wildlife on a national scale." This could be extended across NT Councils. Armidale Regional Council register is available at the following link:

https://epathway.newengland.nsw.gov.au/ePathway/Production/Web/CustomerService/DynamicPages.aspx?CustomerServiceId=42500&PageIndex=0&js=657262340

Recommendation 4 - Update government mapping to reflect current population distribution

As data become available, regulatory maps need to be updated to reflect changes in population distribution and emerging important populations. This ensures that strategies to restore koala habitat, for example, are based on the most up to date information about key populations and their distribution in the landscape and where habitat and linkages need to be restored and enhanced.

- Amend maps to acknowledge newly identified high density populations (e.g. NW of Tenterfield).
- Review the expert panel assessment of populations based on current survey data.
- Ensure any survey contractor reports raw data to Bionet as per NSW licencing conditions.

Recommendation 5 - Gain support of local and state government to assist in local on-ground management actions

- Promote the NT koala populations so that the NT koalas are "put on the map" and become a priority when State Government in particular releases funding. Due to its geographical position, NT koala populations might be less subject to some threats that are high in other KMA (habitat loss and associated anthropogenic threats on the Eastern coast, climate change to the west of NT). This could mean NT populations could potentially act as insurance population and climate refuge. This requires further research but is important as if this is the case, NT is critical for long-term survival of koalas as a species in NSW.

- Seek grants to promote state and local government involvement in on-ground activities that will engage the community and landholders

Recommendation 6 - Scoping an emergency plan document for hotspot populations

The koala observed in the NT through the 2016 surveys showed no signs of the common koala disease chlamydia. It is less risky and would provide better outcome to monitor population and detect early change of this healthy state. This can be done through citizen scientists (see recommendation 3).

NT LLS might wish to investigate an emergency plan in the event of a chlamydia outbreak. At minimum, if NT LLS is able promote the importance of NT koala population (see recommendation 5), funding in an emergency might be easier to access. The emergency plan should describe cost-effective ways to monitor population hotspots, threshold for management actions as well as which actions should be considered (catching / treating koalas). Research project could also be investigated through partnership with universities and interest groups – for example, whether Drinky Bill water delivery stations can deliver vaccine to wild koala populations in the future.

Recommendation 7 - Spatial analysis as a tool to predict koala current and future landscape use and as a tool to communicate with other stakeholders

Mapping corridors and climate refuge could be investigated, especially as collaboration with other projects or universities.

Recommendation 8 - Continue support the koala network on the Northern Tablelands

Many of the threats to koalas are anthropogenically mediated (i.e., vehicle and dog injury, tree clearing) which also means that an educated and empowered community can act to protect koalas. Therefore, NT LLS effort to promote threatened species on the NT and engage landholders to be involved in their protection is critical and should continue. For example, NT LLS should endeavour to pursue these current efforts:

- promote the visibility of the koalas on the NT through social media engagement, including Northern Tablelands Threatened Species Network Facebook page and You Tube channel,

- capitalise on any koala story to develop media releases in order to keep koalas at the front of people minds,

- deliver workshops and public events, with the aim of being practical and breaking all barriers to foster permanent behaviour changes.

A very engaged and committed part of the public are the wildlife rescuers and koala carers. They are a critical, if often extremely busy and already at capacity, part of the network. NT LLS should develop ways to:

- Communicate effectively (for example, carers often cannot go to workshops as they have responsibilities to their animals in care). Long-term rescuers / carers are often very knowledgeable in the local populations, and the value of this on-the-ground experience should not be underestimated.

- Support rescuers / carers effort and investment in the wildlife of NT – for example, several Councils in Queensland now offer “carer grants”, these enable wildlife rescuers / carers to claim petrol and consumables they buy for the wildlife in their care.

7. Appendices

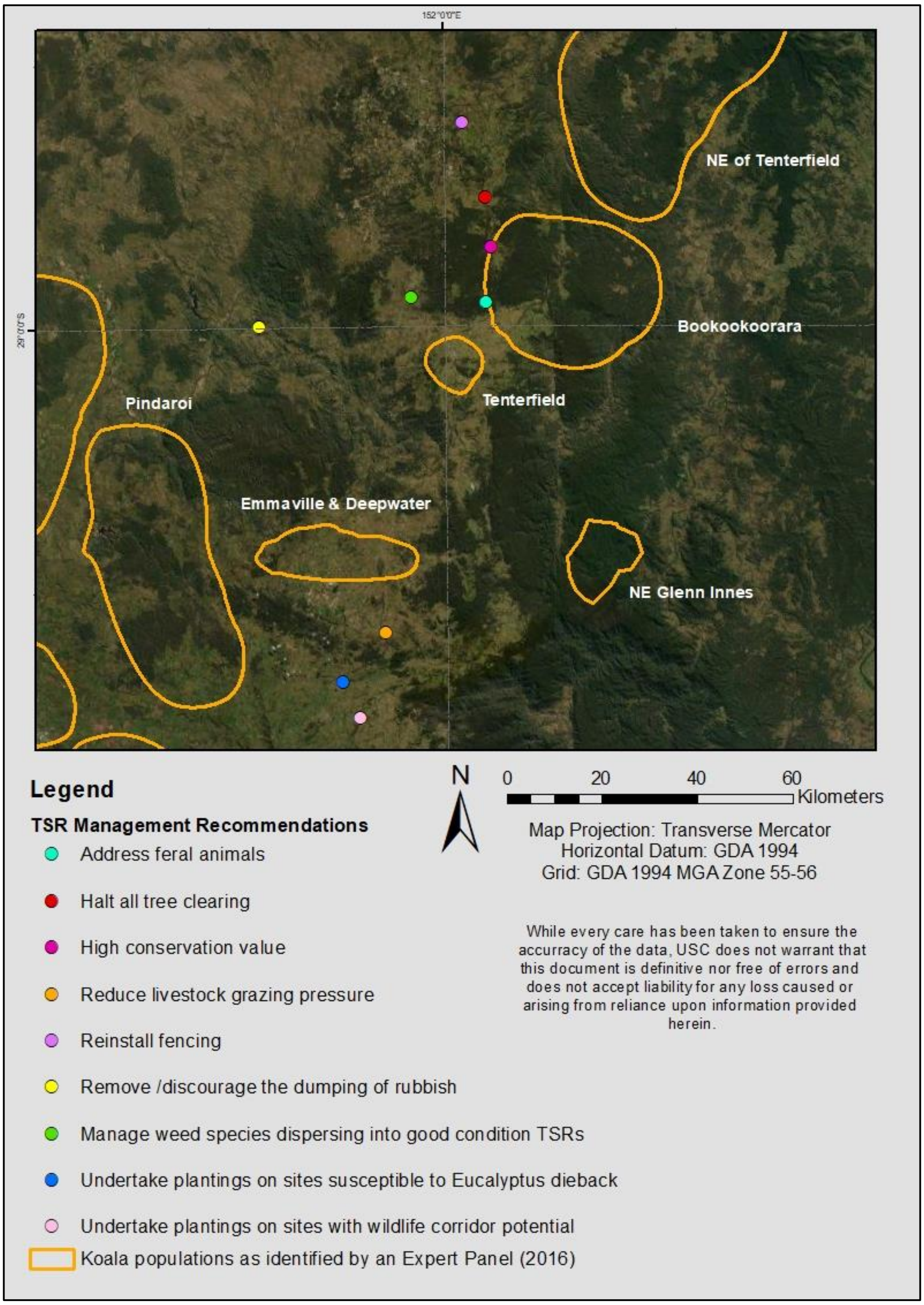
Appendix 1: All tree species that were recorded during koala surveys (systematic and casual) and their respective number of occurrences.

Scientific name	Author	Common Name	Frequency
Eucalyptus caliginosa	Blakely & McKie	New England Stringybark	252
Eucalyptus blakelyi	Maiden	Blakely's Red Gum	207
Eucalyptus melliodora	A.Cunn. ex Schauer	Yellow Box	198
Eucalyptus nova-anglica	H.Deane & Maiden	New England Peppermint	174
Eucalyptus bridgesiana	R.T.Baker	Apple Box	119
Eucalyptus campanulata	R.T.Baker & H.G.Sm.	New England Blackbutt	114
Eucalyptus tereticornis	Sm.	Forest Red Gum	94
Angophora floribunda	(Sm.) Sweet	Rough-barked Apple	70
Eucalyptus deanei	Maiden	Mountain Blue Gum	62
Eucalyptus mckieana	Blakely	McKie's Stringybark	50
Eucalyptus ligustrina	DC.	Privet-leaved Stringybark	46
Eucalyptus pauciflora	Sieber ex Spreng.	Snow Gum	44
Eucalyptus viminalis	Labill.	Ribbon Gum	43
Exocarpos cupressiformis	Labill.	Native Cherry	43
Eucalyptus dalrympleana subsp. *heptantha*	L.A.S.Johnson	Mountain Gum	36
Allocasuarina torulosa	(Aiton) L.A.S.Johnson	Forest Oak	34
Eucalyptus amplifolia subsp. *sessiliflora*	(Blakely) L.A.S.Johnson & K.D.Hill	Cabbage Gum	34
Eucalyptus molucana	Roxb.	Grey Box	28
Eucalyptus propinqua	H.Deane & Maiden	Small-fruited Grey Gum	27
Angophora subvelutina	F.Muell.	Broad-leaved Apple	26
Eucalyptus albens	Benth.	White Box	24
Eucalyptus tindaliae	Blakely	Tindale's Stringybark	23
Allocasuarina luehmannii	(R.T.Baker) L.A.S.Johnson	Bulloak	21
Eucalyptus crebra	F.Muell.	Narrow-leaved Ironbark	18
Eucalyptus camaldulensis	Dehnh.	River Red Gum	15
Leptospermum polygalifolium	Slisb.	Tantoon	15
Banksia integrifolia subsp. *monticola*	K.R.Thiele	White Mountain Banksia	13
Eucalyptus eugenioides	Sieber ex Spreng.	Thin-leaved Stringybark	13
Eucalyptus radiata subsp. *sejuncta*	L.A.S.Johnson & K.D.Hill	Narrow-leaved Peppermint	13
Acacia irorata	Sieber ex Spreng.	Green Wattle	12
Corymbia maculata	(Hook.) K.D.Hill & L.A.S.Johnson	Spotted Gum	12

Eucalyptus melanophloia	F.Muell.	Silver-leaved Ironbark	12
Acacia filicifolia	Cheel & M.B. Welch	Fern-leaved Wattle	11
Callitris glaucophylla	Joy Thomps. & L.A.S.Johnson	White Cypress Pine	11
Casuarina cunninghamiana subsp. *cunninghamiana*	Miq.	River Oak	11
Corymbia gummifera	(Gaertn.) K.D.Hill & L.A.S.Johnson	Red Bloodwood	11
Eucalyptus banksii	Maiden	Tenterfield Woollybutt	11
Eucalyptus carnea	R.T.Baker	Thick-leaved Mahogany	11
Eucalyptus acmenoides	Schauer	White Mahogany	10
Eucalyptus prava	L.A.S.Johnson & K.D.Hill	Orange Gum	10
Eucalyptus interstans	L.A.S.Johnson & K.D.Hill	Narrow-leaved Cabbage Gum	9
Eucalyptus siderophloia	Benth.	Grey Ironbark	8
Eucalyptus acaciiformis	H.Deane & Maiden	Wattle-leaved Peppermint	7
Eucalyptus conica	H.Deane & Maiden	Fuzzy Box	7
Brachychiton populneus subsp. *populneus*	(Schott & Endl.) R.Br.	Kurrajong	6
Corymbia intermedia	(R.T.Baker) K.D.Hill & L.A.S.Johnson	Pink Bloodwood	5
Eucalyptus fibrosa	F.Muell.	Red Ironbark	5
Eucalyptus williamsiana	L.A.S.Johnson & K.D.Hill	William's Stringybark	5
Lophostemon confertus	(R.Br.) Peter G.Wilson & J.T.Waterh.	Brush Box	5
Acacia implexa	Benth.	Hickory Wattle	4
Araucaria cunninghamii	Mudie	Hoop Pine	4
Eucalyptus dunnii	Maiden	White Gum	4
Eucalyptus resinifera subsp. *hemilampra*	(F.Muell.) L.A.S.Johnson & K.D.Hill	Red Mahogany	4
Callitris endlicheri	(Parl.) F.M.Bailey	Black Cypress Pine	3
Cupaniopsis parvifolia	(F.M.Bailey) L.A.S.Johnson	Small-leaved Tuckeroo	3
Eucalyptus microcorys	F.Muell.	Tallowwood	3
Lophostemon suaveolens	(Sol. ex Gaertn.) Peter G.Wilson & J.T.Waterh.	Swamp Mahogany	3
Notelaea microcarpa	R.Br.	Native Olive	3
Acacia melanoxylon	R.Br.	Blackwood	2
Eucalyptus cameronii	Blakely & McKie	Diehard Stringybark	2
Glochidion ferdinandi	(Müll.Arg.) F.M.Bailey	Cheese Tree	2
Acacia falciformis	DC	Broad-leaved Hickory Wattle	1
Callistemon viminalis	(Gaertn.) G.Don	Weeping Bottlebrush	1
Cinnamomum camphora	(L.) T.Nees & C.H.Eberm.	Camphor Laurel	1
Eucalyptus dealbata	A.Cunn. ex Schauer	Tumbledown Red Gum	1

Eucalyptus dorrigoensis	(Blakely) L.A.S.Johnson & K.D.Hill	Dorrigo White Gum	1
Eucalyptus youmanii	Blakely & McKie	Youman's Stringybark	1
Geijera parviflora	Lindl.	Wilga	1
Grevillea robusta	A.Cunn. ex R.Br.	Silky Oak	1
Opuntia stricta	(Haw.) Haw.	Common Prickly Pear	1
Syzigium australe	(J.C.Wendl. ex Link) B.Hyland	Brush Cherry	1

Appendix 2: Management recommendation examples for specific TSR sites surveyed by the DDC in 2018



8. References

Briscoe, N. J., K. A. Handasyde, S. R. Griffiths, W. P. Porter, A. Krockenberger, and M. R. Kearney. 2014. Tree-hugging koalas demonstrate a novel thermoregulatory mechanism for arboreal mammals. Biology Letters **10**.

Cristescu, R., K. Goethals, P. B. Banks, F. Carrick, and C. Frère. 2012. Persistence and detectability of fecal pellets in different environment and the implication for pellet based census of fauna. International Journal of Zoology **2012, Article ID 631856**:doi:10.1155/2012/631856.

Cristescu, R. H., P. B. Banks, F. N. Carrick, and C. Frère. 2013. Potential 'ecological traps' of restored landscapes: Koalas *Phascolarctos cinereus* re-occupy a rehabilitated mine site. PLOS ONE **8**:e80469.

Cristescu, R. H., W. Ellis, D. d. Villiers, K. Lee, O. Woosnam-Merchez, C. Frere, P. Banks, D. Dique, S. Hodgkison, H. Carrick, D. Carter, P. Smith, and F. Carrick. 2011. North Stradbroke Island: An island ark for Queensland's koalas population? Proceedings of the Royal Society of Queensland **117**:309-334.

Cristescu, R. H., E. Foley, A. Markula, G. Jackson, D. Jones, and C. Frère. 2015. Accuracy and efficiency of detection dogs: a powerful new tool for koala conservation and management. Scientific Reports **5**:DOI: 10.1038/srep08349.

Ellis, W., A. Melzer, and F. Bercovitch. 2009. Spatiotemporal dynamics of habitat use by koalas: The checkerboard model. Behavioral Ecology and Sociobiology **63**:1181-1188.

Hawes, W., J. Hunter, A. Lechner, and A. Ede. 2016. Northern Tablelands Koala Recovery Strategy 2015-2025. Inverell.

Hemming, V., M. Hoffmann, F. Jarrad, and L. Rumpff. 2018. NSW Koala Research Plan: Expert Elicitation. Prepared for the Office of Environment and Heritage, Sydney, NSW. The University of Melbourne, Australia. .

Kéry, M. 2002. Inferring the absence of a species: A case study of snakes. Journal of Wildlife Management **66**:330-338.

MacKenzie, D. I., and J. A. Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. Journal of Applied Ecology **42**:1105-1114.

Martin, R. W., and K. Handasyde. 1999. The Koala: Natural history, conservation and management, Australian Natural History Series. University of New South Wales Press Ldt, Hong Kong.

McAlpine, C., D. Lunney, A. Melzer, P. Menkhorst, S. Phillips, D. Phalen, W. Ellis, W. Foley, G. Baxter, D. de Villiers, R. Kavanagh, C. Adams-Hosking, C. Todd, D. Whisson, R. Molsher, M. Walter, I. Lawler, and R. Close. 2015. Conserving koalas: a review of the contrasting regional trends, outlooks and policy challenges. Biological Conservation **192**:226-236.

Melzer, A., R. H. Cristescu, W. Ellis, S. FitzGibbon, and G. Manno. 2014. The habitat and diet of koalas (*Phascolarctos cinereus*) in Queensland. Australian Mammalogy **36**:189-199.

New South Wales Department of Industry, n. d. Regional Profile.

NSW, D. o. E. a. C. C. 2008. Recovery plan for the koala (*Phascolarctos cinereus*). Sydney, Australia.

Office of Environment and Heritage. 2017. Securing the Koala in the wild in NSW for 100 years, Saving Our Species Iconic Koala Project 2017–21. Sydney, Australia.

Office of Environment and Heritage. 2019. NSW Koala Research Plan 2019–28, A 10-year plan under the NSW Koala Strategy. Sydney, Australia.

Phillips, S., and J. Callaghan. 2011. The Spot Assessment Technique: a tool for determining localised levels of habitat use by Koalas *Phascolarctos cinereus*. Australian Zoologist **35**:774-780.

Phillips, S., and M. Hopkins. 2008. The utility of regularized, grid-based SAT (RGB-SAT) sampling for the purposes of identifying areas being utilized by koalas (*Phascolarctos cinereus*) in the South-east Forests of NSW – a Pilot Study.

Putman, R. J. 1984. Facts from faeces. Mammal Review **14**:79-97.

Rhodes, J. R., D. Lunney, C. Moon, A. Matthews, and C. A. McAlpine. 2011. The consequences of using indirect signs that decay to determine species' occupancy. Ecography **34**:141-150.

Shumway, N., D. Lunney, L. Seabrook, and C. McAlpine. 2015. Saving our national icon: An ecological analysis of the 2011 Australian Senate inquiry into status of the koala. Environmental Science & Policy **54**:297-303.

Triggs, B. 1996. Tracks, scats and other traces: A field guide to Australian mammals. Oxford University Press, South Melbourne.

Tyre, A. J., H. P. Possingham, and D. B. Lindenmayer. 2001. Inferring process from pattern: Can territory occupancy provide information about life history parameters? Ecological Applications **11**:1722-1737.

Wilson, G. J., and R. J. Delahay. 2001. A review of methods to estimate the abundance of terrestrial carnivores using field signs and observation. Wildlife Research **28**:151-164.